

Safety related attributes of registered vehicles and of vehicles that crash in South Australia

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Abstract

The objective of this study was to characterise and compare a registered fleet and a crashed vehicle fleet with respect to vehicle attributes related to safety.

Two samples of vehicles were examined: a random sample of 2000 passenger vehicles registered in South Australia and all passenger vehicles involved in serious casualty crashes in South Australia in 2008-2009. Vehicles were linked with sales and specification data. The resulting data sets were disaggregated according to the year in which the vehicles were sold. The installation rates of various technologies were estimated in each year-cohort of vehicles.

In general, the availability of technology is similar among crashed vehicles and registered vehicles for a given year of sale, although ESC equipped vehicles are under-represented in crashes. However, given that crashed vehicles are older than in the general registered fleet, availability of safety equipment in crashed vehicles is less than average. Average ANCAP ratings are improving, but not in the area of pedestrian protection.

The full introduction of a safety technology into new vehicles has generally taken between 10 and 20 years. ESC was present in 50% of the registered vehicle sample bought new in 2008 and 2009, but was in only 13% of the fleet overall.

Introduction

“Safer vehicles” are one pillar of the safe system approach to road safety, common to jurisdictions across Australia. Vehicle manufacturers now commonly promote the safety of their product in marketing material, and authorities actively promote safer vehicles through consumer rating programs such as the Australasian New Car Assessment Program and through regulation.

However, the way in which *new* vehicle safety affects road safety is not immediately clear – vehicles on the road are a mixture of old and new, and the latest safety technologies are often in only the most up-market vehicles. Many technologies are of uncertain efficacy. Most drivers and their passengers benefit from new safety developments only when effective safety technologies become commonplace; even then, with a median vehicle age of about 10 years, Australians effectively wait for more than a decade before they begin to benefit from the latest technologies. This is particularly so in states with older fleets, such as South Australia.

This characteristic of vehicle technologies – the inevitable lag between development and benefit – places vehicle technologies in a separate category from other road safety measures. A speed limit can be changed and a benefit is realised immediately, whereas improvements to vehicle technology, while often extremely important, must be considered as part of a much longer-term strategy to improve road safety.

The vehicles that are used by the community for business and private use are a component of the safe-system, but the effects of changes to vehicles on fleet safety, and whether it is possible to mould the future fleet, are not well studied. The characteristics of new vehicles – their size, primary safety and secondary safety features – are largely determined by a free market, in which safety must compete with other ideas of what constitutes value and satisfies the needs and desires of customers. Yet, it is the new vehicle purchaser that determines the restocking of vehicles in the fleet. A new vehicle owner may drive a vehicle for a relatively short time (for as short as two years in some commercial and government fleets), but the legacy of that purchase will persist for almost two decades. New vehicles are the second

hand vehicles of tomorrow, and the safety features of some vehicles may be tested in a crash only after 15 years (if at all).

In a previous study we analysed the age of the registered fleet in South Australia and also that subset of vehicles involved in crashes (Anderson et al., 2008). Other studies by Newstead et al. (e.g. Newstead et al, 2008) have shown that vehicle crashworthiness is improving by around 2.5% per annum; that is, the rate of serious injury and fatal crashes per tow away crash increases by 2.5% per year of vehicle age and that the improvement comes about through improving vehicle design.

While South Australia has, on average, an older fleet of vehicles than the national average, the straightforward estimate that was made in Anderson et al (2009) of the over-representation of serious and fatal crashes in South Australia, associated with the lag in the age of vehicles, was around 3%. It was by no means clear that efforts to modernise the South Australian passenger vehicle fleet would deliver much road safety benefit – a conclusion of that report was that it was probably more important to focus on fleet mix, rather than fleet age, and that a better objective would be to influence the standard of safety of vehicles entering the fleet and then encourage diffusion of those vehicles to those most at risk of crashing.

So with this motivation in mind, this paper has been structured to examine some features of the evolving nature of vehicles in South Australia, both in the general registered fleet and in those involved in crashes.

Methodology

Two samples of vehicles were examined. The first was a set of 2000 vehicles that were a random sample of all passenger vehicles on register in South Australia in April 2010 (cleaned, randomised and then sampled) and the second is all passenger vehicles involved in any kind of casualty crash in South Australia in 2008-2009. Here, passenger vehicle refers to any vehicle described as a “sedan”, “station wagon” or “utility” in the Register. Detailed information about the vehicles in these samples was sourced from RL Polk Australia via the vehicle identification number (VIN) of each vehicle in the sample. The specifications returned from Polk cover a range of vehicle attributes that are relevant to primary safety (crash prevention) and secondary safety (crash protection). Similar methods are outlined by Scully and Newstead (2007), but in that case, several datasets and some hand matching was employed to identify the prevalence of a single feature (ESC). In the present paper, matching vehicles to specifications using the Polk database allowed rapid matching and the determination of the many vehicle attributes simultaneously.

The second sample of vehicles consisted of 2,210 vehicles with data on the number of active units and the crash type of the associated crash. Through matching via the SA Police Vehicle Crash Report system, the VIN of each vehicle (where present or ascertainable) was retrieved. Of these vehicles, a VIN was returned for 1,853 vehicles (84%). Vehicles with VINs that could not be matched to specification data, and those vehicles with no VIN were almost entirely vehicles sold prior to 1991.

Disaggregation

The two groups of vehicles - the sample registered vehicles and population of crashed vehicles - are separated temporally and so methods were used to allow comparisons to be made; the samples were compared by first disaggregating each sample into ‘year-of-sale’ cohorts. The characteristics of each year-of-sale cohort were then compared within and across the two samples. Disaggregating the samples along these lines also has the advantage that any effect of differences in exposure due to differences in vehicle ages are removed from the comparison.

Further, the data were disaggregated according to the feature or attribute of interest. The result was a cross-tabulation of the presence of the feature (usually being along the lines of “standard”, “optional” or “not present”) against the year in which the vehicle was sold. For the

purposes of this paper, only standard installations (that is, features which are present on a vehicle and not optional) were considered.

Attributes examined in the study

The Polk data consisted of VFACTS fields (relating to the sale of the vehicle) and price and specification data. Polk receives sales data from the Federal Chamber of Automotive Industries. The records contain data on many vehicle attributes. Only a small set of attributes was examined for this paper. The focus was on those attributes most associated with vehicle safety advances within the broader categories of 'braking and stability control', 'passive safety', and 'ANCAP performance'.

VFACTS data are of particular interest as they show the origin and type of buyer of every vehicle in the sample. While it is beyond the scope of the present paper to discuss this aspect of the data, it may be noted that slightly fewer than 30% of vehicles registered in South Australia originated in a state other than South Australia, with the majority originating in New South Wales or Victoria. Slightly more than half of all vehicles were first bought (new) by a non-private buyer – largely private fleet and government – highlighting the important influence that these types of buyers might yield over the specification of the general stock of vehicles available to private second hand buyers.

Results

Braking and stability control systems

Systems to improve vehicle handling in emergency situations are promoted as being beneficial for crash prevention. Historically, the effectiveness of such systems has been highly variable. Many studies have been unable to associate any reduction in injury crashes with the fitment of ABS (Cummings and Grossman, 2007). Electronic stability control (ESC) on the other hand has been shown to markedly reduce crash risk for some common crash types (a summary of estimates is given in Ferguson, 2007). Scully and Newstead (2008) found that ESC was associated with a 30% reduction in single vehicle injury crashes in Australia.

Table 1 details the fitment rate of these systems in the two samples of vehicles.

It might be noted that some technologies in Table 1 appear underrepresented in crashes given the figures in the first two columns. However, these differences are due mainly to the differences in the age profile of the crashed vehicles and the registered fleet in general, and partly due to the temporal separation of the two samples, and not necessarily due to a reduced crash risk. As older vehicles are over-represented in crashes due to non-vehicle reasons (see Anderson et al., 2009), and these vehicles are less likely to have any given technology in Table 1, the prevalence of the technology in crashes is lower than in the registered fleet generally.

The progressive introduction of various features into new vehicles can be seen when the data is presented as a disaggregation by year of sale. The earliest system (ABS) is at the top of the charts in Table 1 and the most recent (ESC) at the bottom. The introduction of ABS to almost all new passenger vehicles has taken about 20 years since it was first available in new vehicles. This pattern is common to many of the attributes in the vehicles in the samples (including for attributes not shown here). ESC was fitted to around 50% of vehicles in the registered fleet sample that were sold in 2009; however in April 2010, ESC equipped vehicles constituted only about 13% of all registered vehicles in South Australia.

There is a noticeable downtick in the representation of vehicles with ESC and traction control systems in crashes involving vehicles sold in 2006 onward. It is likely that this is due to the effectiveness of ESC in preventing crashes. Further analysis showed that, for vehicles first sold from 2004 onward, ESC installation was associated with a large under-involvement in single vehicle crashes in 2008 and 2009, compared with multiple vehicle crashes (Table 2).

While it is not possible to exclude confounding effects to do with vehicle type and driver type from this observation, the effect is large and consistent with benefits found in other studies.

Table 1 Fitment of brake assisted primary safety technology in the South Australian fleet

System	Prevalence in the registered passenger vehicle fleet	Prevalence in passengers vehicles involved in serious/fatal crashes	Disaggregation by year of sale
Antilock braking systems	53%	42%	
Traction control systems	21%	14%	
Electronic stability control systems	13%	6%	

Note: The prevalence in the disaggregation figure refers to the fitment rate in each year-of-sale cohort.

Table 2 Cross-tabulation of vehicles involved in serious/fatal crashes in 2008 and 2009 by ESC status and crash type – for vehicles sold between 2004 and 2009 only

ESC fitment	Single vehicle crashes	Multi-vehicle crashes
None / optional	95	236
Standard	9	68

Chi-square = 8.64, p = 0.0033

Passive (secondary) safety features

Passive safety systems are designed to protect occupants or vulnerable road users in a crash. Passive safety systems encompass vehicles structural design (energy absorption, intrusion mitigation) and restraint design (advanced seatbelts, airbags, head restraints). The 1990s were a decade that saw large-scale deployments of many advanced systems into new vehicles.

Specification data from RL Polk include some detail, but not all, of the passive safety features built into vehicles. Certain aspects of restraint design are explicitly coded, but details of the structural crash design are not. However, the specifications do include the performance of vehicles in crash tests performed by the Australasian New Car Assessment Program. ANCAP ratings are described in the next section.

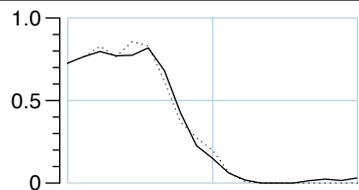
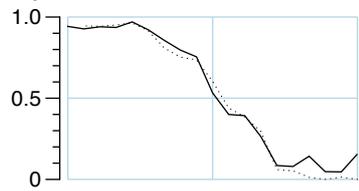
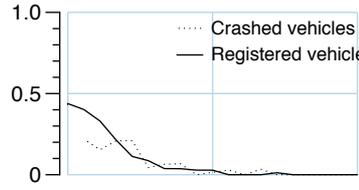
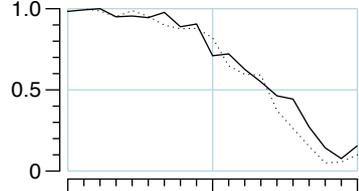
Braking and stability control systems are designed to prevent crashes, whereas passive safety systems mitigate and manage the energy of a crash; so the comparison of the two samples is less likely to show any under-representation of vehicles in injury crashes with respect to the fitment of passive safety systems. This is because the police coding of crashes

does not allow a reduction in severity to be detected, where injuries are reduced but remain serious.

Certain technologies are designed to improve the performance of seatbelts in crashes. The ability of an occupant to “ride down” the crash is impeded if there is any slack in the system – the slack may cause an increase in forces on the body of the occupant. Pretensioners are systems designed to eliminate any slack in the belt system at the onset of a crash. Systems may vary in the means that they employ to perform this function, but often a pyrotechnic charge is used to drive a piston in such a way as to pull the belt tight around the occupant.

While eliminating slack improves the efficiency of the belt system, large forces on the occupant may still arise in more severe crashes. Force limiters allow the belt system to spool out when restraint forces approach injurious levels. Often these systems allow the belt to spool out in a controlled manner so that in a frontal crash, the free space between the occupant and the vehicle interior can be utilized to absorb energy at force levels below the tolerance of the occupant to injury.

Table 3 Fitment of secondary safety restraint technology in the South Australian fleet

System	Prevalence in the registered passenger vehicle fleet	Prevalence in passengers vehicles involved in serious/fatal crashes	Disaggregation by year of sale
Force limiting seat belts	32%	42%	
Seat belt pretensioners	64%	53%	
Side curtain airbags*	12%	6%	
Driver airbags	77%	66%	

* Only crash types likely to benefit from side curtain airbags are considered: hit fixed object, sideswipe, right angle, right turn, rollover, left road out of control crashes only.

Note: The prevalence in the disaggregation figure refers to the fitment rate in each year-of-sale cohort.

The upper two rows of Table 3 show the prevalence of these two types of seatbelt systems in the two samples of vehicles considered in this paper. Almost all vehicles in the registered vehicle sample sold new in the latter half of the 2000s have pretensioners in the front seating positions – almost no vehicles sold new in the early 1990s were equipped with pretensioners.

Overall, almost half of all vehicles in the sample of the registered fleet were equipped with pretensioners in the front seating positions. A similar pattern is observable in the pattern of fitment of force limiting seat belts, although installation appears to have plateaued at around 75% of new vehicles from 2003 onwards.

Injury crashes in 2008-2009, when disaggregated by year of first sale, look much like the registered fleet sample in respect of the fitment of seatbelt pretensioners and force limiting seatbelts. Filtering on crash type to examine only those vehicles that were involved in the type of crashes likely to benefit from improved seatbelt performance did not change the pattern. Any effect that these technologies are having in crashes is therefore not detectable in these samples according to the methods used in this paper.

The lower two rows in Table 3 show the fitment rate of side curtain airbags and driver airbags in the two samples of vehicles. Front passenger frontal airbags are now almost ubiquitous in new passenger vehicles and 77% of the registered vehicle sample has a driver's airbag. Installation of side and curtain airbags appears to be currently increasing with around 50% of vehicles in the sample sold new in 2009 having such airbags as standard.

As with the seatbelt technology, vehicles fitted with airbags are neither particularly underrepresented nor overrepresented in serious casualty crashes. The charts in Table 3 show the prevalence of frontal airbags in vehicles involved in all serious and fatal crashes. For side curtain airbags, only vehicles involved in those serious and fatal crashes that are more likely to benefit from their installation and deployment were profiled.

Having said that, there is some indication that side curtain airbags are reducing the incidence of serious and fatal injury crashes in the subset of all crash types indicated in Table 3, but differences in crash patterns between vehicles with and without side curtain airbags were not significant.

Crash test performance

The ANCAP program began publishing vehicle crashworthiness assessments in 1993. In 1999 ANCAP aligned its crash testing procedures with EuroNCAP and hence began republishing EuroNCAP results in Australia. Results based on the aligned test program are available in the Polk data from about this date onwards. The bottom row of Table 4 shows the variation in the proportion of the sample of registered vehicles that have a known occupant and pedestrian rating, according to year of sale. More than 81% of vehicles sold new in 2009 had an ANCAP occupant rating, but 58% of all vehicles in the registered fleet are without a rating, with composition of the unrated vehicles biased toward older vehicles.

There is a positive association between the occupant rating of vehicles (those that have a rating) and the year of sale (upper left cell of Table 4). Those vehicles in the registered vehicle sample with a star rating that were sold new in 2009 had an average rating of over 4 stars. The equivalent portion of the sample sold new in 2001 had an average star rating of just over 3 stars. The average rating of all vehicles (that have a rating - 32% of the sample) is over 3.5 stars. It is not possible to determine how those vehicles that have no rating compare with those that do in each year of sale cohort, but it is reasonable to speculate that their performance would be inferior. As is the case with other safety features, the average occupant rating of crashed vehicles looks much like the registered fleet sample when disaggregated by year-of-sale.

The pedestrian rating has received less attention than the occupant rating in the past. Nevertheless, the proportion of the fleet with a pedestrian rating mirrors the proportion of the fleet with an occupant rating. In contrast to the occupant rating, there is no positive association between the average pedestrian rating of vehicles and the year of sale in that portion of the sample of registered vehicles with a rating (Top right cell of Table 4). And while the numbers of pedestrian crashes in each year-of-sale cohort are small, the pedestrian rating of these vehicles mirrors that of the registered vehicle sample.

Table 4 ANCAP characteristics of vehicles in the April 2010 South Australian passenger vehicle fleet

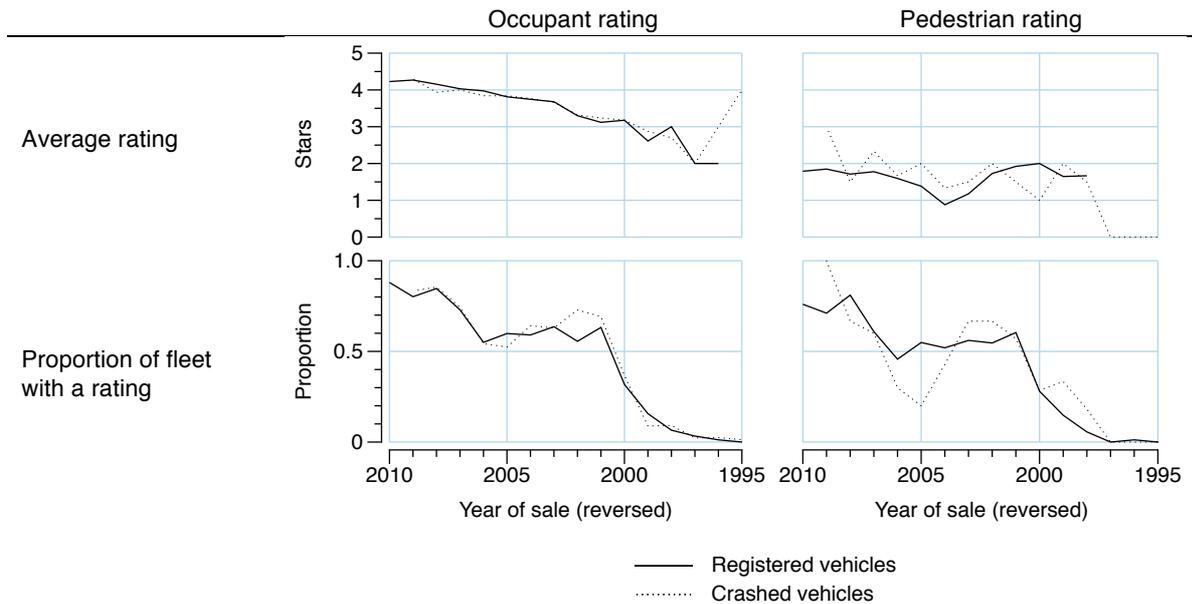


Figure 1 shows the makeup of registered vehicles in each year-of-sale cohort according to the occupant protection star rating and the pedestrian protection star rating. The majority of vehicles with an occupant rating sold new in 2000-2003 had a star rating of three whereas from 2003 onward, a large majority have a star rating of four. The number of five-star vehicles has accelerated in recent years, but it is clear that improving the occupant rating of the registered fleet is still a work in progress after more than 10 years of the current ANCAP program.

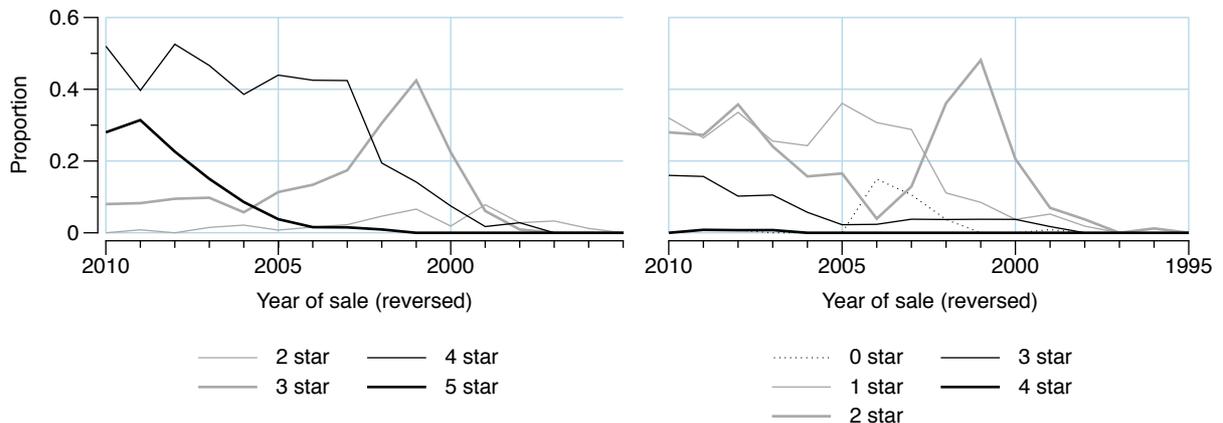


Figure 1 ANCAP performance by year of sale of vehicles in the April 2010 South Australian passenger vehicle fleet - occupant ratings (left) and pedestrian ratings (right).

Figure 1 shows that the pattern in the prevalence of vehicles with a given pedestrian protection star rating has not been stable. In contrast to the vehicles with occupant protection, vehicles with zero or one star have become more common at certain times rather than less common. Only for vehicles sold in 2007 to 2009 does there appear to be a modest shift toward higher levels of pedestrian protection as assessed by the ANCAP procedures.

Summary

This paper has characterised the South Australian passenger vehicle fleet according to several attributes related to safety. By disaggregating vehicles by year of sale, it has been possible to estimate the rate at which these attributes have changed in new vehicle sales.

Two populations of vehicles were studied: a random sample of 2000 passenger vehicles was extracted from registration records in April 2010 to represent the fleet as it was at that time; the second sample involved all passenger vehicles involved in serious and fatal crashes in 2008 and 2009 in South Australia.

Examination of the registered vehicle sample allowed the uptake of technology and the change in other attributes of the general registered fleet to be examined. The crashed vehicle population was of particular interest as it is for these vehicles that safety (in particular, secondary safety) is of most relevance. Furthermore, we have previously seen that crashed vehicles are a biased sub-population of the entire registered fleet – they are older on average and vehicles up to 20 years of age are approximately equally represented (Anderson et al., 2009).

The prevalence of several safety features and other attributes were examined by year of sale in the two groups of vehicles and compared. While it was not the intention to perform a formal evaluation of the effectiveness of features by comparing the prevalence in the two groups of vehicles, it was nonetheless of interest to see whether certain features were under-represented in the crashed vehicles sample, which may be indicating some protective effect. This was only ever likely to be shown in the data for primary safety features where a particular feature may be preventing crashes from occurring in the first place. A secondary safety feature may well prevent injury, but the ability of such features to convert a serious crash to a more minor class of crash is only likely to occur in cases at the lower margin of the serious crash classification, and hence it was less likely that we would detect under-representation for these features.

A particular feature of this analysis was the linkage of registration and accident records to price and specification data and VFACTS data from RL Polk Australia. This allowed the linkage of registration records and crash records to add further information about the vehicles in this study: in the case of prices and specifications, the data were generic to a given make and model identifier, and in the case of VFACTS data (details about the sale) specific to the actual vehicle in the registration/crash record. The partly generic nature of the price and specification data meant that it was not possible to identify whether particular vehicles were fitted with some features when that feature was optional. However, it is reasonable to assume that the take-up rate of optional safety features is quite low in general.

Discussion

Crashed vehicles and registered vehicles are broadly the same in respect of the prevalence of safety attributes. While crashed vehicles and registered vehicles had about the same rate of installation of many features within a year-of-sale cohort, given the older age of crashed vehicles, the overall rate of installation is lower in crashed vehicles compared to the registered fleet sample.

The general lack of under-representation of specific safety features in the crashed vehicle sample is intriguing, as the results do tend to suggest that many vehicle safety systems have not been associated with wholesale changes to the rate of serious injury crashes (broadly defined). However, this aspect of the results does need to be treated very cautiously. This study was not designed to examine effectiveness of any feature (much less the cost-effectiveness of any feature), only to characterise the uptake of such features. Furthermore, the measure of crash severity used in the study may not be sensitive enough to detect improvements in injury outcomes related to any specific feature. This may be particularly true when the benefits being provided by a feature are secondary and marginal, in the technical

sense that they only enhance an already-effective system. The lack of an obvious effect of force limiting seat belts is a potential example of this.

There are also limitations in using the sample of registered vehicles as a comparison group for crashes. First, sampling variance will mean that the data relating to this sample is an approximation of the true character of the entire registered fleet. This means that the relative representations of the various features in crashes are only estimates. Second, it has been implied that travel exposure is unbiased within a year-of-sale cohort, and in the analysis of ESC crashes, across several year-of-sale cohorts. It is known that vehicle use declines with a vehicle's 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 the ABS data for the whole of Australia suggests an average annual decline in vehicle kilometres driven of 5.1% per year of vehicle age. Thus, disaggregating according to vehicle age has an important purpose in this paper, as it controls for such effects. But other factors affecting travel exposure, and hence the results, may exist.

The one feature that seemed to be clearly underrepresented in crashed vehicles was electronic stability control (ESC) – while the numbers were small, it was clear that the prevalence of ESC systems in serious casualty crashes was smaller than in the general registered fleet, indicating that the prevention of crashes via ESC systems are detectable in South Australian data at the level of aggregation used in the study. An additional analysis of single and multiple vehicle crashes confirmed that ESC equipped vehicles are substantially under-represented in single vehicle serious casualty crashes.

The disaggregation by year of sale showed that the introduction of a safety technology into new vehicles has generally taken between 10 and 20 years to reach saturation (for those technologies that have achieved an almost 100% fitment rate). The rate of uptake may well be lower than it might otherwise be. For example, Sweden is similar to Australia in that the average age of vehicles is about 10 years (while the mix of makes and model of vehicles is likely to be quite different). ESC was deployed into new vehicles very quickly in Sweden such that the fitment rate had risen to 95% in new vehicles in 2008, from a rate of 15% in 2003 (not dissimilar to that in SA at that time) (Krafft et al., 2009).

On the positive side, occupant safety ratings of vehicles are rapidly improving such that more than half of all new vehicles sold in South Australia should be rated at five stars in the ANCAP program. However, the average star rating of all registered vehicles that have a rating is 3.78 stars, and given that ratings exist for only 42% of registered vehicles, the average of all registered vehicles is likely to be much lower than this (possibly under 3 stars), demonstrating that even the improved passive safety of vehicles in the general registered fleet is a work in progress. Unfortunately, the pedestrian safety ratings of vehicles have not kept pace with occupant ratings and the average star ratings of the newest vehicles remains under 2 stars (of a possible 4) and has remained almost unchanged over the last 10 years. This aspect of vehicle safety has not received the attention over the last 10 to 15 years that occupant safety has, and is not promoted by vehicle manufacturers to consumers. Recent changes to the ANCAP and EuroNCAP rating protocols that will include pedestrian performance in the overall vehicle rating can be expected to improve the average pedestrian passive safety performance of vehicles in the future. Regulation of pedestrian safety is likely to have a lesser effect on pedestrian safety performance, as the proposed regulation is weaker than ANCAP requirements (Searson and Anderson, 2011). Regulation of pedestrian safety in Australia is, in any case, stalled (King, 2011).

It might be possible to use the sort of data described in this paper, and current uptake rates, to model the future prevalence of safety technologies in vehicles that are at risk of crashing. For example, such a model would allow us to predict the future prevalence of ESC in vehicles likely to be at risk of single vehicle crashes. The next generation of safety technologies may be quite effective in reducing certain types of crash, and understanding how crash patterns may change in response to these technologies would provide the basis

for a nuanced approach to investment in activities aimed an encouraging uptake, and in the coordination of associated road infrastructure investment.

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