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Vehicle age-related crashworthiness of the South Australian passenger fleet

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ABSTRACT

In this report, the crashworthiness of passenger vehicles in South Australia is characterised. For this purpose crashworthiness is defined as the rate of serious and fatal crashes per crash of any severity. The relationship between this rate and the ages of passenger vehicles is used to characterise and compare the crashworthiness of the South Australian registered passenger vehicle fleet and the fleets of other Australian jurisdictions. The mean age of passenger vehicles registered in South Australia is around 11.2 years compared with 9.9 years for the entire Australian registered passenger vehicle fleet and 9.3 years for registered passenger vehicles of New South Wales. Based on these mean vehicle ages, tow-away crashes in South Australia have a 3% over-representation of seriously injured or killed drivers compared with the national average (assuming a crashworthiness decline of 2.53% per year of vehicle age). Analysis of only those vehicles that crash confirm these estimates and suggest an over-representation of 3.5%. Young drivers appear to be doubly disadvantaged in that they have a higher rate of serious and fatal crashes for a given vehicle age, and they tend to crash vehicles that are much older than the vehicles crashed by those drivers who are over 25 years of age. Despite this, the benefits of fleet renewal on average age-related crashworthiness are relatively modest and it may be more fruitful to encourage the safest new car fleet now so that road safety benefits can be realised in 10-15 years time. In the mean time, removal of impediments to younger drivers who would otherwise drive newer and safer cars could be considered.

KEYWORDS

Vehicle Crashworthiness, Registered Fleet, Crash Rates

Summary

In this report, crashworthiness is defined as the rate of serious and fatal crashes per crash of any severity. The relationship between this rate and the ages of passenger vehicles is used to characterise and compare the crashworthiness of the South Australian registered passenger vehicle fleet and the fleets of other Australian jurisdictions.

Newstead et al. (2008) found that the average crashworthiness of vehicles improves with year of manufacture, implying that drivers of newer cars are less likely to be killed or admitted to hospital after a crash. Their data suggests that the rate of serious and fatal crashes increased 2.53% per year of vehicle age.

For this report, Newstead et al.'s empirical relationship was applied to data on vehicle ages in the registered fleet and the crashed vehicle fleet. The analysis was as follows:

- the composition of the South Australian registered fleet was described;
- the distribution of vehicle ages in the South Australian fleet was calculated;
- a comparison was made between the distribution of the ages of the registered passenger vehicle fleet in various Australian jurisdictions, at which point an estimate was made of the relative crashworthiness of the South Australian registered passenger fleet;
- adjustments were made for driving exposure and crash exposure; and finally
- some observations of the ages of vehicles crashed by younger and older drivers were made.

Data came from the registration and licensing database held by the Department for Transport, Energy and Infrastructure, the Australian Bureau of Statistics and the South Australian Traffic Accident Reporting System.

The mean age of the passenger vehicles, utilities and vans in South Australia is 10.9 years and the median age is 8.9 years. The mean age varies between vehicle types. For 'Cars' the mean age is 11.2 years, 'Station wagons' – 9.7 years, 'Panel vans' – 12.7 years and 'Utilities' – 10.5 years. The mean age of 'cars' plus 'station wagons', which broadly fits the ABS definition of 'Passenger vehicle' is 10.9 years, and the median age is 9.0 years. The average age of the entire registered fleet, minus trailers and caravans is 11.36 years.

Considering only passenger vehicles, and fitting a standard Weibull distribution to the vehicle age data, produced a mean age of 11.2 years for South Australia compared with 9.9 years for the entire Australian registered passenger vehicle fleet and 9.3 years for registered passenger vehicles in New South Wales. Based on these mean vehicle ages, tow-away crashes in South Australia have a 3% over-representation of seriously injured or killed drivers compared with the national average (assuming a crashworthiness decline of 2.53% per year of vehicle age).

The distribution of the ages of passenger vehicles that crash in South Australia is broadly similar to the registered passenger vehicle fleet, but dissimilar to the distribution of vehicle ages in the registered fleet weighted for driving exposure.

Further modelling showed that if the distribution of vehicle ages of vehicles that crash were in line with the distribution of the Australian registered fleet, there would be around 3.5% fewer serious and fatal crashes in South Australia (a result similar to that obtained using the mean age of the fleet). To effect a 10% decline in such crashes through fleet renewal would require a radical change to the age distribution including a reduction in the mean age to 7.5 years.

Young drivers appear to be doubly disadvantaged in that they have a higher rate of serious and fatal crashes for a given vehicle age, and they tend to crash vehicles that are much older on average than the vehicles crashed by other drivers.

Some consideration was given to the ability of periodic motor vehicle inspections to reduce the age of the fleet, but a review of the literature found little evidence for this. There is some evidence that inspections can initially remove the oldest vehicles in the fleet, but after that better maintenance could prolong the service life of vehicles, thereby increasing the age of the fleet. However it was noted that the States with such inspections schemes do have younger registered fleets. But this apparent relationship is probably confounded by lower rates of vehicle ownership, fewer cars per household, and in the case of New South Wales, higher public transport use.

While this report examined the crashworthiness of the South Australian registered passenger vehicle fleet, it did not investigate any factors that influence the composition of the fleet. Data not published in this report indicate that, in South Australia, the number of vehicles built in a given year tends to increase for up to a decade after the build year, suggesting significant importation of second-hand vehicles from interstate. Similar data from New South Wales indicated an immediate decline in the number of vehicles of given build year in subsequent years.

When looking to affect the safety characteristics of passenger vehicles on the road, it should be borne in mind that the influence of new-car safety on the fleet’s average safety is not immediate. Of course, if all vehicles were replaced instantaneously with new vehicles, there would be a significant benefit, but the reality is that this benefit takes many years to realise, and new vehicle safety will mainly benefit a future cohort of drivers that are presently young children. In the shorter term, there may well be merit in understanding the impediments to young drivers driving newer (and safer) vehicles; for example, there may be conditions on vehicle insurance which may inhibit the use of newer cars to members of households that are young drivers.

It may be fruitful to focus on trends in vehicle safety technology and other safety related characteristics of the fleet, particularly with vehicles entering the registered fleet for the first time (either as new cars or as imported second-had cars). It is probable that positively influencing the level of safety in vehicles entering the registered fleet will have road safety benefits many years into the future.

There would be a benefit in gaining a clearer picture of how and why vehicles enter the registered fleet and how and why they leave. Knowledge of this aspect of the turn-over of the registered fleet will allow a better understanding of the likely trends in vehicle ages as well as trends in the penetration of vehicle safety technology.

Contents

1 Introduction

1.1 The concept of crashworthiness

The concept of vehicle crashworthiness has had currency for more than 50 years. The term "crashworthiness" itself was coined in 1949 by John Lane of the Australian Department of Civil Aviation in relation to aircraft safety "when he said that it was time we stopped considering only whether an airplane was airworthy; [but also] whether it is crashworthy" (Stieglitz, 1962). It has since entered into the vehicle safety vernacular to refer to the ability of a vehicle to manage the energy of an impact to minimise the risk of injury to its occupants.

More formal definitions of crashworthiness exist. For example, a useful definition may be derived from considering the number of serious injury or fatal crashes as a product of an exposure based risk of a serious crash and the exposure to that risk; i.e:

Number of serious crashes (N) = risk of a serious crash x exposure

Furthermore, the risk of a serious crash may be thought of as the product of the risk of having a crash and the risk that any given crash is serious in nature, so:

N = risk of having a crash x risk that a given crash is serious x exposure.

Broadly, to reduce N, the three components on the right hand side of this equation provide distinct opportunities for intervention. Factors determining the risk of having a crash are often described as *primary* safety factors and they include, for example, driver behaviours and vehicle active safety (crash avoidance) technologies plus a host of road environmental factors. The risk that a given crash is serious primarily is related to the energy of the crash and the management of the vehicle's and occupants' energy in the crash. It also encompasses some aspects of road and road user safety (lower speeds reduce the energy of the impact). It is in this risk, that a given crash is serious, that a vehicle's crashworthiness plays its role in determining the severity of the outcome of the crash. The crashworthiness of the vehicle is often described by its *secondary* safety features.

1.2 Considering crashworthiness as the risk that a given crash is serious

Newstead et al. (2008) operationalised the concept of crashworthiness as an adjusted rate of serious and fatal driver fatalities per tow-away crash, with a lower number indicating better crashworthiness. Newstead et al. reserve the term "crashworthiness" to the self-protection of the driver, and use the term "aggressivity" to characterise the risk that a vehicle poses to the drivers of other vehicles (or pedestrians) in a crash involving more than one crash unit. Newstead et al. call the overall measure of risk to any driver or vulnerable road user in a crash "total secondary safety".

Newstead et al. define crashworthiness in this way to allow them to measure the crashworthiness of individual vehicle models, market segments, and vehicle vintages. To do this, they constructed a logistic regression model based on crash data from Victoria and New South Wales from 1987 to 2006, Western Australia and Queensland from 1991 to 2006, and South Australia from 1995 to 2006. 1,716,373 drivers were included in the model, 322,242 of whom were injured, and 66,520 of whom were severely injured. One objective of the model was to relate the vehicle year of manufacture to injury risk, injury severity and crashworthiness. Injury risk was defined as the rate of injuries (any severity) to drivers involved in crashes that resulted in a vehicle being towed away. Injury severity was defined as the rate of death of hospital admission amongst injured drivers. Crashworthiness was defined as the product of injury risk and injury severity[1]. Defined this way, a lower percentage indicates a higher level of crashworthiness.

The covariates in the model were driver sex, driver age (<26; 26 to 59; >59), speed limit at the crash location(<76km/h; >79km/h), the number of vehicles involved (1; >1), State (data from several States of Australia were included) and year of crash. These covariates, as well as many interactions between them, where found to be significantly associated with injury risk and injury severity and were therefore included in the model.

The model was then used to calculate crashworthiness and aggressivity ratings for individual models of vehicle, market groups, and vehicle age groups.

1.3 The crashworthiness of vehicles related to vehicle year of manufacture

It seems intuitive that a newer vehicle fleet is a safer vehicle fleet. And prior research results appear to support this idea. Conceptually, this report will assume that age-related crashworthiness relates to improving design with successive vehicle model releases, rather than age-related vehicle condition. Vehicle age therefore represents improving built-in crashworthiness, not roadworthiness.

Newstead et al. (2008) found that the average crashworthiness of vehicles in each particular age cohort improves with year of manufacture, implying that drivers of newer cars are less likely to be killed or admitted to hospital after a crash. The average crashworthiness value for all vehicles in their sample was 3.8%, the best average crashworthiness was for vehicles manufactured in 2003 at 2.17% and the worst for vehicles manufactured in 1969 at 6.42%. On average, injury risk also decreased as the year of manufacture increased, similarly to injury severity. Similar trends were observed when the vehicle fleet was divided into market groups - e.g. small cars, four wheel drives, etc.

If an exponential function is fitted to the measured relationship between average crashworthiness and age measured by Newstead et al. (2008), the decrease in average crashworthiness of passenger vehicles is 2.53% per year of age (Figure 2.1).

In a case control study conducted in the Auckland region, Blows et al. (2003) also found that there were crashworthiness benefits from newer vehicles. The focus of the study was light vehicles driving on non-local public roads between April 1998 and July 1999. In the study, 615 drivers who had been involved in a crash where an occupant had been hospitalised or killed were identified, of which 571 were interviewed. Controls were selected by stopping all vehicles at a randomly assigned location and time on a non-public local road to achieve a representative sample of 746 control cars, of which 588 drivers where interviewed.

The analysis of the effect of vehicle age on crash outcome included numerous adjustments. Covariates that were found to be significant were driver’s age, sex, education level, ethnicity, time of day, acute sleepiness score, marijuana and alcohol use before the crash, seatbelt use, driving exposure in hours per week, licence type, current vehicle safety inspection certificate, insurance status of the vehicle, number of passengers, travelling speed and engine size.

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[1] Newstead et al., split crashworthiness into the two components injury risk and injury severity because non-injury crashes are not recorded in some Australian States, making the direct measurement of crashworthiness impossible with that crash data. The data could, however, be used to measure the injury risk component of crashworthiness and so add to the statistical power of that component of the crashworthiness estimates.

After the model was adjusted for all these covariates it was found that there was, on average, a 5% increase of the risk of being involved in a serious injury crash with each additional year of vehicle age, but with confidence intervals of -1% to 11%. When vehicle ages where grouped by vehicle year: pre-1984, 1984-1989, 1989-1994 and post-1994 it was found that the risk was 2.88 times higher for pre-1984 vehicles than post 1994 vehicles, but was only 1.38 times higher for 1989-1993 vehicles and 1.02 times higher for 1984-1989 vehicles.

Vaughan (1993) looked at the relationship between vehicle age and safety, based on vehicle occupant deaths in New South Wales. The author found that the occupant death rate per kilometre travelled was consistently higher for older vehicles. In 1991, occupants of vehicles that were at least 13 years old had twice the death rate per kilometre travelled compared with occupants of vehicles that were less than 4 years old. One limitation of this study was that it did not control for other salient factors such as the age of the driver.

The relationships between average crashworthiness and vehicle age from Newstead et al. (2008) and Blows et al. (2003) are shown in Figure 2.1.

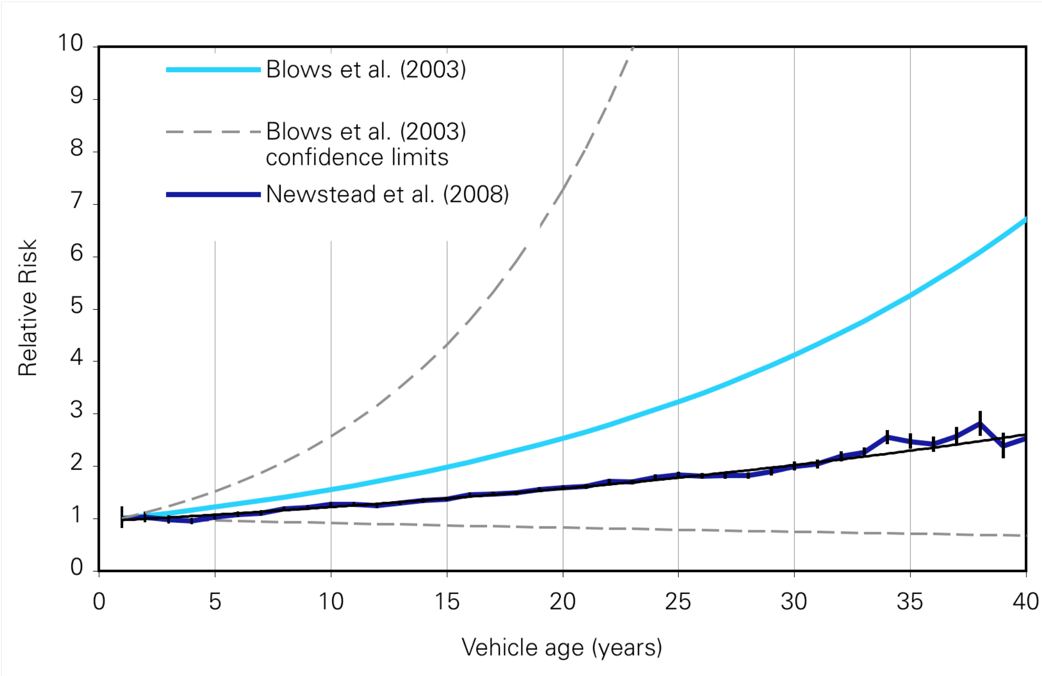


Figure 1.1
The relationship between average crashworthiness and vehicle age, relative to vehicles that are one year old, based on Newstead et al. (2008) and Blows et al (2003)

2 The crashworthiness of the South Australian registered vehicle fleet

In this Section, the vehicle age-related crashworthiness of the South Australian fleet is examined. The Section is organised as follows:

- the composition of the South Australian registered fleet is described;
- the distribution of vehicle ages in the South Australian fleet is calculated;
- a comparison is made between the distribution of the ages of the registered passenger vehicle fleet in various Australian jurisdictions, at which point an estimate is made of the relative crashworthiness of the South Australian registered passenger fleet;
- adjustments are made for driving exposure and crash exposure; and finally
- some observations of the ages of vehicles crashed by younger and older drivers are made.

2.1 Methodology

2.1.1 Data sources

Two data sources were used in the analysis of the registered fleet:

- Data from the registration and licensing database held by the Department for Transport, Energy and Infrastructure describe the current composition of the South Australian registered fleet. The Safety and Regulation Division produces a regular report of current registrations from "TRUMPS". Vehicles are categorised in the TRUMPS report by vehicle type, body type, configuration and insurance class.
- The Australian Bureau of Statistics (ABS) produces a regular report "Motor Vehicle Census" (9309.0) and associated data tables. At the time of writing, the most recent data from the ABS on vehicle registrations was a census taken on the 31st of March 2007.

For adjusting the distribution of vehicle ages for driving exposure, the relationship between vehicle age and vehicle kilometres driven derived by Skutenko et al. (2006) was used.

For the distribution of ages of the South Australian crashed car fleet, data from the South Australian Traffic Accident Reporting System was used.

More information on these data sources and how they were used are given in later Sections of this report.

2.1.2 Determining vehicle ages

In this report, vehicle age will be defined in accordance with the definition used by the ABS in their regular censuses of motor vehicle registrations (ABS, 2007). For vehicles manufactured in the year current with the census or query, vehicle age is defined as

$$\text{Vehicle age} = \text{Reference month}/24$$

where the reference month is the number of whole months at the end of which the query or census is performed. For vehicles manufactured in previous years, vehicle age is defined as

Vehicle age = Current year - Year of manufacture + (Reference month - 6)/12

These definitions assume a constant rate of manufacture throughout the year, and provide the average age of each cohort of vehicles.

2.1.3 Fitting a statistical distribution to vehicle ages

One objective of this analysis was to fit a standard distribution to the vehicle age data. This allows the distribution to be parameterised and hence will allow a simple exploration of the effect of a hypothetically newer fleet on the level of crashworthiness.

One particular aspect of the data on registrations from the States of Australia is that, individually, each set of registrations is not a 'closed system.' That is, not only do vehicles disappear from registration data between consecutive census dates due to scrappage, but they may also not be re-registered because they were transferred interstate. Concomitantly, vehicles may not enter the registration of a particular State as a new car registration, but they may also enter as a result of a transfer from another State.

Despite the peculiarities that may arise due to interstate transfers of vehicles, there may be apparent vehicle scrap rates for each State; these rates may not be constant over time, and may even be negative if a large number of vehicles of a particular vintage enter the State in years subsequent to the year of manufacture.

As the registration database is a system where (apparent) scrap rates may partly determine the distribution of ages, the Wiebull distribution (often used in survival analysis) was considered first for fitting to the vehicle age data. Note that the normal interpretation of Weibull parameters in survival analysis may not apply, as the distribution of vehicle ages is not a distribution of survival times. At this stage, the justification of the use of the Weibull distribution is its goodness-of-fit. Any interpretation of the meaning of Weibull parameters in relation to the distribution of vehicle ages will be examined in a future publication.

The Weibull cumulative distribution is given by

$$F(t) = 1 - e^{-(t/\eta)^{\beta}} \quad (1)$$

Rearranging and taking the natural logarithms of both sides of the distribution gives

$$\ln(-\ln(1 - F(t))) = \beta \ln(t) + \beta \ln(\eta) \quad (2)$$

which is in the form

$$y = ax + b$$

Hence, a test for the suitability of the Weibull distribution can be made by plotting the function on the left hand side of (2) against the logarithm of time. The goodness-of-fit can then be assessed by the linearity of the resulting function.

2.1.4 Transforming the distribution of vehicle ages to a distribution of average crashworthiness

Both Newstead et al, (2008) and Blows et al. (2003) identified improvements in average relative crashworthiness that could be expressed as a constant rate from one year to the next; that is:

$$c_{rel} = (1 + r)^{t} \qquad (3)$$

where c_{rel} is the relative crashworthiness of a vehicle compared to a newly manufactured vehicle (age t = 0), r is the rate of increase in the crashworthiness number per time, t (recalling that a higher crashworthiness number indicates a higher rate of serious and fatal crashes). Taking logs of the both sides of this expression and rearranging gives:

$$\ln(t) = \ln\left(\frac{\ln(c_{rel})}{\ln(1+r)}\right) \qquad (4)$$

Note that because the relationship given by Equation 2 is linear with respect to the natural logarithm of time, it is also linear with respect to the right-hand side of Equation 4. As such Equation 4 provides a means of transforming a distribution of vehicle ages to a distribution of average age-related relative crashworthiness. A graph of the cumulative distribution of vehicle ages, plotted according to Equation 2, will also represent the cumulative distribution of the average age related crashworthiness of those vehicles when the x-axis is rescaled according to Equation 4.

It is important to note, that in applying this transformation to any given population of vehicles, that there is an implicit assumption that the makeup of the fleet is otherwise uniform across age cohorts in terms of crashworthiness and also across fleets where comparisons are made between those fleets.

2.2 Results

2.2.1 General characteristics of the current South Australian registered fleet

The TRUMPS report of the 31/7/08 showed that there were a total of 1,499,206 registered vehicles in South Australia, including all classes of vehicle subject to registration requirements in the State. Table 2.1 shows a summarised extract of the report showing the numbers of vehicles registered by vehicle and body type. Excluded from this extract are 225,283 trailers, 42,524 trucks, 36,513 motorcycles, 35,277 caravans, 31,972 tractors and 59,425 other vehicles that include commercial trailers, buses, prime movers, and specialised commercial vehicles.

In this report, we wish to examine the segment of the registered fleet most relevant to the concept of crashworthiness we have previously described. Newstead et al (2008) consider the crashworthiness of several market segments, namely: large, medium, small, luxury, sports, 4-wheel drive, passenger vans and commercial vehicles with GVM < 3000 kg. The application of crashworthiness estimates to the vehicle types of cars, station wagons, utilities, and panel vans will be sufficient to characterise the crashworthiness of the most relevant segment of the fleet. These categories cover the types of vehicle for which crashworthiness estimates exist. These vehicles will be referred to henceforth in this report as passenger vehicles, utilities and vans.

Note that definitions of vehicle types vary from State to State. In subsequent Sections where comparisons will be made with other States, and other data sources are used, some variations to the subpopulation of vehicles will be considered.

Table 2.1
A summarised extract of DTEI's TRUMP report of 31/7/08

Vehicle type	Body type	Number
Cars	CHAUFFEURED VEHICLE	531
	SEDAN	702,901
	TAXI	887
	TOURER	6,433
	TOURING UTILITY	798
	TRI CAR	8
Cars Total		**711,558**
Station Wagons	HEARSE	100
	STATION WAGON	212,219
	TAXI-WAGON	163
	TOURING VAN	799
Station Wagons Total		**213,281**
Utilities	UTILITY	108,787
Utilities Total		**108,787**
Panel Vans	CARAVAN VEHICLE	3,562
	NONCOMMERCIAL-VAN	102
	PANEL VAN	12,792
	VAN VEHICLE	18,190
Panel Vans Total		**34,646**
Subtotal of listed vehicle types		**1,068,272**

2.2.2 Age distribution of the South Australian registered fleet

The TRUMPS database also records the year of manufacture of each registered vehicle. The DTEI TRUMPS report provides this data by Vehicle Type.

Figure 2.1 shows the age distribution of passenger vehicles, utilities and vans registered in South Australia. The mean age of the vehicles in this data is 10.9 years and the median age is 8.9 years. The mean age varies between vehicle types. For 'Cars' the mean age is 11.2 years, 'Station wagons' – 9.7 years, 'Panel vans' – 12.7 years and 'Utilities' – 10.5 years. The mean age of 'cars' plus 'station wagons', which broadly fits the ABS definition of 'Passenger vehicle' is 10.9 years, and the median age is 9.0 years

The average age of the entire registered fleet, minus trailers and caravans, was also computed for the TRUMPS report. The average age of this segment was 11.36 years, compared with the ABS estimate of 11.1 years for South Australia (ABS, 2007).

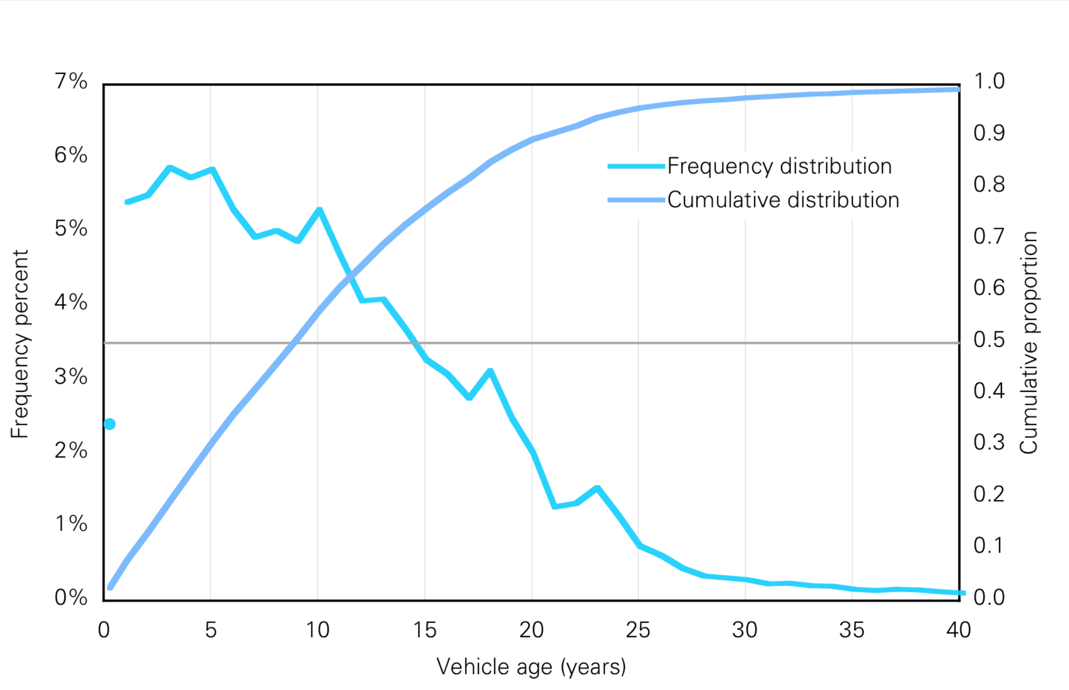


Figure 2.1
Age distribution of registered passenger vehicles, utilities and vans in South Australia as at 31/7/08. For the density distribution, vehicle age corresponds with the average age of vehicles in each particular bin. The first frequency bin covers a smaller cohort of vehicle ages than the subsequent age bins. (Source: DTEI TRUMPS report 31/7/08)

2.2.3 A comparison with other States of Australia

ABS data on vehicle ages from all States and Australia

Because of inconsistencies of vehicle body type definitions between States, the ABS perform their own categorisation of vehicle types based on make and model data, matched via the VIN code (ABS, 2007). Hence some subtle differences between TRUMPS categorisations and ABS categorisations may exist. Inspection of the various definitions suggests that a combination of the TRUMPS categories of 'Cars' and 'Station wagons' would largely be equivalent to the ABS's category 'Passenger vehicles'. Utilities and forward control vans would be part of the ABS category 'Light commercial vehicles', which also includes vehicles up to 3.5 t GVM. For this reason, this Section examines differences between States in the ABS category 'Passenger vehicle'.

Figure 2.2 shows cumulative density functions of the ages of the registered passenger vehicle fleet of four Australian jurisdictions on a Weibull-log scale (representing the linear relationship expressed in Equation 2). Other States have not been included for clarity, but they are similarly linear on these axes.

The Northern Territory has the newest fleet of any Australian jurisdiction and Tasmania the oldest (not shown).

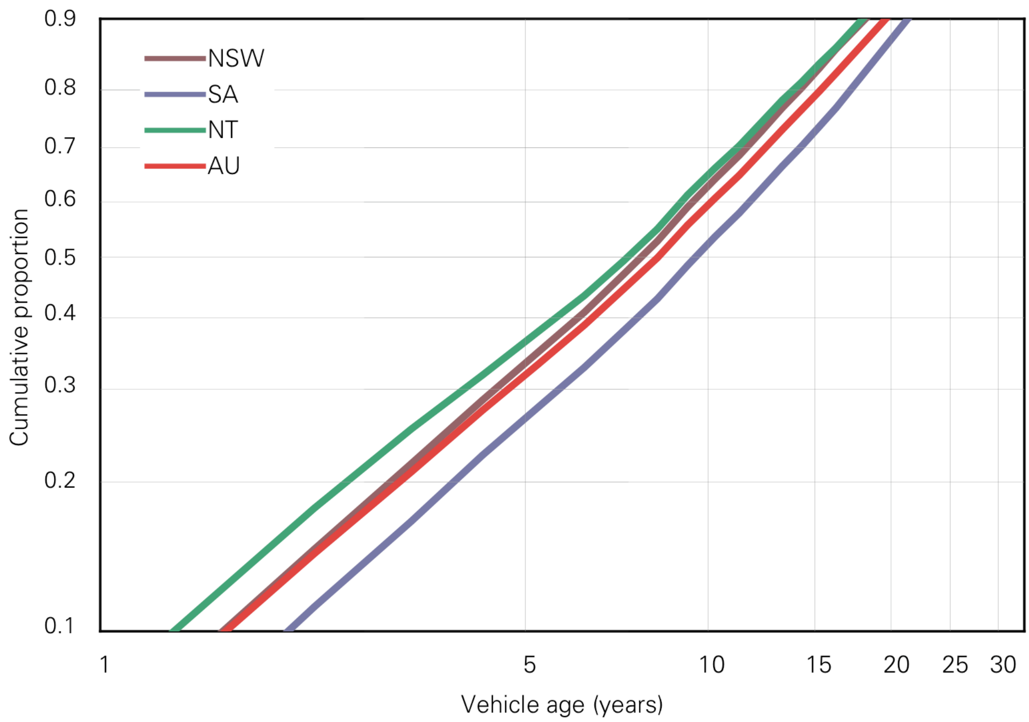


Figure 2.2
Cumulative distributions of registered passenger vehicles of some Australian jurisdictions. Axes are linear in the Weibull transformation (Weibull – log) (data sourced from ABS, 2007)

Least-squares regression suggests Weibull distributions as detailed in Table 2.2 for registered passenger vehicles in South Australia, New South Wales and Australia. Note that the mean and median vehicle ages of the fitted SA distribution are slightly higher than the equivalent numerical values, but are within 3%.

Table 2.2
Parameters of Weibull distributions fitted to the distribution of the vehicle ages of the registered passenger vehicle fleets of South Australia, New South Wales and Australia

State	Equation	R^2	beta	eta	Weibull median (years)	Weibull mean (years)
SA	$\ln(-\ln(1-F(t))) = 1.2914 \ln(t) - 3.2252$	0.998	1.298	12.2	9.2	11.2
NSW	$\ln(-\ln(1-F(t))) = 1.2486 \ln(t) - 2.8852$	0.999	1.248	10.0	7.4	9.3
Australia	$\ln(-\ln(1-F(t))) = 1.2212 \ln(t) - 2.8946$	0.999	1.225	10.6	7.9	9.9

The probability density functions of the fitted Weibull distributions for Australia, NSW and SA are shown in Figure 2.3.

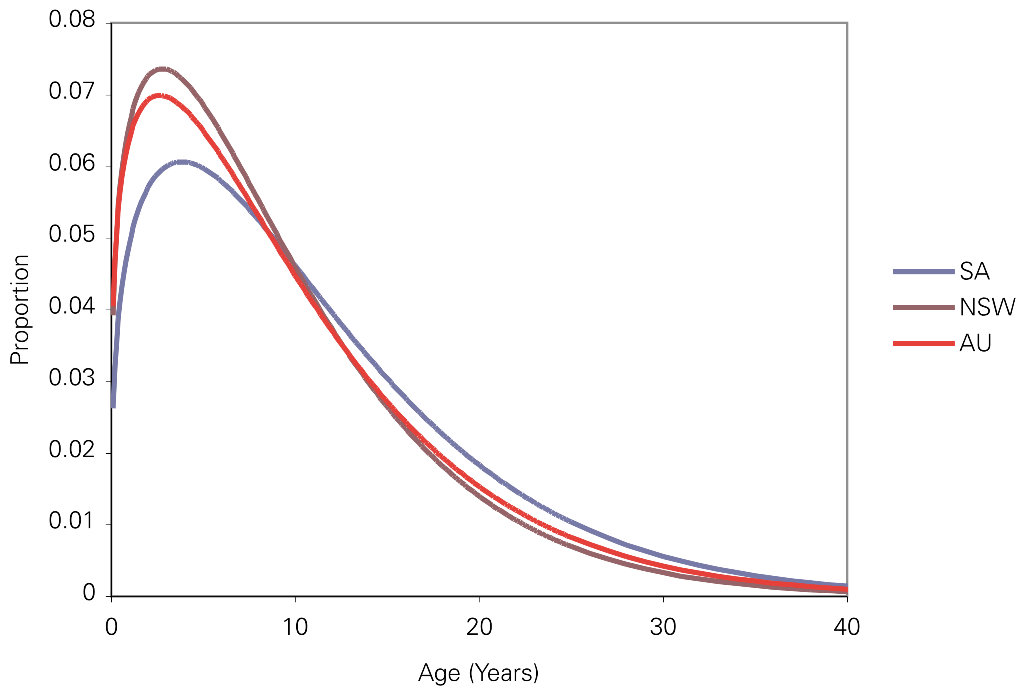


Figure 2.3
Age distribution of registered passenger vehicles in SA , NSW and Australia as at 31/3/07.

In Section 1.3 average crashworthiness was expressed as a function of age. Relative average crashworthiness was found to increase exponentially with the age of the vehicle. Because the relative average crashworthiness of each age-cohort of vehicles sits in a known relationship to the age of the cohort (see Equation 4), it is straightforward to transform the x-axes of Figure 2.3 to describe the distribution of the age-related average crashworthiness of the registered passenger vehicle fleet as described in Section 2.1.4.

Figure 2.4 shows the age-distribution of the passenger fleets with the x-axis appropriately transformed to show the relative age-related average crashworthiness of the registered passenger fleets for various Australian jurisdictions, assuming r = 2.53% decline in relative average crashworthiness with each preceding year of manufacture (after Newstead et al., 2008).

Figure 2.5 shows the same data, but assuming r = 5% decline in relative average crashworthiness (after Blows et al. 2004). Note though that a rate of 2.53% appears to match the crude crashworthiness of vehicles in South Australia (see later Section 2.2.5).

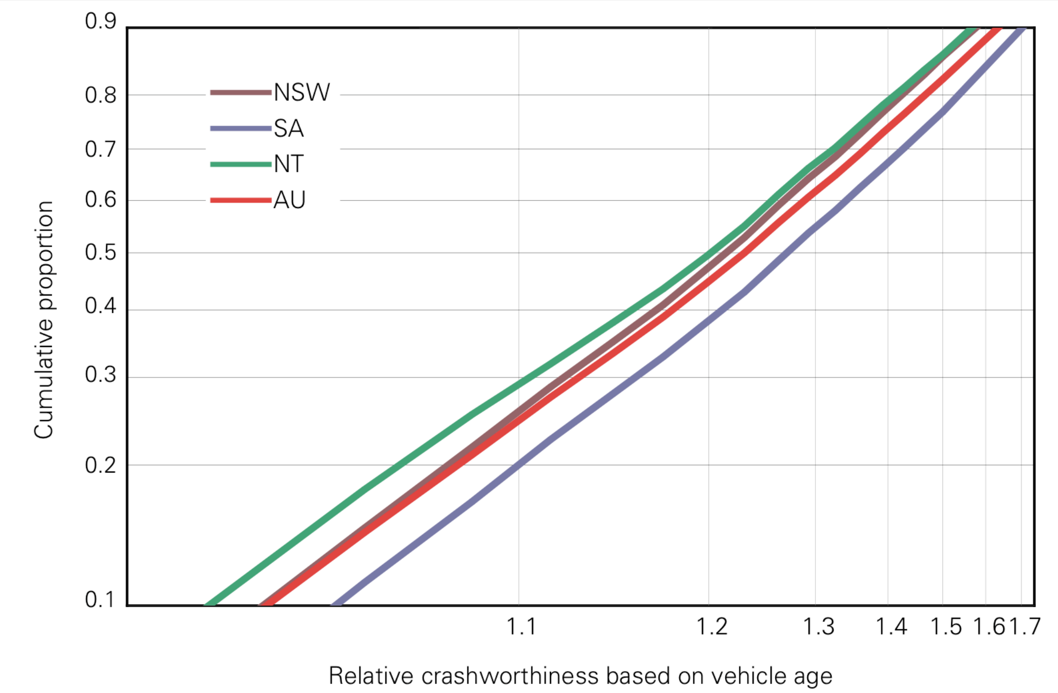


Figure 2.4
Crashworthiness cumulative density function of registered passenger vehicles in SA , NSW, NT and Australia as at 31/3/07 (data sourced from ABS, 2007)), based on a 2.53% p.a. decrease in average relative crashworthiness (i.e. an increase in the crashworthiness number).

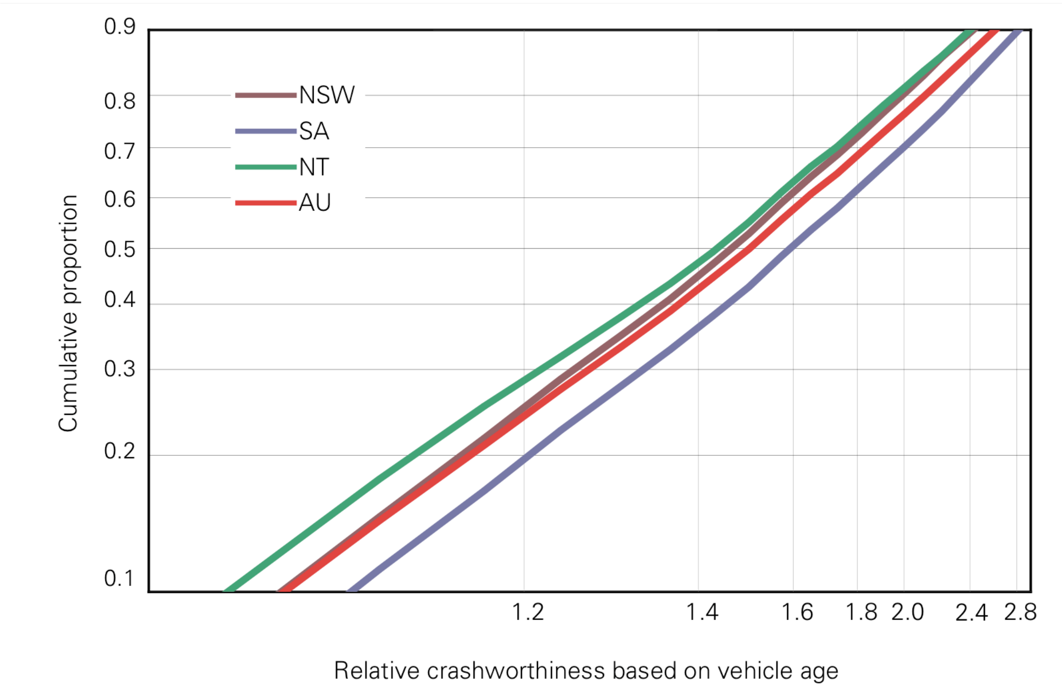


Figure 2.5
Crashworthiness cumulative density function of registered passenger vehicles in SA , NSW, NT and Australia as at 31/3/07 (data sourced from ABS, 2007), based on a 5% p.a. decrease in average relative crashworthiness (i.e. an increase in the crashworthiness number).

As with the age distribution of each fleet, a linear function can be fitted to the relative age-related average crashworthiness distributions in Figures 2.4 and 2.5. Having done so, the mean and median relative age-related average crashworthiness of each fleet can be calculated. The results of these calculations are given in Tables 2.2 and 2.3, the first table using the annual crashworthiness improvement of 2.53% p.a., and the latter 5% p.a.

It may be noted that, assuming a 2.53% decline in relative age-related average crashworthiness with each preceding year of manufacture, the relative average crashworthiness (driver serious injury and deaths per tow away crash) of the national and NSW fleets are 3% and 4% lower than the average passenger vehicle in South Australia. Assuming a 5% decline in relative average crashworthiness with each preceding year of manufacture, the relative average crashworthiness (driver serious injury and deaths per tow away crash) of the national and NSW fleets are 6% and 8% lower than the average passenger vehicle in South Australia. If passenger vehicles involved in crashes were a random sample of vehicles from the registered passenger vehicle fleet, these numbers would imply that tow-away crashes in South Australia have a 3% over-representation of seriously injured or killed drivers compared with the national average (assuming a crashworthiness decline of 2.53% per year of vehicle age.

Table 2.2
Median and mean relative average crashworthiness of the registered passenger vehicle fleets of SA, NSW and Australia, assuming a crashworthiness improvement of 2.53% p.a. (after Newstead et al.)

State	Relative average crashworthiness (based on the ages of vehicles only)	
	Median of the fitted distribution (drivers seriously injured or killed/tow away crash relative to the new car rate)	Mean of the fitted distribution (drivers seriously injured or killed/tow away crash relative to the new car rate)
SA	1.26	1.32
NSW	1.20	1.27
Australia	1.22	1.28

Table 2.3
Median and mean relative average crashworthiness of the registered passenger vehicle fleets of SA, NSW and Australia, assuming a crashworthiness improvement of 5% p.a. (after Blows et al.)

State	Relative average crashworthiness (based on the ages of vehicles only)	
	Median of the fitted distribution (drivers seriously injured or killed/tow away crash relative to the new car rate)	Mean of the fitted distribution (drivers seriously injured or killed/tow away crash relative to the new car rate)
SA	1.56	1.79
NSW	1.44	1.65
Australia	1.47	1.69

Assuming that the age distribution of the passenger fleet is stable over time, it should be noted that the overall crashworthiness of the fleet will improve with the passage of time. Therefore the difference between the relative average crashworthiness of the South Australian registered passenger vehicle fleet and those of other fleets, can also be expressed as a time constant. This time constant corresponds to the time elapsed before the future South Australian registered passenger fleet has an equivalent average crashworthiness to that of the current New South Wales or Australian registered passenger vehicle fleets.

Given that

$$\ln c_{rel} = t \ln(1 + r)$$

it follows that the lag between the average crashworthiness of two fleets may be expressed as:

$$t_1 - t_2 = \frac{\ln c_1 - \ln c_2}{\ln(1+r)}$$

where c_1 and c_2 are the mean average relative crashworthiness of each fleet. As such, the time lag between the mean crashworthiness of the South Australian and New South Wales passenger fleets is 19 or 20 months (for 2.53% and 5%), and between the South Australian and Australian passenger vehicle fleets, it is 14 months (for both 2.53% and 5%).

2.2.4 Adjustment for driving exposure

As mentioned in the previous Section, assuming that 2.53% is the rate at which average crashworthiness improves with vehicle age, and assuming that the passenger vehicles that crash are representative of the South Australian registered passenger vehicle fleet, South Australia may experience an excess of approximately 3% serious and fatal driver crashes per tow-away passenger vehicle crash.

However, the assumption that vehicles that crash are representative of the registered fleet is not a given. In this Section, the registered fleet is adjusted for driving exposure.

Surveys of motor vehicle use show that vehicle use declines with vehicle age. Stukento et al (2006) pooled data from the ABS annual Survey of Motor Vehicle Use from 1998 to 2003 and found that vehicle use declines exponentially with vehicle age. A curve fitted to this ABS data for the whole of Australia suggests a decline in annual vehicle kilometres driven of 5.1% per year of vehicle age. An estimate of the average distribution of ages of vehicles on the road may be found by weighting the distributions in Figure 2.3 to take account of the decline in vehicle usage with age.

Applying a 5.1% decline to all Australian jurisdictions is imperfect, as the pattern of declining use is unlikely to be independent of the age distribution itself. However, it is nevertheless useful to examine the weighted distributions to examine the effect of accounting for vehicle use.

Figures 2.6 and 2.7 show the effect of applying such a weight to the vehicle age distributions for South Australia, New South Wales and Australia. The weighting skews the distributions to the left, and the resulting distributions have a lower median and mean vehicle age and better apparent crashworthiness.

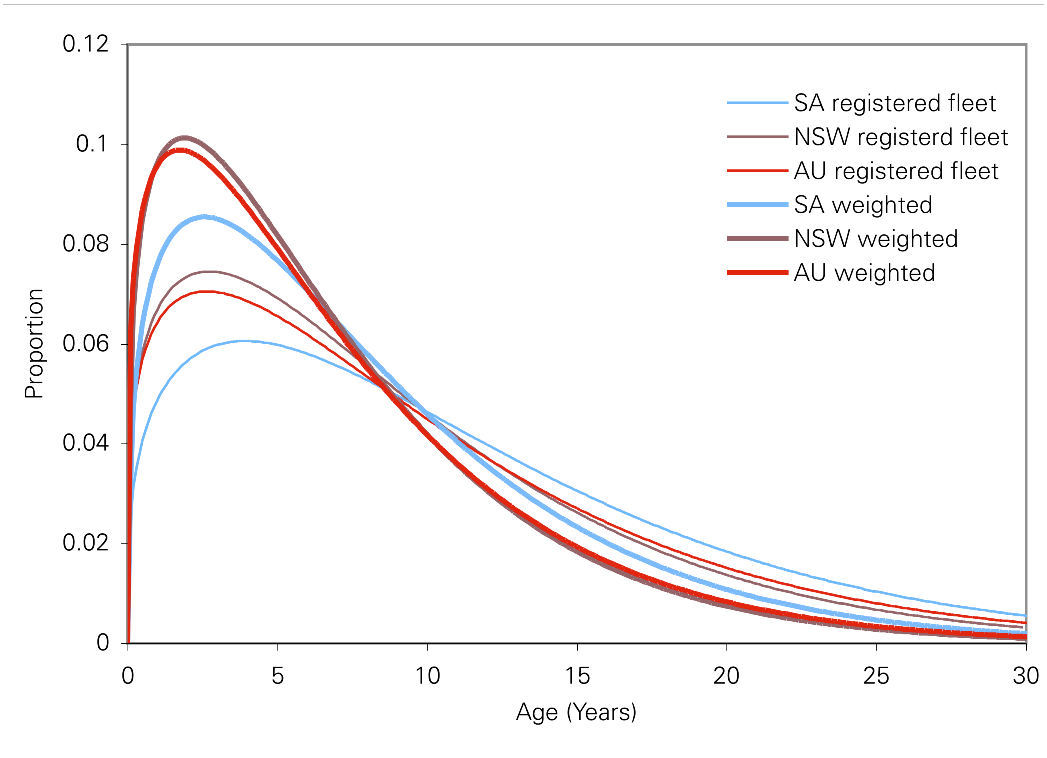


Figure 2.6
Probability density functions of the SA, NSW and Australian registered passenger vehicle fleets, and those distributions weighted to take account of declining vehicle usage with vehicle age.

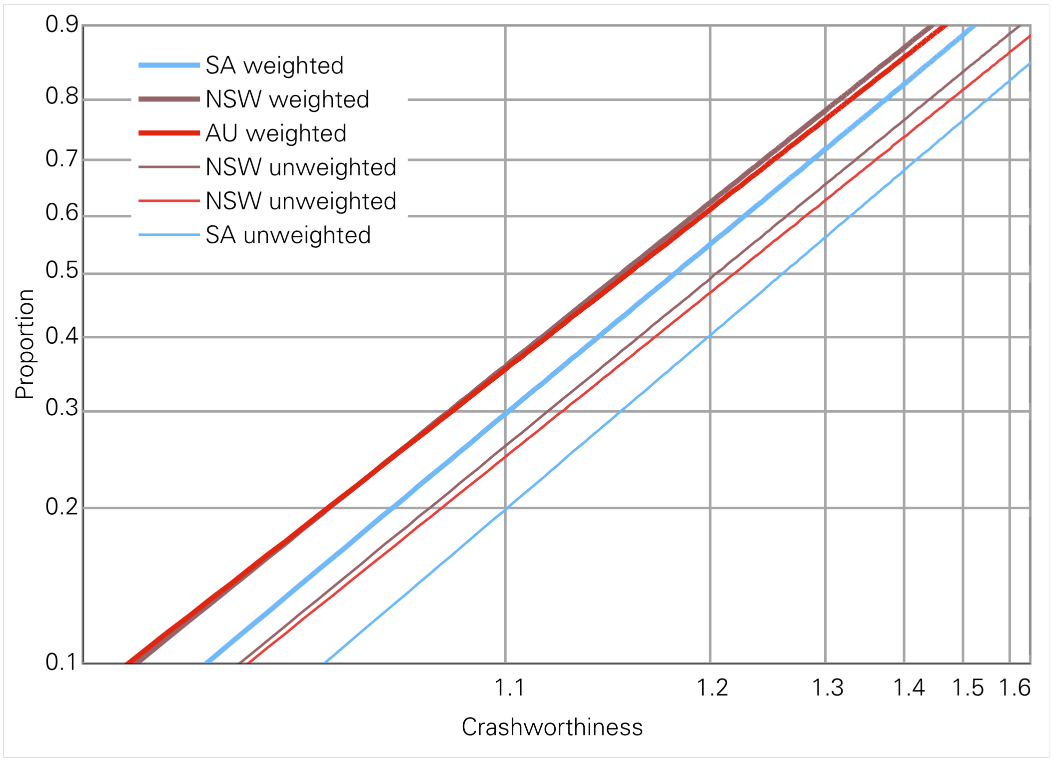


Figure 2.7
Crashworthiness cumulative density function of registered passenger vehicles in SA , NSW, and Australia as at 31/3/07 (data sourced from ABS, 2007)), based on a 2.53% p.a. decrease in average relative crashworthiness, for weighted and unweighted fleets.

2.2.5 Adjustments for crash exposure

An alternative to examining the distribution of crashworthiness of registered vehicles, or the distribution weighted for exposure, is to consider the distribution of crashworthiness among vehicles that actually crash – it is for this subpopulation of vehicles that crashworthiness is most relevant. Rather than applying an adjustment by weighting each vehicle age by a crash rate, the following analysis examines the distribution of the ages of crashed cars directly.

The number of vehicles involved in serious and fatal crashes in each vehicle age cohort will not be independent of the vehicle age (as the rate of such crashes per tow away crash is believed to increase with vehicle age) so, it is appropriate to examine the vehicle age distribution of the entire crashed car fleet.

The South Australian Traffic Accident Reporting System (TARS) was queried to extract data on crashed vehicles from the 5 year period 2003-2007, where the severity of the crash was either $3,000 damage (the minimum reporting limit) or worse. Vehicle types included were: "Car", "Station wagon", "Panel van", "Utility", "Taxi cab", "Motor vehicle – type unknown", "Forward control passenger van", and "4WD" (separately coded for fatal crashes only). It should be noted that the vehicles examined were all vehicles of the types mentioned above, involved in each crash, and the severity of the crash relates to the highest injury severity of any person involved.

The age of vehicles at the time of the crash were calculated. Some averaging was required to do this. The year of vehicle manufacture is recorded in the TARS database, and also the date of the crash. In this sense, the date of the crash may be considered analogous to the census date the ABS census of motor vehicle registrations. So while the exact age is not ascertainable from the TARS record, the average of all possible ages can be determined from the following equations:

$$\text{Vehicle age} = \text{Month of crash}/24$$

for vehicles which crash in the same year as the year of manufacture, and

$$\text{Vehicle age} = \text{Year of crash} - \text{Year of manufacture} + (\text{Month of crash} - 6)/12$$

for vehicles that were manufactured in a year prior to the year of the crash.

The distribution of vehicle ages of the crashed vehicles is shown in Figure 2.8. The cumulative distribution of the vehicles' ages is also shown on the transformed axes (Weibull – log axes) with the age distribution of the registered passenger vehicle fleet and the weighted distribution shown in Figure 2.9. It may be noted in this figure that the crashed vehicle fleet sits closer to the registered passenger vehicle fleet, than the version of the registered passenger vehicle fleet distribution weighted for driver exposure shown in Figure 2.7.

At this point, it is pertinent to use the TARS data to calculate the crude relationship between vehicle age and crashworthiness in this set of crash records. To do this, the TARS query was altered to extract only those crashes that resulted in at least one person being admitted to hospital, or killed (i.e. serious or fatal crashes). For each age cohort of vehicles, the number of serious or fatal crashes was expressed as a rate, per crash of any severity (>$3,000 damage). The results of this are shown in Figure 2.10. An exponential line was fitted to the data, which indicates an increase in the rate of serious and fatal crashes of 2.8% per year of vehicle age, an increase almost identical to that adjusted rate of driver serious injuries and fatalities per tow away crash estimated by Newstead et al. (2008).

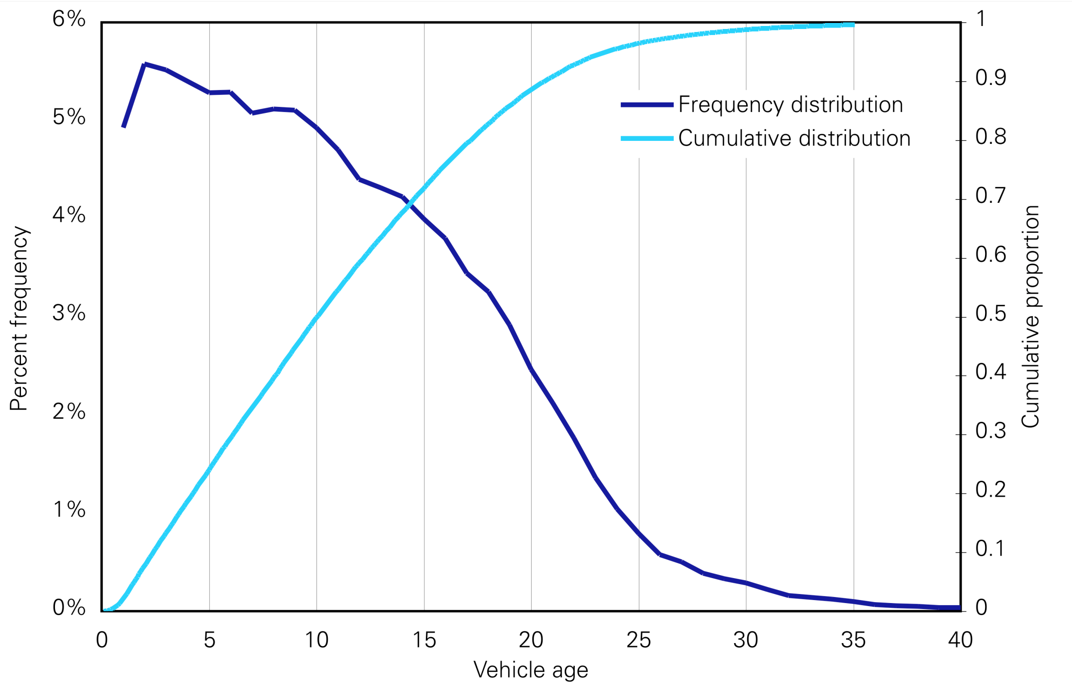


Figure 2.8
Age distribution of crashed passenger vehicles, utilities and vans in South Australia between 2003-2007 (Severity >= $3,000 damage). For the frequency distribution, vehicle age corresponds with the average age of vehicles in each particular bin.(Source: TARS)

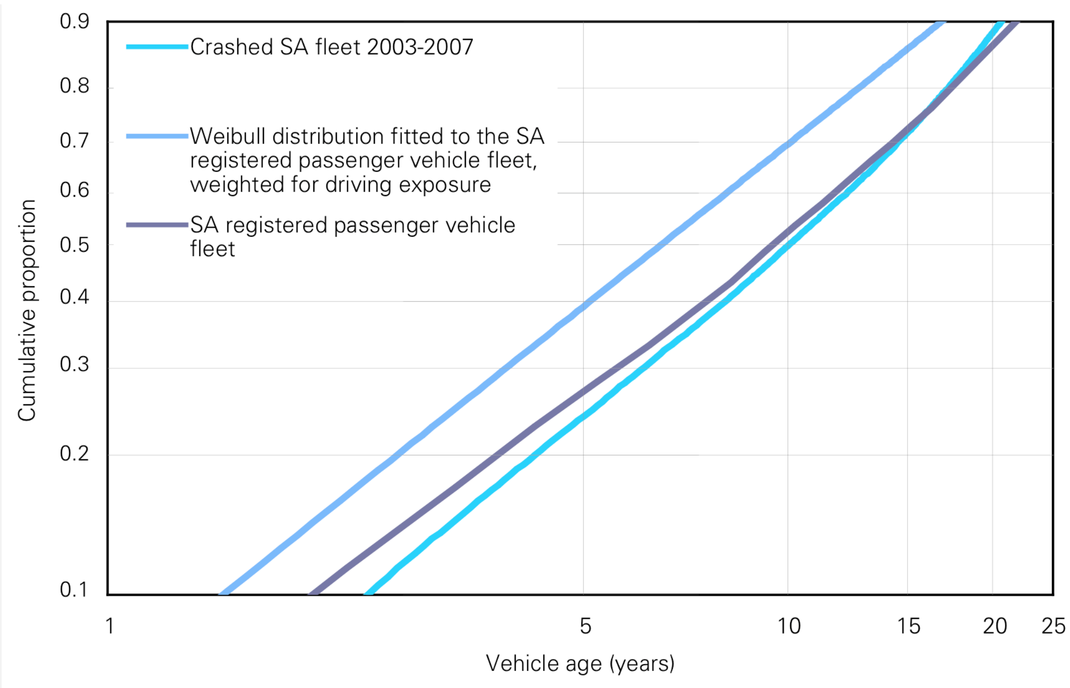


Figure 2.9
A comparison between the cumulative distributions of the crashed vehicles (shown in Figure 2.9) and the registered passenger fleet, and a fitted distribution of the registered passenger vehicle fleet, adjusted for driving exposure.

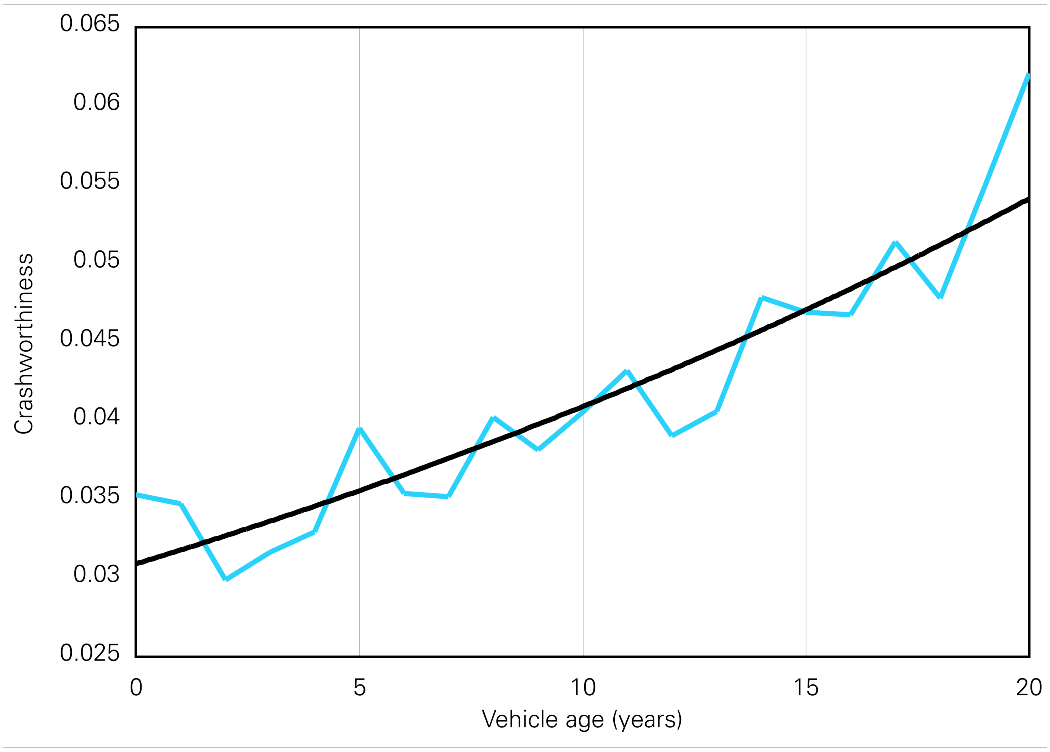


Figure 2.10
Unadjusted crashworthiness calculated from raw South Australian crash data 2003-2007. Crashworthiness is calculated as the number of serious and fatal crashes per crash where the damage cost was at least $3,000. The average increase in the serious injury/fatal rate is 2.8% per year of vehicle age.

2.2.6 Possible changes to the number of serious and fatal crashes arising from altering the vehicle age distribution of the crashed car fleet

In the previous Section, it was noted that the distribution of the age of the crashed passenger vehicle fleet was somewhat represented by the distribution of ages of the passenger fleet in general. It will therefore be assumed that changes to the distribution of vehicle ages in the registered passenger vehicle fleet would also be reflected in the distribution of vehicle ages in the crashed car fleet.

To confirm the earlier estimate of a 3% benefit of bringing the distribution of the general fleet into line with the overall Australian fleet, a simulation of crash severity was undertaken using all crashes that occurred from 2003-2007.

In this simulation it was assumed that the total number of crashes is constant. So the effect of altering the distribution of vehicle ages (and the related crashworthiness) would be to alter the distribution of severity within the sample of crashes.

Two simulations were performed:

- the first was to apply the age distribution of the Australian average fleet to the total number of crashed vehicles to estimate the effect of bringing the ages of crashed vehicles into line with the Australian average. That is, the proportion of the total number of crashed vehicles in each vehicle age group reflected that age group's representation in the entire Australian Fleet;
- the second simulation determined the required change in the vehicle distribution to effect a 10% reduction in the number of serious and fatal crashes in the State.

Applying the distribution of vehicle ages of the Australian average fleet

The actual distribution of vehicle ages of crashes reported to police in South Australia between 2003 and 2007 is given in Figure 2.8. The simulation will assume that this distribution is changed to reflect the Australian registered passenger vehicle fleet as shown in Figure 2.3 and given mathematically in Table 2.2.

The normalised frequency distribution of the vehicle ages of the Australian passenger vehicle fleet was multiplied by the total number of crashed vehicles in the 2003-2007 period (162,703 crashed vehicles) to arrive at hypothetical numbers of crashed vehicles in each age group. From Figure 2.10, crashes involving the newest vehicles include 3% that are serious or fatal. This number was applied to crashes involving vehicles in the first age group (age = 0, with an average age of 0.5 years) to arrive at a hypothetical number of serious and fatal crashes involving brand new passenger vehicles equal to 114.7.

The process was then repeated for every other vehicle age group (from 1 to 65 inclusive) but compounding the rate of serious and fatal crashes by 2.53% per year of vehicle age. Finally the total number of hypothetical serious and fatal injury crashes was calculated by tallying the number of such crashes in each age group.

For comparison purposes, the process was repeated using the Weibull distribution fitted to the actual South Australian registered passenger vehicle fleet. This step was also used to check that the method would accurately estimate the actual number of serious and fatal crashes that have occurred: this produced an estimate of an average of 1325 serious and fatal crashes per year over the period (compared to the actual value of 1360 crashes per year).

The simulation predicted that, if the distribution of vehicle ages of passenger vehicles crashed in South Australia was representative of the average Australian registered passenger vehicle fleet, there would be 47 fewer serious and fatal crashes per year, or 3.5%. This number is close to the estimate made earlier in Section 2.6.

Producing a 10% reduction in serious and fatal crashes

The Weibull distribution fitted to vehicle ages in the Australian registered passenger vehicle fleet is described in Table 2.2. Recalling that the Weibull distribution is given by:

$$F(t) = 1 - e^{-(t/\eta)^{\beta}} \quad (1)$$

the values for beta and eta for the Australian fleet are 1.225 and 10.6. Comparing the values of beta amongst Australian jurisdictions reveals it to relatively constant.

The simulation used in the previous Section was altered to reframe the question from, what effect on the serious and fatal crashes would a change in beta and eta have (i.e. making the SA fleet similar to Australia's fleet), to what change in eta (holding beta constant) would effect a 10% reduction in the number of serious and fatal crashes in South Australia. The "goal seek" function in Microsoft Excel was used to determine the appropriate value of eta.

The resulting value of eta was 8.03 (beta = 1.225), giving a fleet with an average vehicle age of 7.5 years and median of 6 years. The resulting distribution is shown alongside the distributions of current vehicle ages of various Australian jurisdictions in Figure 2.11. It may be noted that the relative numbers of vehicles 5 years or younger would need to increase by approximately 50%. The resulting fleet would the youngest of any Australian jurisdiction.

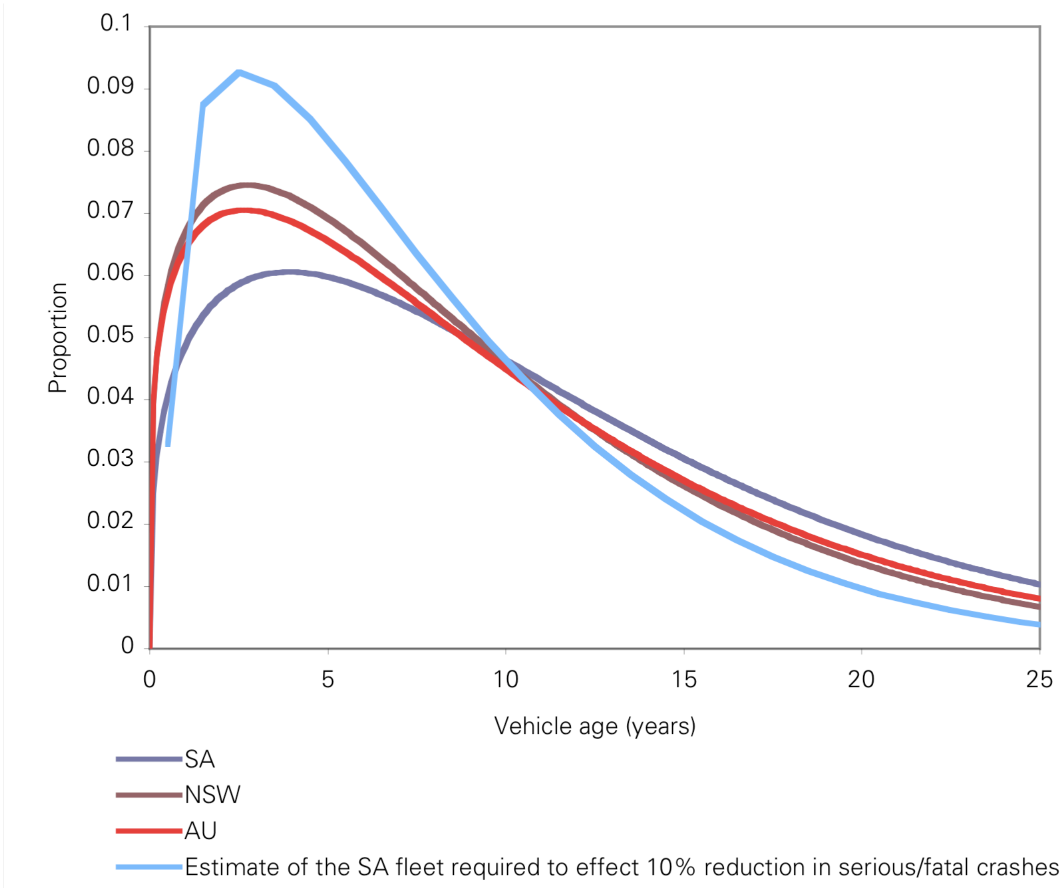


Figure 2.11
An estimate of the distribution of vehicle ages in South Australia required to effect a 10% reduction in the number of serious and fatal crashes.

2.2.7 Observations related to driver age

A subject of repeated observation is the over-representation of young drivers in crashes. In the years 2003-2007, drivers under 25 years of age were involved in around 24% of all reported crashes (at least $3,000 damage) and in around 29% of all serious and fatal crashes (Source: TARS). They therefore also have a higher serious/fatal crash rate in general.

Figure 2.12 shows that there is a correlation between the age of the driver and the age of their vehicle in crashes in South Australia. The graph in this Figure shows that the modal vehicle age for vehicles involved in crashes and driven by teenage drivers is around 13 years, whereas for drivers over 30 who crash, the modal vehicle age is around 2 years.

These differences are emphasised further in Figures 2.13 to 2.15; these Figures show the distribution of vehicle ages in crashes for drivers 25 years and older, the same distribution but for drivers younger than 25 years and finally, the cumulative age distributions shown on transformed axes that show the cumulative proportions of vehicles in crashes driven by the two age groups, plotted against the relative age-related average crashworthiness of the vehicles.

Figure 2.16 shows the crude crashworthiness of vehicles showing the dependence of the apparent rate of serious and fatal crashes on the age of the driver. In effect, vehicles appear less crashworthy when driven by a younger driver.

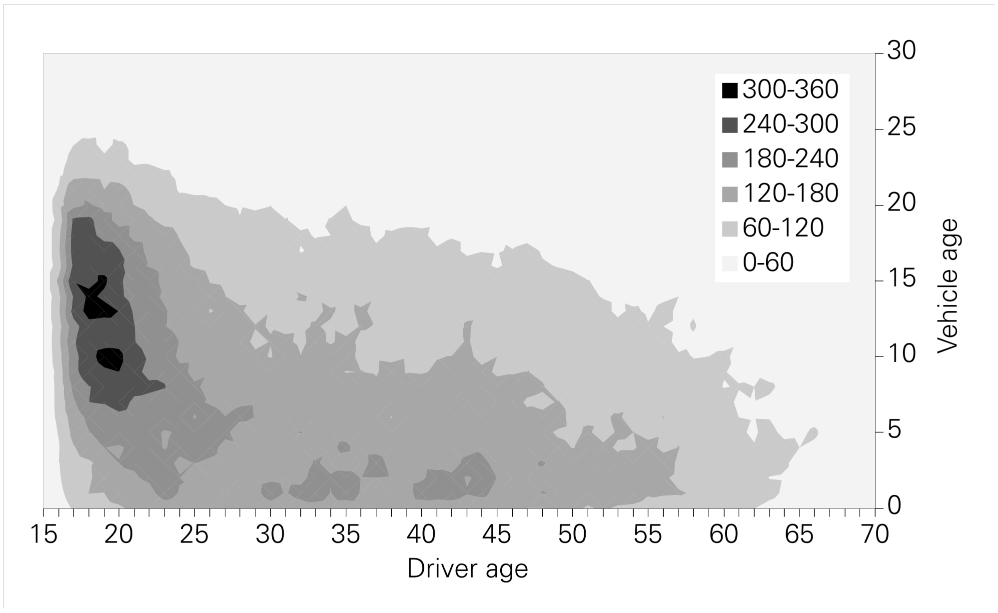


Figure 2.12
The number of crashes in the 5 years 2003-2007, disaggregated by vehicle age and driver age

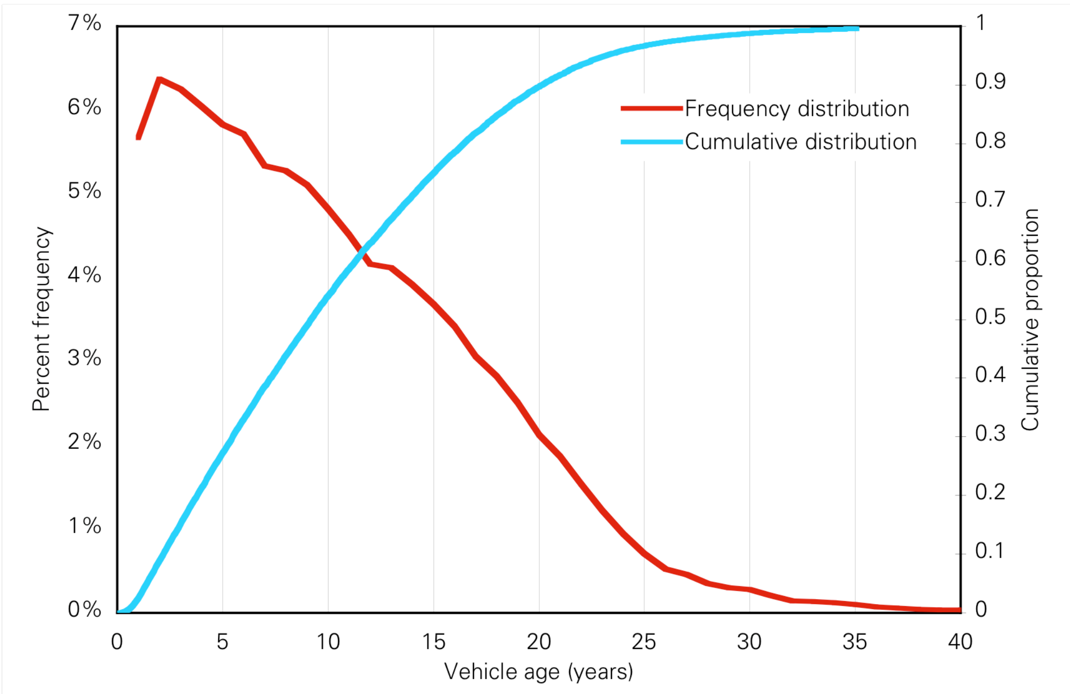


Figure 2.13
Age distribution of crashed passenger vehicles, utilities and vans in South Australia between 2003-2007 (Severity >= $3,000 damage) for drivers aged >= 25 years. For the frequency distribution, vehicle age corresponds with the average age of vehicles in each particular bin.(Source: TARS)

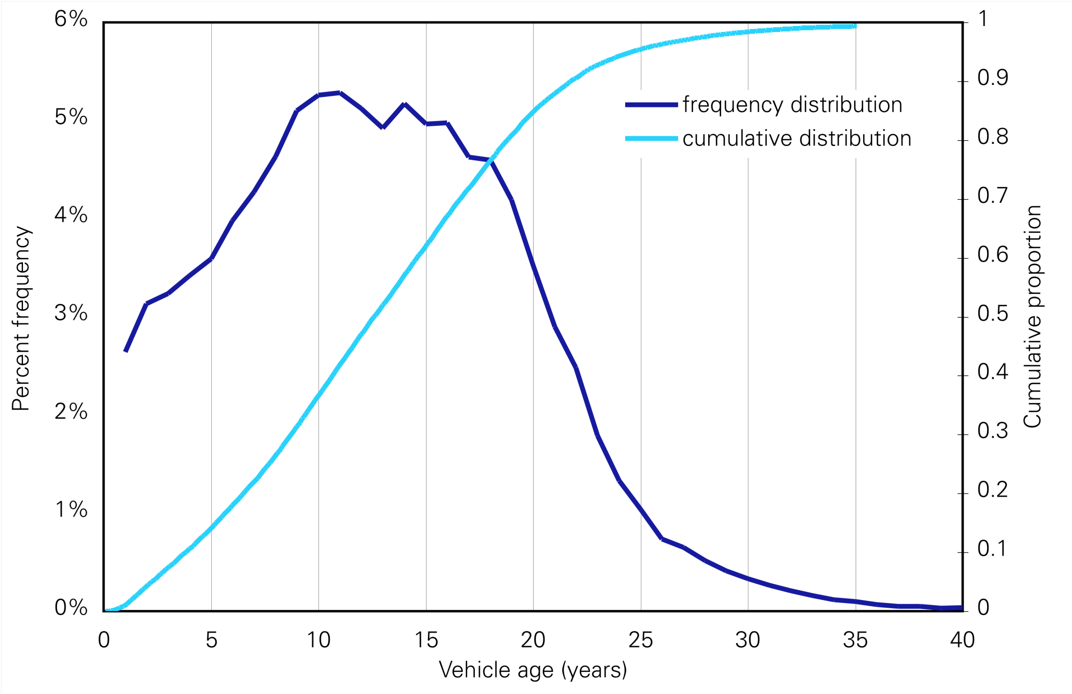


Figure 2.14
Age distribution of crashed passenger vehicles, utilities and vans in South Australia between 2003-2007 (Severity >= $3,000 damage) for drivers aged < 25. For the frequency distribution, vehicle age corresponds with the average age of vehicles in each particular bin.(Source: TARS)

Figure 2.15
Cumulative distributions of registered passenger vehicles in South Australia and the crashed vehicle fleet for younger and older drivers. Axes are linear in the Weibull transformation (Source: TARS)

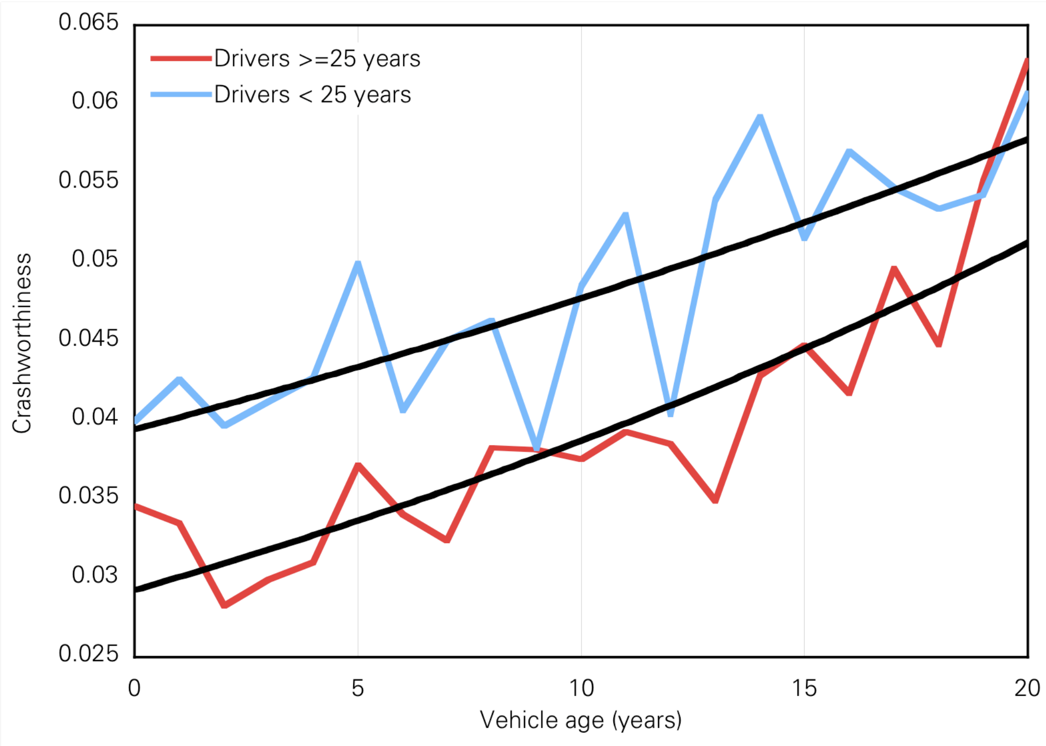


Figure 2.16
Unadjusted crashworthiness calculated from raw South Australian crash data 2003-2007. Crashworthiness is calculated as the number of serious and fatal crashes per crash where the damage cost was at least $3,000.

3 The link between compulsory periodic vehicle inspection and the age of the fleet[2]

Periodic motor vehicle inspections have been made compulsory in many countries around the world, and in some parts of Australia. The schemes involve compulsory inspections conducted at regular intervals, typically from six months up to three years. The length of time between inspections often depends on the age of the vehicle, with older vehicles being inspected at more regular intervals.

There have been many studies into whether compulsory vehicle inspections are effective in improving road safety (Rechnitzer et al., 2000; Keatsdale, 1999; Fosser, 1992). There appears to be no clear consensus on whether compulsory vehicle inspections have a significant effect on road safety, with estimates ranging from no effect, to a 21% reduction (Rechnitzer et al., 2000).

One possible side effect of compulsory vehicle inspection schemes is that they may act to refresh the vehicle fleet. Some vehicles may be considered by their owners to be too expensive to be made roadworthy. These vehicles may then be scrapped, and are replaced in the fleet with newer vehicles. As newer vehicles are associated with lower crash risk and injury risk (Newstead et al., 2008; Blows et al., 2003; Vaughan, 1993) it is possible that road safety benefits may become apparent through this side-effect.

The consistent message of existing research is that newer vehicles are associated with lower crash risk as well as lower injury risk (see Section 1.3). On the basis of such findings it might be concluded that refreshing the vehicle fleet by replacing older vehicles with new vehicles should have a positive effect on road safety.

This Section consists of a brief review of research into the value of refreshing the vehicle fleet, and whether compulsory vehicle inspection schemes are effective in refreshing the vehicle fleet. An assessment of whether further investigation is needed has also been made.

3.1 Does compulsory vehicle inspection refresh the fleet?

3.1.1 Overseas

Fosser et al. (1992) examined vehicle scrap rates as part of an investigation on the relationship between vehicle inspections and accident rates in Norway. 204,000 cars were tracked over three years from 1986 to 1990. 46,000 cars were inspected on a yearly basis, another 46,000 cars were inspected once at the beginning of the three period, and the remaining 112,000 were not inspected at all. The study was limited to cars that were between 6 to 8 years old at the beginning of the study.

At the end of the three year study 6.1% of vehicles inspected annually had been scrapped, as had 6.12% of the cars inspected once only. 6.58% of cars not inspected had been scrapped. That is, around 8% more vehicles never inspected had been scrapped. The author of the study concluded that periodic motor vehicle inspections may have prolonged the service life of the inspected cars resulting in a lower scrap rate. This result would suggest

[2] This Section is an update of the majority of an unpublished report prepared for the Motor Accident Commission in mid 2008.

that compulsory vehicle inspections may in fact increase the average fleet age, as older cars are kept maintained for longer.

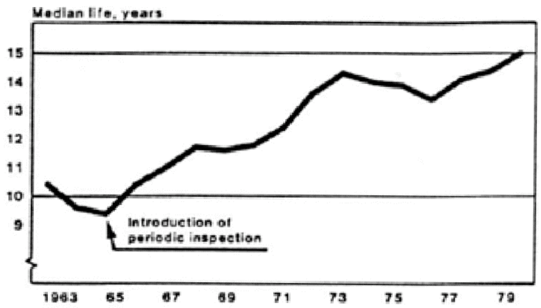
However, as the Norwegian study was restricted to vehicles 6 to 8 years old at the beginning of the three year study, it is possible that the cars that most likely to be scrapped would be those that were older than this, particularly when motor vehicle inspections were first introduced. By omitting this segment of the vehicle population, the result does not clearly indicate whether older segments of the vehicle fleet would be refreshed.

Poitras and Sutter (2002) looked at vehicle registration data from 1953 to 1967 in the USA, in order to study whether periodic vehicle inspections affected the number of old cars in use. In 1953, there were 15 states that required vehicle inspections, and in 1967 there were 22. Changes in inspection requirements were also taken into account in the study. The author concluded that "inspection does not significantly reduce the number of old cars on the road".

Asander (1992) discussed the introduction of compulsory vehicle inspections in Sweden in 1965. In the first year of compulsory inspections, 13 cars per 1000 were defected. After five years, this had reduced to 3.5 per 1000 and after the mid-1980s the number of cars defected was less than 1 per 1000. In 1964 to 1965, the scrap rate of vehicles increased dramatically in Sweden, and was balanced by new vehicle sales. The scrap rate rose from 10% p.a. to 17-18% p.a. after the introduction of compulsory vehicle inspections.

Asander suggested that this was "an expression of the fact that many vehicle owners were well aware of the bad condition of their vehicles and believed, right or wrong, that they could not be expected to pass the inspection". This supports the possibility that the 'worst' vehicles are likely to be scrapped when vehicle inspections are first introduced. Note though that the study related to the introduction of an inspection regime more than 40 years ago in an environment that not analogous to that of Australia.

Svenson (1987) also discussed the introduction of compulsory vehicle inspections in Sweden. It would appear that despite the initially higher scrap rates mentioned by Asander, the useful service life of vehicles in Sweden continued to rise after the introduction of vehicle inspections (Figure below). The useful life of passenger cars in Sweden increased by about 50% during the 15 years following the introduction of vehicle inspections. Svenson mentioned that the larger proportion of older cars did not result in lower safety standards, as the safety standards improved across all age-groups after 1965. There may have also been a wide variety of other factors influencing the service life of vehicles, aside from compulsory inspections. Again, it is worth noting that this study refers to data from 3 to 4 decades ago in an environment that not analogous to that of Australia.



Median life of passenger cars in Sweden 1963-1979 (Svenson 1987)

The view that inspection may actually increase the age of the fleet is supported by Rompe and Seul (1985). The authors quoted a report by the Danish Ministry of Justice which suggested that motor vehicle inspections may add 1 to 1.5 years to vehicle road life. Rompe and Seul wrote the following:

> …it has to be borne in mind that, in the initial stages at least, some old vehicles will be scrapped earlier than they otherwise would have been, since it would not be economic to make the repairs called for. So, at least to begin with, this would mean a shorter road life.

The report also shows that, in 1982 in a number of European countries, the distributions of the ages of vehicles were similar, regardless of whether the country had compulsory vehicle inspections.

3.1.2 Australia

In a submission to the Victorian Parliament Road Safety Committee, Paine (2000) stated that reducing the average age of the vehicle fleet may have potential road safety benefits. The author also stated that the "inability to pass an annual safety check is a major reason for scrappage of older vehicles in NSW", although this claim was not referenced. The author referred to a report by Caldwell (1992) who found that the median age of vehicles in New South Wales and the ACT, who had periodic vehicle inspection schemes in place, was lower than that in Victoria (and also South Australia).

Rechnitzer et al. (2000) quote Asander (1992) when stating that vehicle inspections were responsible for the replacement of 7-8% of vehicles with serious defects in Sweden. However, the 7-8% referred to is actually the increase in vehicle scrapping rates, on top of the usual 10% (Asander, 1992). There is no further mention on the influence of vehicle inspections on fleet age in Rechnitzer et al.

A report by Keatsdale Pty Ltd (1999) discussed briefly the relationship between motor vehicle inspection and fleet age in a report on the cost-effectiveness of periodic motor vehicle inspections. The report refers to the conclusions from Rompe and Seul (1985) and Fosser (1992), regarding vehicle service life. After considering these reports, the authors chose not to make any allowances in their cost-effectiveness study for increases in fleet renewal due to periodic motor vehicle inspection.

According to the ABS, in 2007, the average age of all vehicles in Australia was 10.0 years. As mentioned earlier in this report, in South Australia the average vehicle age is 11.1 years. The Northern Territory and New South Wales have the lowest average vehicle ages at 9.0 and 9.3 years. Currently these two jurisdictions are the only states/territories in Australia to have any compulsory periodic vehicle inspection schemes in place, although Victoria has a compulsory inspection on change of vehicle ownership. Additionally, data from the ABS (2007) showed that the Northern Territory and New South Wales had the lowest percentage of pre-1992 vehicles, at around 16% for both jurisdictions. In South Australia, 26% of the vehicle fleet was comprised of pre-1992 vehicles. The possible role of vehicle inspections in reducing the age of the passenger fleet is discussed further in the next Section.

4 Summary and discussion

This report has made a preliminary analysis of the age-related crashworthiness of the South Australian passenger vehicle fleet. Several analyses were performed including

- comparisons of the ages and related crashworthiness of vehicles between South Australia and the other States of Australia,
- potential adjustments of these measures to account for vehicle usage,
- an examination of the age and related crashworthiness of crashed vehicles in South Australia
- some "what if?" analyses to examine the effects of renewal of the registered passenger vehicle fleet
- examining the disparity in the ages of vehicle in crashes when the driver is younger compared to other drivers, and
- a short review of the evidence for fleet renewal through compulsory periodic inspection of passenger vehicles.

There appears to be a modest but measurable road safety benefit associated with reduction of the vehicle fleet age. Vehicle age has been correlated with increased crash risk and crash severity (Newstead et al, 2008; Blows et al, 2003) and accordingly, there is probably more serious and fatal crashes in South Australia due to the State's generally older vehicle ages. If the distribution of vehicle ages in South Australia was representative of the current distribution of vehicle ages in Australia, then, all other factors being equal, there would be 3.5% fewer serious and fatal crashes in the State. This is equivalent to the natural changes in the fleet that occur over 14 months.

However, to effect a 10% reduction in the number would require radically altering the distribution of vehicle ages, including increasing the number of cars under 5 years old by around 50%.

For analysis purposes, crashed cars appear to be represented by the registered fleet, with no weighting required. It is not clear why the ages of crashed vehicles did not match the weighted distribution of the ages of vehicles in general. The result is somewhat surprising given that vehicle kilometres travelled declines with vehicle age (Stukento et al., 2006). It may be that crash involvement per kilometre travelled is not independent of the distance travelled by a vehicle. Certainly there is some evidence that drivers who drive less have a higher per kilometre crash involvement (Elvik and Vaa, 2004, p. 83). The bias in the age of drivers of older vehicles may also be a confounder.

Cars appear less crashworthy in South Australia when a young driver (<25) is behind the wheel, as younger drivers have a higher rate of serious and fatal crashes per crash of any severity. This effect exacerbates the poorer average crashworthiness of vehicles crashed by this age group: the modal age of vehicles crashed by drivers under 25 years of age is the vicinity of 10-15 years, whereas the modal age of vehicles crashed by drivers aged 25 years and older is around 2 or 3 years of age. The differences between the ages of vehicles driven by younger drivers and the general registered fleet may be of more practical significance than the fact that the South Australian fleet is older than the Australian average or than other Australian jurisdictions.

Similarly, it is instructive to place the results of this report in the context of the differences in crashworthiness between market groups. On the measure of the rate of seriously and fatally injured drivers per tow away crash, based on the average age of vehicles in the registered fleet, South Australia exceeds the national average by 3%. Compare this with the crashworthiness of the average new model light passenger vehicle which is around 4%, twice that of the average new model large vehicle (Newstead et al., 2008, p87). The mix of models in the fleet is likely to be far more influential on crashworthiness than small movements in the average age of vehicles.

This points to a limitation of the analysis in this report: when computing and comparing the age-related crashworthiness of the different fleets, the assumption has been that in all other respects (fleet mix, driver characteristics, crash configurations) are equivalent across jurisdictions.

4.1.1 A link between average vehicle age and compulsory periodic vehicle inspections?

Despite a significant number of studies on the relationship between compulsory vehicle inspections and road safety, there would appear to have been little research done on the relationship between the introduction of compulsory vehicle inspections and fleet age. One limitation of existing research in this area is that it may be outdated, with data from as early as the 1950s being used to draw conclusions (Poitras and Sutter, 2002). This may have limited applicability to the current situation due to changes in vehicle durability, repairability and ownership patterns. Another limitation is that much of the existing research is from overseas, and the results may not apply equally to the Australian fleet.

However, the existing research would imply that there may be an immediate effect of refreshing the vehicle fleet with the introduction of compulsory vehicle inspections. This would be due to older un-roadworthy vehicles being scrapped initially, as their owners realise they would not pass the inspection (Asander, 1992). Following this, the average fleet age may actually begin to increase, as older vehicles are being kept in better condition in order to pass the inspections, which prolongs their service life (Fosser, 1992).

Nevertheless, compulsory vehicle inspections may depress the second hand car markets in those jurisdictions where the requirement exists, relative to jurisdictions where no requirement exists. This is sometimes cited anecdotally as a reason for lower wholesale prices of second hand motor vehicles in the Eastern States compared with South Australia, the lower prices providing an incentive for large scale importation of second hand vehicles into South Australia from New South Wales and Victoria. (Further, vehicle transport costs have been relatively cheap for such operations because of the export of manufactured vehicles from South Australia into New South Wales and Victoria – this provides fleets of trucks with space for vehicles to enter South Australia on the return trips; MTA, 2008).

Market distortions created by mandatory vehicle inspections (or lack thereof) provide a convenient explanation for the surfeit of older vehicles in South Australia. However, such reasoning is speculative at this stage; even if inspection regimes interstate contribute in some way toward older average vehicle ages in South Australia, its contribution may only be partial, as the average vehicle age may also be related to patterns of motor vehicle ownership in each jurisdiction.

ABS data from the 2006 census shows that New South Wales and the Northern Territory have the lowest rate of car ownership per household in Australia (ABS, 2008). Indeed there appears to be a weak positive correlation between the average number of vehicles per household and the average age of the passenger vehicle fleets in Australia. (Note though that South Australia and Tasmania appear to be outliers, with Queensland, Victoria and Western Australia having similar or greater average number of vehicles per household, yet younger average passenger vehicle ages.) New South Wales and the Northern Territory also have a higher proportion of households with no motor vehicle.

Kenworthy and Laube (1999) found that, in 1990, Sydney ranked highest out of all Australian cities on measures of public transport intensity (Adelaide ranked lowest), rail service intensity, public transport trips per person and proportion of all travel by public transport. Census data from 2006 shows that, public transport use for the purpose of travelling to work is nearly twice as common in New South Wales as in South Australia (ABS, 2008).). It is not beyond the realms of reasonable speculation that households requiring only a single motor vehicle may be able to afford a newer vehicle, and/or that the second vehicle in a two car household is likely to be older than the primary vehicle, and these effects contribute to the differences between the distribution of vehicle ages within Australian jurisdictions.

A more complete explanation of the differences in the distribution of vehicle ages (whether in terms of registered vehicles or crashed vehicles) in each State of Australia is therefore likely to account for the numbers of vehicles per household, measures of economic conditions, availability and use of alternative transport modes, as well as the presence of periodic compulsory vehicle inspections.

McIntosh (1998) outlined several strategies for reducing the age of the Australian vehicle fleet, including tax incentives, awareness campaigns and financial incentives for scrapping older vehicles. He did not include compulsory vehicle inspections in his consideration, nor decreasing reliance on the motor vehicle as a mechanism to reduce the numbers of old vehicles on the road. A 'New Vehicle Benefits Taskforce' was established in 1998 which considered similar options to those discussed by McIntosh (AAA, 1998). The use of financial incentives for scrapping older vehicles has been discussed in detail by Paine (1995). Further investigation into these options for reducing the age of the vehicle fleet are out of the scope of this review, however they may well include providing access to alternative transport modes to lessen the need for private vehicle ownership, assuming that the vehicles that would remain would be newer and hence more crashworthy.

4.1.2 Recommendations

While this report has examined the crashworthiness of the South Australian registered passenger vehicle fleet, it has not investigated any factors that influence the composition of the fleet. It was noted that the South Australian fleet is older than the fleets of several of the other States of Australia and data not published in this report indicate that, in South Australia, the number of vehicles built in a given year tends to increase for up to a decade after the build year, suggesting significant importation of second-hand vehicles from interstate. Similar data from New South Wales indicated an immediate decline in the number of vehicles of given build year in subsequent years.

The influence of new-car safety on the fleet's average safety is not immediate. Of course, if all vehicles were replaced instantaneously with new vehicles, there would be a significant benefit, but the reality is that a benefit of that sort of magnitude takes many years to realise. The young drivers that will crash the new cars being built today are currently young children and it is only once these children grow old enough to drive that the benefits of today's new car technology will be fully realised. In the shorter term, there may well be merit in understanding the impediments to young drivers driving newer (and safer) vehicles; for example, there may be restrictions on vehicle insurance which deny the use of newer cars to members of households that are young drivers.

With this in mind, rather than be concerned about the ages of vehicles in the fleet, it may be more fruitful to instead focus on trends in vehicle safety technology and other safety related characteristics of the fleet, particularly with vehicles entering the registered fleet for the first time (either as new cars or as imported second-had cars). It is probable that positively influencing the level of safety in vehicles entering the registered fleet will have road safety benefits many years into the future.

There would be a benefit in gaining a clearer picture of how and why vehicles enter the registered fleet and how and why they leave. Knowledge of this aspect of the turn-over of the registered fleet will allow a better understanding of the likely trends in vehicle ages as well as trends in the penetration of vehicle safety technology.

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Appendix A – A further examination of the trend in the median age of passenger vehicles

The preceding report found that the median age of passenger vehicles in South Australia exceeds the overall median age of passenger vehicles in Australia, and that the difference is leading to an excess of serious and fatal crashes of around 3.5%. This Appendix to the report examines how stable this difference is. The Australian Bureau of Statistics Census of Motor Vehicles has collected vehicle data at regular intervals over several years. The data provides an opportunity to examine the difference in vehicle ages over time.

METHOD

Consecutive Census of Motor Vehicles from the ABS were collated. The Census reports that were used related to census dates from 1995 to 2007.

The ages of the populations of vehicles in SA and Australia were characterised by the median age of vehicles in each population. Some estimation was required to do this as the build dates of vehicles are grouped into one-year cohorts (for recent build years) and into five and ten year cohorts for older vehicles. At each census date, the ABS (2007a) estimates the ages of each vehicle according to the formula:

$$\text{Vehicle age} = \text{Current year} - \text{Year of manufacture} + (\text{Reference month} - 6)/12$$

where the Reference month is the month of the census. To estimate the median age, linear interpolation was used across the cohort to which the vehicle of median age belonged.

For census dates in 2002 and before, the median age lay in cohorts spanning 5 or more years, and so the method of estimation described above was not used for these census dates. For these census dates, estimates of median age were made by fitting a Weibull distribution to the census data, and using the distribution's median as the estimate. Methods for fitting the distribution are described in the preceding report.

RESULTS

Figure A1 shows the difference in the median age of passenger vehicles between those registered in South Australia and in Australia as a whole, for the years 2003 to 2007. The Figure shows the results from both the numerical estimation and from the Weibull estimation method.

Both methods of estimating the median age show downward trend in the difference between the South Australian and Australian median vehicle ages. Note that the fitted model appears to underestimate the difference in median age in earlier years.

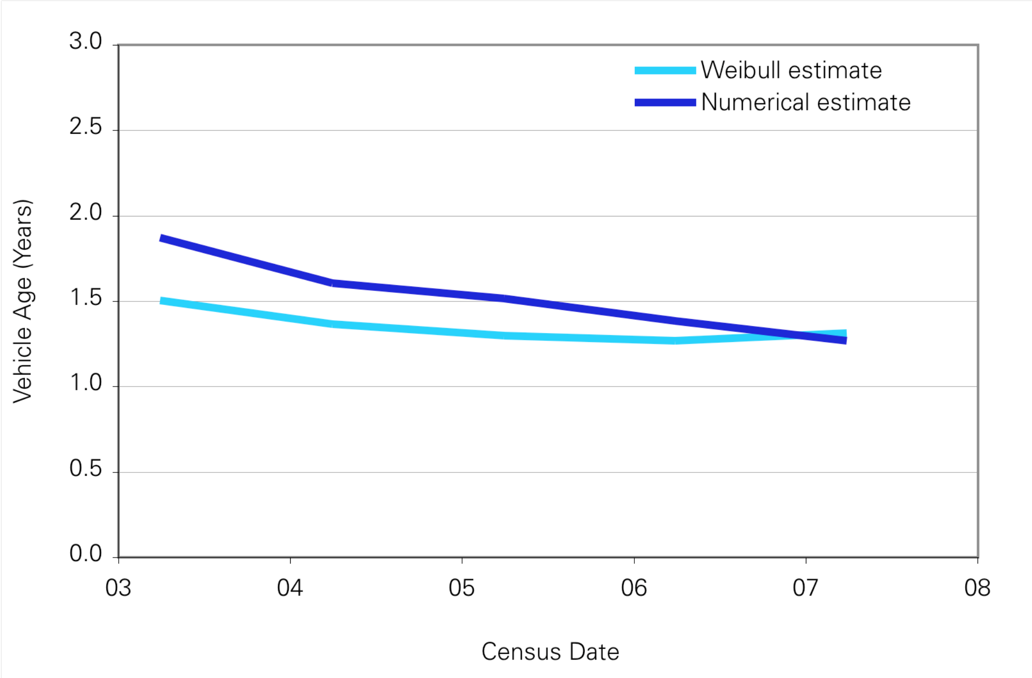

Figure A1
The difference in median vehicle age between South Australia and Australia from March 2003 to March 2007 using a fitted distribution and a direct numerical approach (Source ABS 2007b)

Figure A2 shows the median vehicle age calculated from the Weibull distributions fitted to the data for South Australia and Australia for each census date, and the difference between the two medians, over the time period May 1995 to March 2007. The graph suggests that the median vehicle ages of the fleets of both South Australia and Australia have declined since 1997, as has the difference between them. Linear regression was used to analyse this trend. It showed that, based on the more conservative Weibull estimates of median age, the current difference might be reduced to a year and eight days by 2010 and just over five months in ten years time (2019), if the trend continues unchanged.

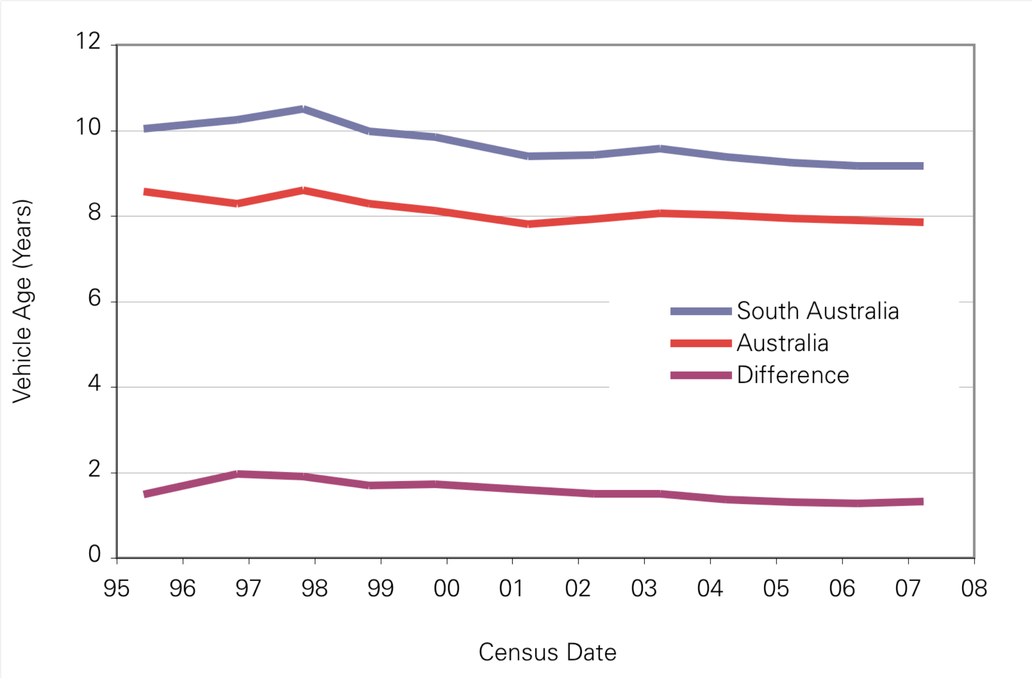

Figure A2
Estimated median vehicle age of South Australian and Australian passenger vehicle fleets between May 1995 and March 2007. (Estimate based on fitted Weibull distributions; source ABS 2007b)

DISCUSSION

ABS data on the average vehicle age of the entire Australian fleet are shown in Figure A3. It shows that the point at which the difference between the South Australian and Australian median age decreases (Figure A2) coincides with the peak in average age of the Australian vehicle fleet in Figure A3. It appears that as the average age of the Australian fleet decreased, the difference between the median age of the Australian and South Australian fleets also decreased. Whether this trend will continue is uncertain, as the exact factors that affect the median fleet age are not known precisely, although new vehicle sales volumes must certainly play some part. What can be said is that the median age has been decreasing for the past ten years and so has the difference between the median vehicle age of the South Australian and Australian fleets.

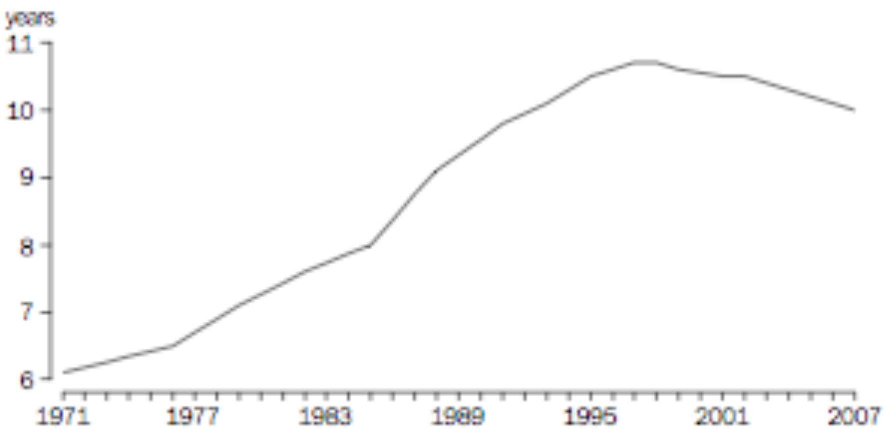

Figure A3
Average Australian Fleet Age from 1971 to 2007 (ABS, 2007a)

As the Weibull distribution appears to be a poorer fit for older census data, the magnitude of the trend in the difference in median ages should be treated with some caution. However, the current trend shows a narrowing in the difference between the SA and Australian fleets' median ages.

CONCLUSION

The difference in the median age of South Australian and Australian vehicle fleets has not been static, but has declined over the recent past. The future difference in median vehicle age will probably depend largely on the trend in age profile of the Australian vehicle fleet as a whole. If the Australian vehicles on register become younger, as they have for the past ten years, the discrepancy between the age of South Australian fleet and the age of the Australian fleet should also reduce, as should the related discrepancy in the number of serious and fatal crashes.

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