

## The relative age related crashworthiness of the registered South Australian passenger vehicle fleet

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### Abstract

In this paper, 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 drivers 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, Vehicle Age, South Australia, Modelling

### Introduction

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” [1]. 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:

$$\text{Number of serious crashes (N)} = \text{risk of a serious crash} \times \text{exposure}$$

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:

$$N = \text{risk of having a crash} \times \text{risk that a given crash is serious} \times \text{exposure}.$$

To reduce N, the three components on the right hand side of this equation provide broadly 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 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.

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

Newstead et al. [2] 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. [2] 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. The overall measure of risk to any driver or vulnerable road user in a crash is called “total secondary safety” [2].

*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. For the present purpose, it will be assumed 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. [2] 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.

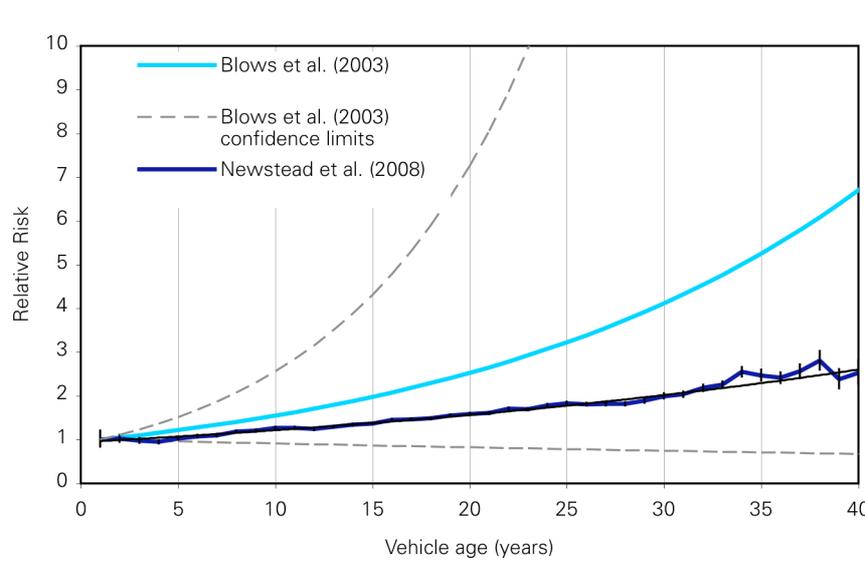
If an exponential function is fitted to the measured relationship between average crashworthiness and age measured by Newstead et al. [2], the decrease in average crashworthiness of passenger vehicles is 2.53% per year of age (Figure 1).

In a case control study conducted in the Auckland region, Blows et al. [3] 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 were interviewed. The analysis of the effect of vehicle age on crash outcome included numerous adjustments. Covariates that were found to be significant were drivers 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.

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 were 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 [4] 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.

The relationships between average crashworthiness and vehicle age from Newstead et al. [2] and Blows et al. [3] are shown in Figure 1.



**Figure 1:** The relationship between average crashworthiness and vehicle age, relative to vehicles that are one year old, based on Newstead et al. [2] and Blows et al [3]

## Objectives

In this Paper, the vehicle age-related crashworthiness of the South Australian fleet will be examined. The Paper 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 crash exposure; and finally
- some observations of the ages of vehicles crashed by younger and older drivers are made.

## Methods

### Data sources

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

- Data from the registration and licensing database held by the South Australian 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 the distribution of ages of the South Australian crashed car fleet, data from the South Australian Traffic Accident Reporting System was used.

### Determining vehicle ages

In this study, vehicle age will be defined in accordance with the definition used by the ABS in the regular censuses of motor vehicle registrations [5]. 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

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

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

*Fitting a statistical distribution to vehicle ages*

The Weibull distribution [6] (often used in survival analysis) was fitted 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. The justification of the use of the Weibull distribution is its goodness-of-fit.

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.

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

Both Newstead et al, [2] and Blows et al. [3] identified improvements in average relative crashworthiness that could be expressed as a constant rate from one year to the next; that is:

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

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:

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

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.

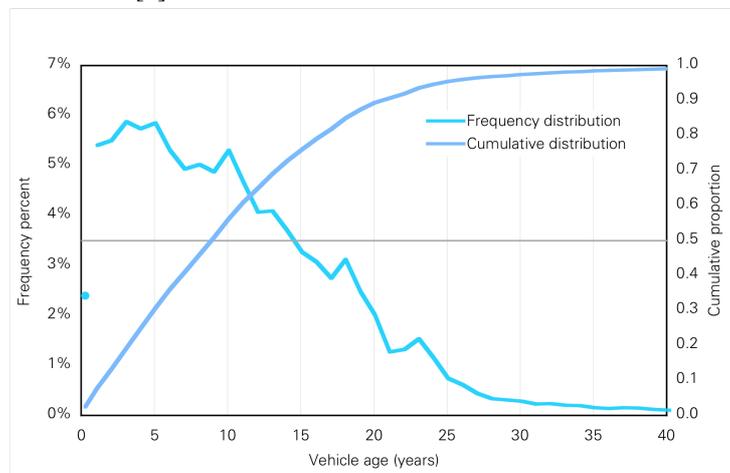
## Results

### Age distribution of the South Australian registered fleet

The TRUMPS database records, amongst other items, the year of manufacture of each registered vehicle. The DTEI TRUMPS report provides this data by vehicle type.

Figure 2 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 [5].



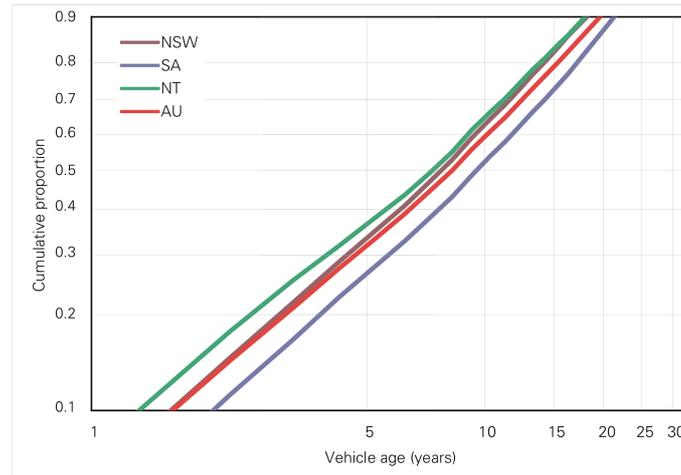
**Figure 2:** Age distribution of registered passenger vehicles, utilities and vans in South Australia as at 31/7/08. For the density distribution, vehicle age corresponds with the average age of vehicles in each particular bin. The first frequency bin covers a smaller cohort of vehicle ages than the subsequent age bins. (Source: DTEI TRUMPS report 31/7/08)

### A comparison with other States of 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 [5]. 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 3 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 3:** Cumulative distributions of registered passenger vehicles of some Australian jurisdictions. Axes are linear in the Weibull transformation (Weibull – log) [5]

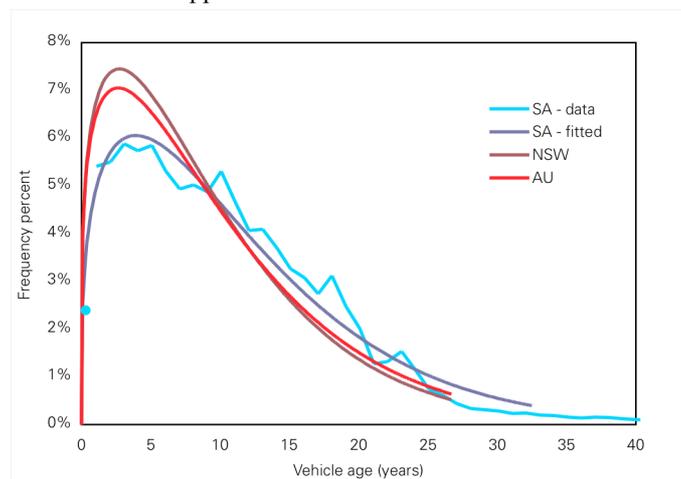
Least-squares regression suggests Weibull distributions as detailed in Table 1 for registered passenger vehicles in South Australia, New South Wales and Australia. Note that the mean and median vehicle ages of the fitted SA distribution are slightly higher than the equivalent numerical values, but are within 3%.

**Table 1:** Parameters of Weibull distributions (Equ. 1) 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 <sup>2</sup>	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

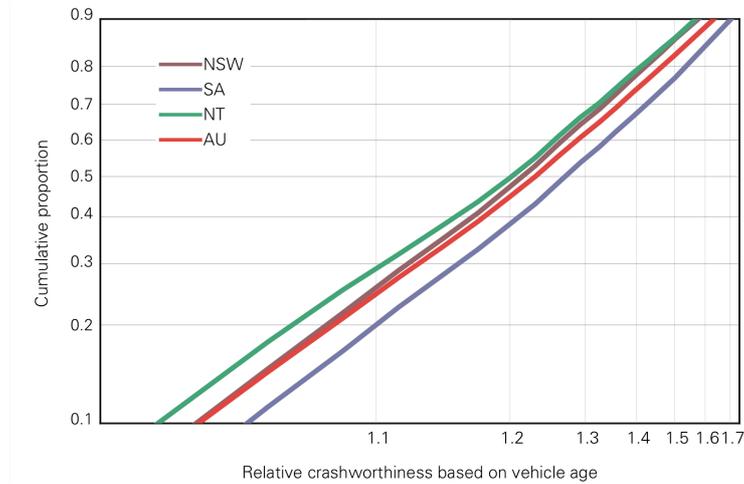
Note: R<sup>2</sup> values refer to the correlation between  $\ln(t)$  and  $\ln(-\ln(1-f(t)))$

The probability density functions of the fitted Weibull distributions for Australia, NSW and SA are shown in Figure 4. Figure 4 also shows the age profile of the South Australian fleet given in Figure 2. The adequacy of the fitted distribution is apparent.



**Figure 4:** Fitted age distributions of registered passenger vehicles in SA, NSW and Australia as at 31/3/07. Actual data for South Australia is shown also

Figure 5 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. [2]). Note that a rate of 2.53% appears to match the crude crashworthiness of vehicles in South Australia.



**Figure 5:** Crashworthiness cumulative density function of registered passenger vehicles in SA , NSW, NT and Australia as at 31/3/07 [5], based on a 2.53% 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 Figure 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 Table 2.

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. 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.

**Table 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. [2])

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

Assuming that the age distribution of the passenger fleet is stable over time, 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. For example, a certain time constant corresponds to the time that elapses 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 months and between the South Australian and Australian passenger vehicle fleets, it is 14 months.

### Adjustments for crash exposure

An alternative to examining the distribution of crashworthiness of registered vehicles, 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 report processing 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 ages of vehicles at the time of the crash were calculated. Some averaging was required to do this. The year of the vehicle’s 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

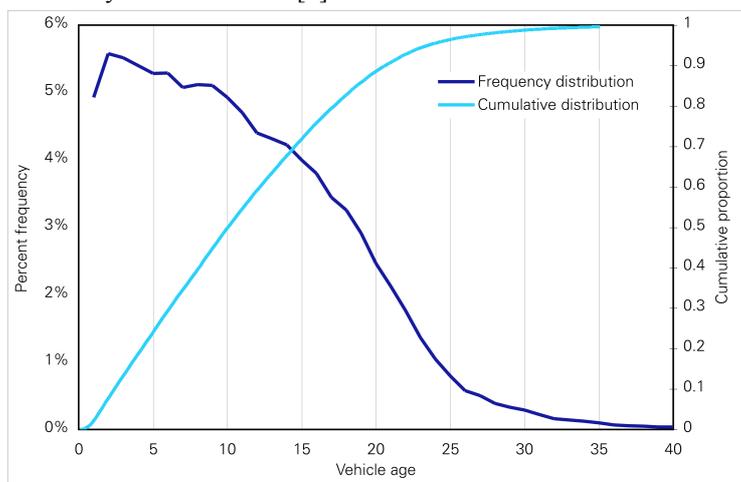
$$\text{Vehicle age} = \text{Year of crash} - \text{Year of manufacture} + (\text{Month of crash} - 6)/12$$

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

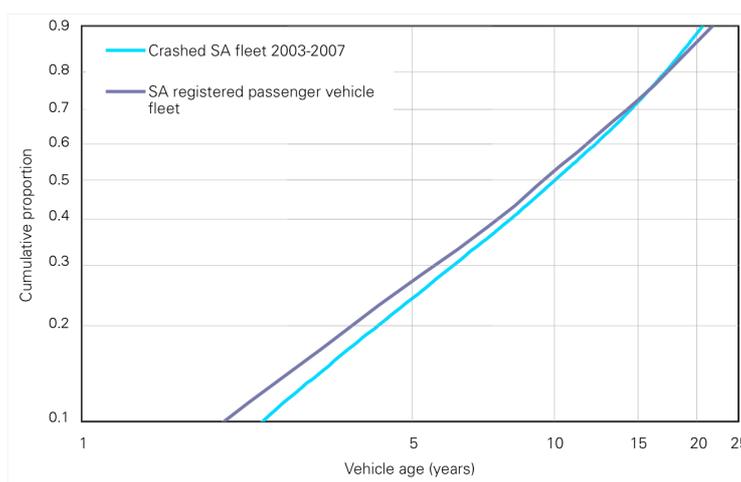
The distribution of vehicle ages of the crashed vehicles is shown in Figure 6. The cumulative distribution of the vehicles’ ages is shown on transformed axes (Weibull – log axes) with the age distribution of the registered passenger vehicle fleet in Figure 7.

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 8. 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

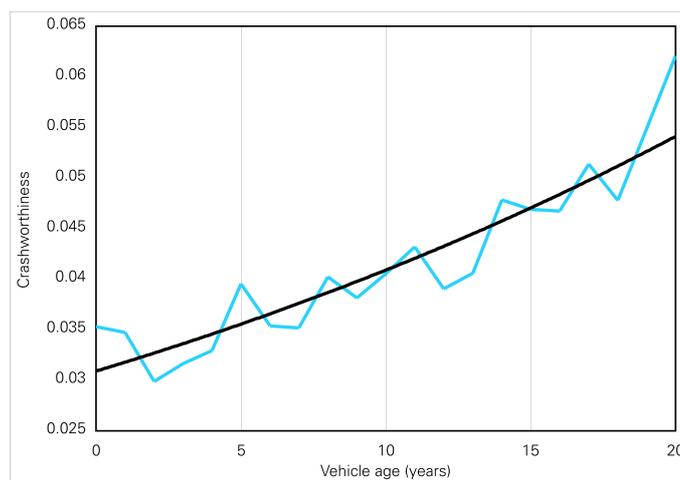
of vehicle age, an increase almost identical to that adjusted rate of driver serious injuries and fatalities per tow away crash estimated by Newstead et al. [2].



**Figure 6:** Age distribution of crashed passenger vehicles, utilities and vans in South Australia between 2003-2007 (Severity  $\geq$  \$3,000 damage). For the frequency distribution, vehicle age corresponds with the average age of vehicles in each particular bin. (Source: TARS)



**Figure 7:** A comparison between the cumulative distributions of the crashed vehicles (shown in Figure 6) and the registered passenger fleet.



**Figure 8:** 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.

### 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 6. The simulation will assume that this distribution is changed to reflect the Australian registered passenger vehicle fleet as shown in Figure 4 and given mathematically in Table 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 7, 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.

To validate the procedure (and for comparison purposes), the procedure was repeated using the Weibull distribution fitted to the *actual* South Australian registered passenger vehicle fleet: 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 were 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.

### Producing a 10% reduction in serious and fatal crashes

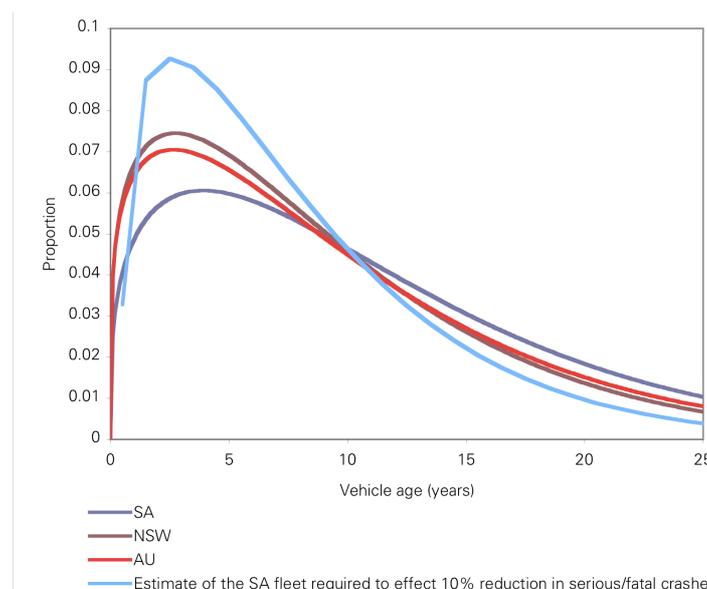
The Weibull distribution fitted to vehicle ages in the Australian registered passenger vehicle fleet is described in Table 2. Recalling that the Weibull distribution is given by:

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

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 be 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 9. 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 be the youngest of any Australian jurisdiction.



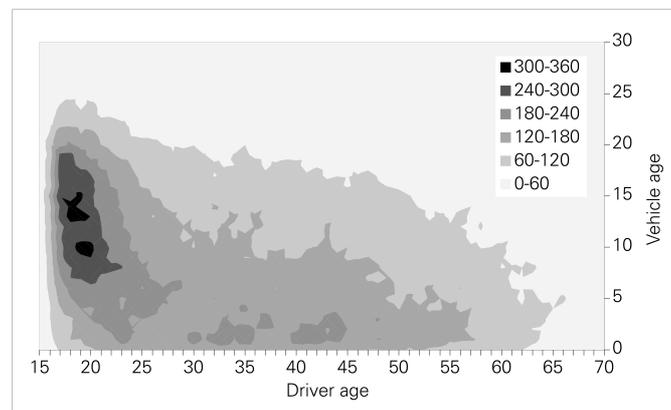
**Figure 9:** An estimate of the distribution of vehicle ages in South Australia required to effect a 10% reduction in the number of serious and fatal crashes.

**Observations related to driver age**

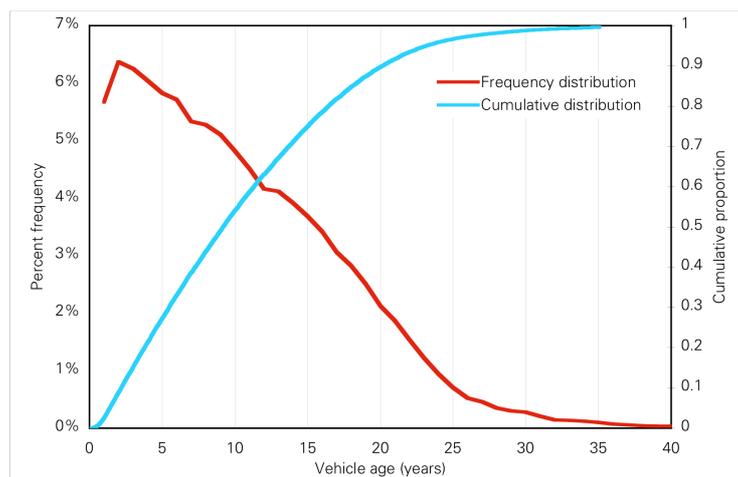
A subject of repeated observation is the over-representation of young drivers in crashes. In the years 2003-2007, drivers under 25 years of age were involved in around 24% of all reported crashes (at least \$3,000 damage) and in around 29% of all serious and fatal crashes (Source: TARS). They therefore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

Figure 10 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 11 years, whereas for drivers over 30 who crash, the modal (most common) vehicle age is around 2 years.

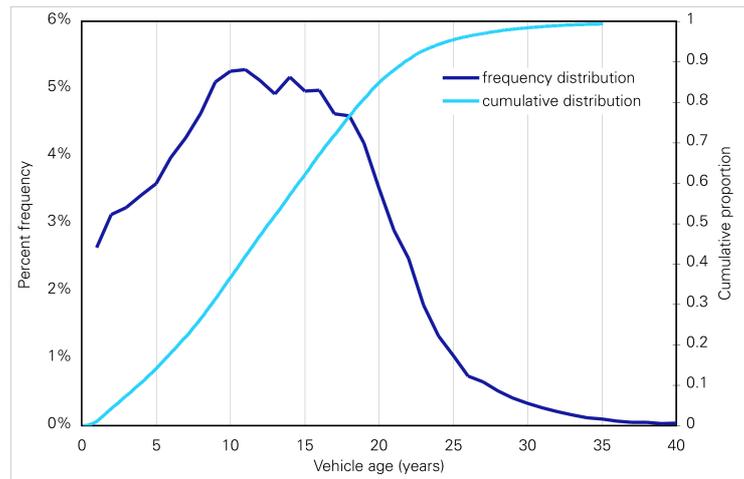
These differences are emphasised further in Figures 11 to 13. These Figures show the distribution of vehicle ages in crashes for drivers 25 years and older, the same distribution but for drivers younger than 25 years and finally, the cumulative age distributions shown on transformed axes that show the cumulative proportions of vehicles in crashes driven by the two age groups, plotted against the relative age-related average crashworthiness of the vehicles.



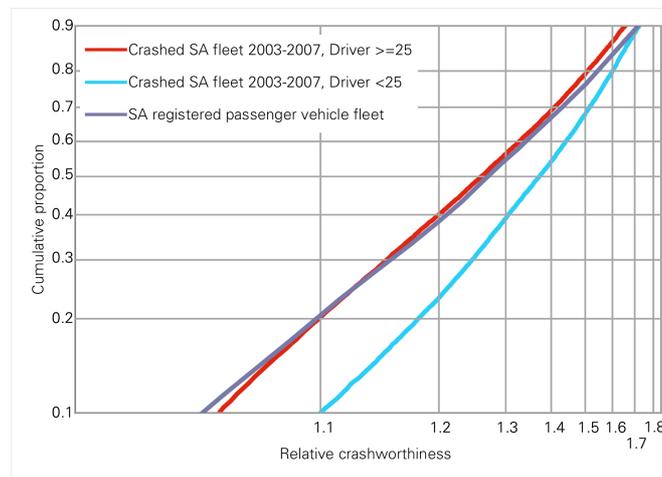
**Figure 10:** The number of crashes in the 5 years 2003-2007, disaggregated by vehicle age and driver age



**Figure 11:** Age distribution of crashed passenger vehicles, utilities and vans in South Australia between 2003-2007 (Severity  $\geq$  \$3,000 damage) for drivers aged  $\geq$  25 years. For the frequency distribution, vehicle age corresponds with the average age of vehicles in each particular bin. (Source: TARS)

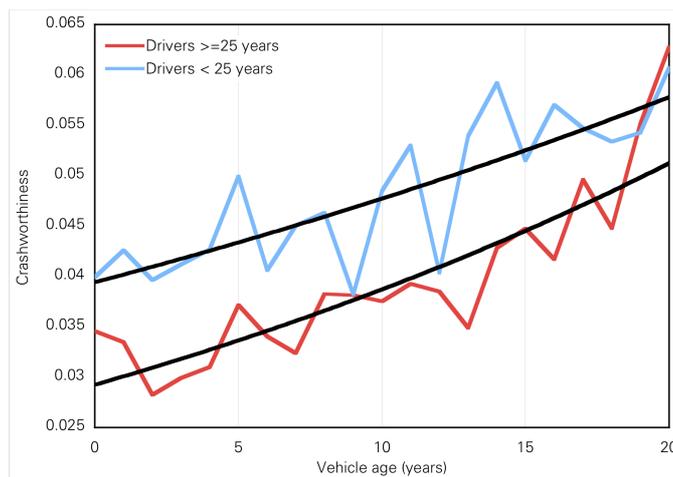


**Figure 12:** Age distribution of crashed passenger vehicles, utilities and vans in South Australia between 2003-2007 (Severity  $\geq$  \$3,000 damage) for drivers aged  $< 25$ . For the frequency distribution, vehicle age corresponds with the average age of vehicles in each particular bin. (Source: TARS)



**Figure 13:** 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 14 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 crashed by a younger driver.



**Figure 14:** 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.

### Discussion

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, [2]; Blows et al, [3]) 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. This is somewhat surprising given that vehicle kilometres travelled declines with vehicle age [7]. 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 [8, 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 study 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., [2], 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 study: 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) fleets are equivalent across jurisdictions.

While this study 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 paper 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 be merit in understanding the impediments to young drivers driving newer (and safer) vehicles; for example, there may be restrictions/surcharges on vehicle insurance that discourages 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-hand 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.

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