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Potential Road Safety Benefits of Making Safer Vehicle Choices in Australia

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Abstract:

Observed variation on the measured real-world safety of light passenger vehicles suggests there is considerable opportunity to improve road traffic injury outcomes by improving the safety of vehicles. This study examined features of the 2016 Australian crashed vehicle population, including the way the safety of vehicles varied within years of manufacture and vehicle market group, with the objective of quantifying the road safety benefits in terms of reduced fatalities and serious injuries that could be achieved through safer vehicle choices. In 2004, MUARC completed an analysis of the potential road safety benefits of improving consumer choice in Australia with regards to vehicle safety (Newstead, Delaney et al. 2004). It was estimated that if all motorists had crashed in the safest vehicle by market group available in the year 2000, road trauma involving light vehicles could have been reduced by a further 26% compared to the levels observed. The aim of this study was to update the previous analysis to see if the potential of safer vehicle choices had changed in 2016. This study expanded on the previous study by considering potential benefits of safer vehicle choices through optimising both vehicle own occupant protection (crashworthiness) as well as across all people involved in crashes (total secondary safety). It also considered a greater range of constraints for optimising the fleet related to optimising within combinations of year of vehicle manufacture and market group.

This study has shown significant savings in fatalities and serious injuries from road crashes are possible through safer vehicle choices and in particular optimising total secondary safety. The largest savings could be derived if all current vehicles in the fleet were replaced with the safest vehicles available with savings of nearly 80% of fatal and serious injuries resulting from crashes involving a light vehicle. Replacing the entire current fleet is unrealistic, however analysis demonstrated that if every vehicle was replaced with the safest vehicle of the same age and within the same market group, fatal and serious injury savings of around 33% would be possible, representing savings to the Australian community of nearly $2b per annum through reduced trauma costs. Safety benefits are maximised by choosing not vehicles that prioritise protection of their own occupants (crashworthiness) but rather through choosing vehicles that provide best possible protection from injury for all people involved in a crash (total secondary safety). Increasing the uptake of electronic stability control in vehicles prior to its mandate in 2012 would have provided an additional 5% crash savings in 2016. Fitment of autonomous emergency braking to all new vehicles would have the benefit of providing an additional 5% savings in future crashes. Large additional savings were also possible through increased fitment of AEB and ESC and through market group shifts. The latent potential for additional trauma savings through safer vehicle choices was estimated to be larger in 2016 than estimated previously for the year 2000 light vehicle fleet. The additional latent potential available in 2016 merits increased investment in consumer programs and possible incentives which encourage safer vehicle choices.

Key Words:	Disclaimer
Injury, Vehicle Occupant, Collision, Passenger Car Unit, Passive Safety System, Crash Risk, Statistics	This Report is produced for the purposes of providing information concerning the safety of vehicles involved in crashes. It is based upon information provided to the Monash University Accident Research Centre by VicRoads, the Transport Accident Commission, New South Wales Roads and Maritime Services, NRMA Ltd, Queensland Transport and Main Roads, the Western Australian Department of Main Roads, South Australian Department of Planning, Transport and Infrastructure and the New Zealand Ministry of Transport. Any republication of the findings of the Report whether by way of summary or reproduction of the tables or otherwise is prohibited unless prior written consent is obtained from the Monash University Accident Research Centre and any conditions attached to that consent are satisfied.

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Contributor Statement

- Stuart Newstead: Study design, report writing and editing
- Laurie Budd: Australian analysis and report

Ethics Statement

Ethics approval was not required for this project.

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Linda Watson is acknowledged for preparation of the crash data sets and producing the safety ratings for the Used Car Safety Ratings (UCSR) program. The data preparation included enhancement of the crash data sets with registration data and vehicle makes and model codes. Linda Watson and Casey Rampollard are also acknowledged for preparation of the matched UCSR vehicle model codes and enhancing the data with ESC and AEB fitment data derived from information provided by RedBook.

GLOSSARY

"**Crashworthiness ratings (CWR)**" assesses the risk of fatal or serious injury to the driver of a vehicle involved in a crash (where the vehicle is damaged enough to be towed away, or some injury occurs in the crash).

"Aggressivity (AGG)" is a measure of the risk of injury or serious injury that a vehicle poses to road users other than its own occupants (including other vehicle drivers, pedestrians, motorcyclists and bicyclists) (Newstead, Keall et al. 2011).

"Total Secondary Safety Ratings (TSS or TSI)" encompasses crashworthiness and aggressivity, by assessing the risk of a fatal or serious injury in a crash (where the injured party may be an occupant of the vehicle, or another road user). Total Secondary Safety Ratings are used interchangeably with Total Secondary Safety Indices.

"Primary safety ratings (PSR or PSI)" provide a measure of the vehicle's ability to enable the driver avoid a crash (Keall and Newstead 2015). Primary Safety Ratings are used interchangeably with Primary Safety Indices.

EXECUTIVE SUMMARY

Observed variation on the measured real-world safety of light passenger vehicles suggests there is considerable opportunity to improve road traffic injury outcomes by improving the safety of vehicles. This study examined features of the 2016 Australian crashed vehicle population, including the way the safety of vehicles varied within years of manufacture and vehicle market group, with the objective of quantifying the road safety benefits in terms of reduced fatalities and serious injuries that could be achieved through safer vehicle choices. In 2004, MUARC completed an analysis of the potential road safety benefits of improving consumer choice with regards to vehicle safety (Newstead, Delaney et al. 2004). It was estimated that if all motorists had chosen the safest available vehicle in the same market group as the vehicle actually purchased, road trauma involving light vehicles could have been reduced by a further 26% compared to the levels observed. However, the Australian light vehicle fleet has changed significantly in the profile of vehicles purchased since this study was undertaken. The aim of this study was to update the previous analysis to see if the potential of safer vehicle choices had changed in 2016. This study expanded on the previous study by considering potential benefits of safer vehicle choices through optimising both vehicle own occupant protection (crashworthiness) as well as across all people involved in crashes (total secondary safety). It also considered a greater range of constraints for optimising the fleet related to optimising within combinations of year of vehicle manufacture and market group.

Data

Australian police reported crash data from 2016 was analysed for injury crashes that involved light passenger vehicles where the vehicle was manufactured in 1982 or beyond. The data were provided by the jurisdictional bodies of Western Australia, South Australia, Victoria, Queensland and New South Wales for the 2018 Used Car Safety Ratings update (Newstead, Watson et al. 2018). During the process of calculation of the Used Car Safety Ratings, model codes and market groups were added to the crash data where possible through a process of decoding vehicle identification numbers. Around 16% of Australian light passenger vehicle fleet was unable to be coded to a market group. The Australian data consisted of 79,232 light passenger vehicles manufactured from 1982 onwards that crashed during 2016.

Crashworthiness Ratings (CWR – the risk of death or serious injury to the driver of the rated vehicle), Aggressivity Ratings (AGG – the risk of death or serious injury to road users impacts by the rated vehicle) and Total Secondary Safety Ratings (TSS – the combined crashworthiness and aggressivity performance of the vehicle representing the average risk of death or serious injury to all people in a crash involving the rated vehicle) as estimated in the 2018 UCSRs were attached to each crashed vehicle in 2016 in the following way: where a model code was available for the crashed vehicle the relevant rating was attached at this level; otherwise, the rating appropriate for the given market group and year of manufacture (YOM) was attached unless market group had not been defined, in which case a value appropriate to the YOM was attached. Electronic stability control (ESC) and autonomous emergency braking (AEB) fitment status for each crashed vehicle was determined from RedBook data were matched with Australian crash data models by model code and year of manufacture.

Australian community costs for people injured in road crashes were derived from the Australian Bureau of Infrastructure, Transport and Regional Economics, crash weighted and adjusted to 2018 values using the Australian Bureau of Statistics consumer price indices.

Method

Assessment was made with respect to the following measures of vehicle safety:

- Crashworthiness (CWR)
- Aggressivity (AGG) and
- Total Secondary Safety (TSS)

A largely deterministic methodology was used to measure the potential for additional road trauma reductions from safer vehicle choices or from shifts in market group composition. The methodology was as follows:

1. A baseline measure of safety performance was established to reflect the average safety of the crashed light vehicles in 2016 by year of manufacture and market group distribution.
2. For each year of manufacture, the safest vehicles with respect to CWR and TSS within
    - each market group, and

- across all market groups

were identified. The safest vehicle ratings were identified not only as those of the top-ranking vehicle but also as the average ratings of the top tenth percentile.

3. For each market group, the safest vehicles were identified with respect to crashworthiness and total secondary safety across all years of manufacture. The safest vehicle across all market groups was also identified across all years of manufacture. Again, the safest vehicle ratings were identified not only as those of the top-ranking vehicle but also as the average ratings of the top tenth percentile.
4. Ratings for the optimal vehicle choice with respect to crashworthiness or total secondary safety (identified at '2' and '3') were applied to all vehicles in the same group as the optimum vehicle as a measure of safety that could be achieved if all people purchased the safest vehicle in the specific group. The optimum group was market group, YOM or YOM and market group or all vehicles. Each different optimum substitution considered was termed a "scenario". When the scenario being considered was modelling market group composition shifts, the optimal ratings for one market group were substituted for all vehicles of another market group.
5. The average safety rating across all vehicles in the fleet calculated for each of the scenarios were then compared with the baseline measure to ascertain the latent potential for improved safety in the fleet. This was expressed as either a percentage reduction in deaths and serious injury or an absolute saving in these outcomes based on current levels of trauma.

Further scenarios around greater penetration of the proven safety technologies of ESC and AEB were surmised. The safety benefits of fitment were taken from analysis of real-world effectiveness. These scenarios were based on assuming a fraction of crashes could be prevented through increased uptake of ESC and AEB technologies. Reductions sourced from the literature were applied to crashes sensitive to the technologies and the proportion that these savings make of the total crash population were then calculated.

Scenarios

Scenarios were modelled by averaging the fleet CWR, TSS, and AGG after the substitution of a crashed light vehicle safety rating with the safest (or mean of safest decile) CWR and TSS ratings for a specific group. The specific groups included: (i) the entire fleet, (ii) market groups, (iii) year of manufacture within market groups and (iv) year of manufacture.

The safety optimisation scenarios are listed below.

i. Within the whole fleet substitute with
   a. the ratings for the vehicle with the best CWR,
   b. the mean ratings for the models of the best CWR decile,
   c. the ratings for the vehicle with the best TSS, or
   d. the mean ratings for the models of the best TSS decile.

ii. Within each market groups substitute with
   a. the ratings for the vehicle with the best CWR,
   b. the mean ratings for the models of the best CWR decile,
   c. the ratings for the vehicle with the best TSS, or
   d. the mean ratings for the models of the best TSS decile.

iii. Within each market and year of manufacture groups substitute with
   a. the ratings for the vehicle with the best CWR,
   b. the mean ratings for the models of the best CWR decile,
   c. the ratings for the vehicle with the best TSS, or
   d. the mean ratings for the models of the best TSS decile.

iv. Within each year of manufacture groups substitute with
   a. the ratings for the vehicle with the best CWR,
   b. the mean ratings for the models of the best CWR decile,
   c. the ratings for the vehicle with the best TSS, or
   d. the mean ratings for the models of the best TSS decile.

v. Substitute commercial utility ratings with
   a. those of the medium SUV model with matching year of manufacture with the best CWR,

b. the mean ratings for the top CWR decile of medium SUV models with matching year of manufacture,
c. those of the medium SUV model with matching year of manufacture with the best TSS, or
d. the mean ratings for the top TSS decile of medium SUV models with matching year of manufacture.

vi. Substitute commercial utility ratings with
   a. those of the medium model with matching year of manufacture with the best CWR,
   b. the mean ratings for the top CWR decile of medium models with matching year of manufacture,
   c. those of the medium model with matching year of manufacture with the best TSS, or
   d. the mean ratings for the top TSS decile of medium models with matching year of manufacture.

Two additional scenarios based on increased ESC and AEB fitment were modelled:

vii. Changed market penetration of AEB fitment: All light (passenger) vehicles were fitted with AEB.
viii. Changed market penetration of ESC fitment: All light (passenger) vehicles were fitted with ESC.

Results

The latent potential road trauma savings available through safer vehicle choice and market shift are presented in Section 5.1 for Australia in 2016. Each estimate represents the percentage saving in deaths and serious injuries in light vehicle involved crashes possible through implementation of the scenario.

Table E1: Percentage fatal and serious injury savings in light vehicle crashes possible through safer vehicle choices

	Crashworthiness	Total Secondary Safety	Aggressivity
Safest model (i)			
Avg of top CWR vehicle	49.4%	30.1%	-4.4%
Avg of top TSS vehicle	41.8%	40.3%	12.3%
Best vehicle CWR	93.2%	58.6%	-14.8%
Best vehicle TSS	82.1%	79.1%	29.6%
Safest in Market group (ii)			
Avg of top CWR vehicle	38.1%	23.8%	4.2%
Avg of top TSS vehicle	33.8%	32.7%	17.2%
Best vehicle CWR	63.1%	46.9%	5.9%
Best vehicle TSS	60.5%	50.3%	18.7%
Safest in Market group and year (iii)			
Avg of top CWR vehicle	34.9%	21.2%	3.0%
Avg of top TSS vehicle	23.9%	30.9%	10.8%
Best vehicle CWR	40.3%	24.9%	3.9%
Best vehicle TSS	26.4%	33.8%	9.6%
Safest in year (iv)			
Avg of top CWR vehicle	44.6%	27.0%	-6.4%
Avg of top TSS vehicle	33.2%	35.6%	7.1%
Best vehicle CWR	75.9%	49.5%	10.1%
Best vehicle TSS	33.2%	62.6%	-0.2%
SUVM for commercial utility (v)			
Avg of top SUVM CWR	4.0%	2.6%	1.2%
Avg of top SUVM TSS	3.1%	3.4%	4.7%
Best veh SUVM CWR	4.8%	3.4%	1.2%
Best veh SUVM TSS	4.0%	3.7%	4.4%
M for commercial utility (vi)			
Avg of top M CWR	4.3%	3.7%	4.4%
Avg of top M TSS	4.0%	3.7%	4.7%
Best veh M CWR	6.5%	4.7%	3.9%
Best veh M TSS	5.7%	4.7%	5.4%

M=medium car, SUVM= medium sports utility vehicle

Absolute annual savings in deaths and serious injuries and their cost to the community corresponding to the percentage reductions for each scenario shown in Table E1 are given in Table E2.

Table E2: Fatal and serious injury savings and associated economic costs estimated for each scenario

Scenario	Fatality Savings	Serious Injury Savings	Economic Savings
Safest model (i)			
Avg of top CWR vehicle	283	5667	$1,973.43M
Avg of top TSS vehicle	379	7587	$2,642.16M
Best vehicle CWR	551	11032	$3,841.95M
Best vehicle TSS	744	14891	$5,185.98M
Safest in Market group (ii)			
Avg of top CWR vehicle	224	4481	$1,560.38M
Avg of top TSS vehicle	307	6156	$2,143.89M
Best vehicle CWR	441	8829	$3,074.87M
Best vehicle TSS	473	9469	$3,297.79M
Safest in Market group and year (iii)			
Avg of top CWR vehicle	199	3991	$1,389.92M
Avg of top TSS vehicle	290	5817	$2,025.88M
Best vehicle CWR	234	4688	$1,632.50M
Best vehicle TSS	318	6363	$2,216.01M
Safest in year (iv)			
Avg of top CWR vehicle	254	5083	$1,770.18M
Avg of top TSS vehicle	335	6702	$2,334.02M
Best vehicle CWR	465	9319	$3,245.34M
Best vehicle TSS	588	11785	$4,104.20M
SUVM for commercial utility (v)			
Avg of top SUVM CWR	24	489	$170.46M
Avg of top SUVM TSS	32	640	$222.91M
Best veh SUVM CWR	32	640	$222.91M
Best veh SUVM TSS	35	697	$242.58M
M for commercial utility (vi)			
Avg of top M CWR	35	697	$242.58M
Avg of top M TSS	35	697	$242.58M
Best veh M CWR	44	885	$308.14M
Best veh M TSS	44	885	$308.14M

Estimated total saving from fitting all vehicles in the 2016 fleet with AEB were 5.4% of fatal and serious injuries and 6.8% of minor injuries corresponding to absolute savings of 1076 fatalities and serious injuries and 3099 minor injuries. The estimated potential savings in cost to the community equates to an annual saving of around A$361M. Crash reductions associated with the ESC scenarios were 2303 crashes saved if all vehicles in 2016 were fitted with ESC or 236 crashes saved if all vehicles manufactured after 2010 were fitted with ESC. This equates to a 4.82% saving across all crashes for all vehicles fitted with ESC and 0.49% of total crashes saved if ESC fitment was limited to a year of manufacture of 2011 or later. If the crashes saved had the same severity profile of injuries as all single vehicle crashes, 108 fatalities, 1163 serious injuries and 1571 minor injuries would be prevented through fitting ESC to all vehicles, a total saving in cost to the community of A$533m annually. When only fitting ESC to vehicles with a 2011 or greater year of manufacture, the corresponding community cost saving was estimated at A$54.5m.

Conclusions

This study has shown significant savings in fatalities and serious injuries from road crashes are possible through safer vehicle choices particularly optimised with respect to total secondary safety. The largest savings could be derived if all current vehicles in the fleet were replaced with the safest vehicles available with savings of nearly 80% of fatal and serious injuries resulting from crash crashes involving a light vehicle. Replacing the entire current fleet is unrealistic, however, analysis demonstrated that if every vehicle was replaced with the safest vehicle of the same age and within the same market group, fatal and serious injury savings of around 33% would be possible, representing savings to the Australian community of nearly $2b per annum through reduced trauma costs. Safety benefits are maximised by choosing not vehicles that prioritise protection of their own occupants (crashworthiness) but rather through choosing vehicles that provide best possible protection from injury for all people involved in a crash (total secondary safety). Increasing the uptake of electronic stability control in vehicle prior to its mandate in 2012 would have provided an additional 5% crash savings in 2016. Fitment of autonomous emergency braking to all new vehicles would have the benefit of providing an additional 5% savings in future crashes. Large additional savings were also possible through increased fitment of AEB and ESC and through market group shifts. The latent potential for additional trauma savings through safer vehicle choices was estimated to be larger in 2016 than estimated previously for the year 2000 light vehicle fleet. The additional latent potential available in 2016 merits increased investment in consumer programs and possible incentives which encourage safer vehicle choices.

1 BACKGROUND AND AIMS

In 2004, the Monash University Accident Research Centre (MUARC) completed an analysis of the potential road safety benefits of improving consumer choice with regards to purchasing safer vehicles in Australia (Newstead, Delaney et al. 2004). It was estimated that if all motorists had crashed in the safest available vehicle within the same market group at the time of the crash, road trauma involving light vehicles could have been reduced by 26% compared with the observed levels. This study was important in that it gave a major impetus for programs promoting safe vehicle choices by consumers at the time of purchase.

The Australian light vehicle fleet has changed significantly in the profile of vehicles purchased since the original study was undertaken. Furthermore, the profile of the Australasian New Car Assessment Program (ANCAP) has also increased and the proportion of new vehicles sold that are 5-star rated has correspondingly increased. For these reasons, estimates of potential road safety benefits from safer vehicle choices will likely have changed from the previous study.

The previous study also had 2 key limitations. In making comparisons with existing vehicles to estimate benefits of choosing safer vehicles, the single vehicle with the best numerical safety rating was used as the basis for comparison (Newstead, Delaney et al. 2004). Generally, these best vehicles constituted quite a small proportion of the fleet in each vehicle class meaning the estimated benefits could be quite variable. In addition, analysis considered only the potential safer vehicle choices in terms of maximising crashworthiness, the ability of a vehicle to protect its own occupants in a crash. Since the original study, measures of vehicle safety estimated under the UCSR program have expanded to include both aggressivity, the ability of the vehicle to protect other road users with which it collides from injury, and total secondary safety, the combined crashworthiness and aggressivity performance of a vehicle. Each of the vehicle safety ratings have all been described in detail elsewhere (Newstead, Keall et al. 2011, Keall and Newstead 2015, Newstead, Watson et al. 2018). In terms of providing maximum safety benefits to society as a whole, the total secondary safety index is the more appropriate measure on which to judge the potential for safer vehicle choices. In addition to injury protection ratings, the UCSR program now also incorporates a measure of primary safety (crash avoidance) performance of vehicles (Keall and Newstead 2015). To some degree, the primary safety performance of a vehicle depends on the fitment of new technologies that have become prevalent in vehicles over the past 15 years to assist drivers in avoiding a crash. These include technologies such as electronic stability control and autonomous emergency braking which have both been shown to be effective in reducing crash risk. The potential benefits in increase uptake of these technologies can be considered in combination with the secondary safety (injury prevention) measures to determine safer vehicle choice potential.

1.1 Project Aims and Scope

The aim of the study reported here was to update the results of the original study to estimate the potential road safety benefits of safer vehicle choices in Australia, termed the ‘latent potential’ for safety improvement in the light vehicle fleet.

Specifically, the project aimed to:

- ascertain the level of latent potential for road trauma reduction in the Australian light vehicle fleet from improving safe vehicle choices by comparing the safety of actual vehicle purchases in each year of manufacture and vehicle market group to the optimum purchase profile possible in each year and vehicle market group with respect to safety;
- assess the impact shifts in vehicle market group distribution in the light vehicle fleet have had on road safety outcomes, with particular focus on the increasing popularity of commercial utilities as a family vehicle; and
- compare changes in current latent safety potential of the fleet since the previous assessment over ten years ago.

To overcome noted deficiencies in the previous study, the current study aimed to incorporate methodological changes. First, optimum safety choices were considered with respect to a wider range of measures of vehicle safety including:

- Primary Safety (crash avoidance),
- Crashworthiness (vehicle own occupant protection from injury in a crash),

- Total Secondary Safety (protection of all people involved in a crash both inside and outside the focus vehicle) and
- Primary Safety + Total Secondary Safety.

Instead of benchmarking best possible safety performance on a single vehicle, this study aimed to produce more robust estimates of latent safety potential by benchmarking against the average of the 10th percentile of best rating vehicles both overall or within market group.

Outcomes from the project were estimates of the potential savings, in terms of lives saved and serious injuries avoided, due to the optimisation of vehicle safety choices in terms of primary safety, crashworthiness, total secondary safety or a combination of all three. Furthermore, potential savings available through different levels of uptake of Electronic Stability Control (ESC) and Autonomous Emergency Braking (AEB) were also estimated.

2 DATA

2.1 Crash data

Australian Police reported crash data from the most recent year available to the study, 2016, was used which covered injury crash involved light passenger vehicles. The study was limited to vehicles manufactured for the year 1982 and beyond[1] since safety performance information on a make and model basis was available for vehicles in this year range. The data were provided for the states of Western Australia, South Australia, Victoria, Queensland and New South Wales and are a subset of the data used for calculation of the 2018 Used Car Safety Ratings (Newstead, Watson et al. 2018).

During the process of calculation of the Used Car Safety Ratings, make and model groupings homogeneous with respect to vehicle safety specification (generally defined by a discrete vehicle model series) and associated market groups were assigned to vehicles in the Australian crash data where possible. This was achieved through a combined process of Vehicle Identification Number decoding and grouping of makes and models by year of manufacture where VIN was not available. Only 16% of Australian light passenger vehicles remained un-coded to a market group. The resulting data comprised 79,232 light passenger vehicles crashed in 2016.

2.2 Vehicle Secondary Safety Assessment - Used Car Safety Ratings

Total Secondary Safety Ratings (TSS), Aggressivity Ratings (AGG), Crashworthiness Ratings (CWR) and Primary Safety Ratings (PSR) as estimated in the 2018 UCSR (Newstead, Watson et al. 2018) were attached to each crashed vehicle in the following way: where a model code was able to be identified for a vehicle in the crash data through a process VIN decoding described in Newstead, Watson et al, (2018), a vehicle specific rating was attached; otherwise, the rating average for the given market group and year of manufacture (YOM) was attached unless market group had not been defined, in which case an average rating value for the YOM was attached.

2.3 ESC fitment and AEB fitment status

ESC and AEB fitment status were determined using the RedBook Lookup Guide (Automotive Data Services Pty Ltd 2014) and with data purchased from Redbook; Redbook provides specification data for vehicles sold in Australia. Redbook fitment data was matched with UCSR model codes and reclassified as “ALL” where all model variants within a model grouping were fitted with the standard feature, and “SOME” where only some of the model variants were fitted with the standard feature. The reclassified fitment codes (all, some or unknown) were matched with Australian crash data models by model code and year of manufacture. In Australia, ESC has been mandated in all light vehicles manufactured from November 2017; for passenger cars, ESC was mandated in all those manufactured from November 2013.

2.4 Crash and injury costs

Australian injury costs were derived from the (2009) BITRE report number 118, “Cost of road crashes in 2006”. The human loss value of a fatality was costed at $2.4 million and the human loss of a hospitalisation at $214,000, both costs in 2006 Australian dollar values. A fatal crash is valued a $2.67 million, a serious

[1] 20% of the Australian light passenger vehicles involved in crashes of all injury levels were either missing a year of manufacture or were manufactured prior to 1982.

injury crash at $26.6 thousand and a minor injury crash at $14.7 thousand Australian 2006 dollars. BITRE uses a hybrid of the human capital and the willingness-to-pay approaches which is further explained in https://bitre.gov.au/publications/2010/files/sp_003_Risbey_Cregan_deSilva.pdf.

The 2006 social costs of fatal and hospitalised injuries from road crashes by jurisdiction were inflated to 2018 costs by using the June (2018) Australian Bureau of Statistics consumer price index data cube and weighted with 2016 Australian passenger vehicle crash data using the crash injuries by type and jurisdiction to produce an average 2018 cost of fatal and serious injury of $331,693. The 2018 value of human losses for a fatality were $2.504 million and for a serious injury were $223,244.

3 ILLUSTRATION OF TRENDS IN SAFE VEHICLE CHOICES – COMMERCIAL UTILITY VEHICLES

This section provides a brief description of the current influence of commercial utilities on vehicle safety in Australia which formed the basis of some of the scenario modelling presented in the Results section. Presentation of this data also assists in understanding the methodology presented in the next section.

Over the past decade, commercial utilities have made up approximately 9-10% of the identified crash involved light vehicles in Australia with evidence of a strongly increasing market share. Over the 20 years from 1997 to 2016 the percentage of new light vehicle registrations which are commercial utilities has doubled from around 7% to over 14% becoming the most popular segment after small cars and medium SUVs. This trend of growth has continued beyond 2016 with the Toyota Hilux utility being the top selling vehicle in Australia every year since 2016 with 3 or 4 of the top selling vehicles each year being commercial utilities. The growth in these vehicles has had a possible impact on the safety of the fleet since the Used Car Safety Ratings show commercial utilities have poorer crashworthiness and higher aggressivity than other market groups which might be used in preference to these vehicles, such as medium SUVs. The exact reason for the rise in the popularity of commercial utilities is not fully understood but might be related to lifestyle choices, the construction boom in Australia as well as artefacts of the tax system encouraging the use of these vehicles as family transport.

Two proposed scenarios considered in this study have explored the safety impacts of the trend to increasing purchase of commercial utilities through the estimation of the safety benefits possible though considering the safety impacts of choosing commercial utilities in preference to either medium sized cars and SUVs. These scenarios are designed to show the possible safety impacts of the increasing preference for purchase of commercial utility vehicles. Additional scenarios have also been considered in the study which are outlined later in the report.

Figure 1 illustrates the crashworthiness performance of the commercial utility vehicles fleet in Australia by year of vehicle manufacture from 1982 to 2016 in comparison to the fleet as a whole and to both medium passenger vehicles and medium SUVs which have both been considered in the substitution scenarios. A number of measures of safety are given in Figure 1. The grey background shading shows the average crashworthiness for the 2016 fleet across all years of manufacture. The green and white shaded areas show the average crashworthiness of the commercial utility fleet and the whole fleet respectively by year of manufacture. Comparison of the commercial utility fleet to the fleet as a whole in Figure 1 shows that crashworthiness is consistently worse (higher) for commercial utilities than for the entire fleet, across all years of manufacture but particularly in recent years of manufacture. This result shows that choosing a commercial utility over the average vehicle in the fleet is likely to have a negative safety impact.

Also shown in Figure 1 is the crashworthiness of the commercial utility (light blue bar), medium SUV (grey line) and medium car (dotted line) on sale with the best (lowest) crashworthiness in each year of manufacture. Also shown are the corresponding estimates not based on the single best vehicle but the average crashworthiness of 10% of vehicles with the best crashworthiness in each class (dark blue bar, blue double line and grey double line respectively). It shows that the crashworthiness of the best available commercial utility is significantly better than the average of those actually crashed, immediately illustrating the potential for safety improvements if consumers had chosen the safest available vehicle in each year. Similarly, it also shows that the crashworthiness of the best performing medium cars or medium SUVs is generally better than that of the best available commercial utilities showing safety could be further improved by choosing the best medium car or medium SUV in preference to the best commercial utility.

Analysis for the study presented in the remainder of the report has developed methodology to quantify the road safety benefit potential illustrated in Figure 1 from safety vehicle choices both within and across market group including looking specifically at the impact of the growth in sales of commercial utilities.

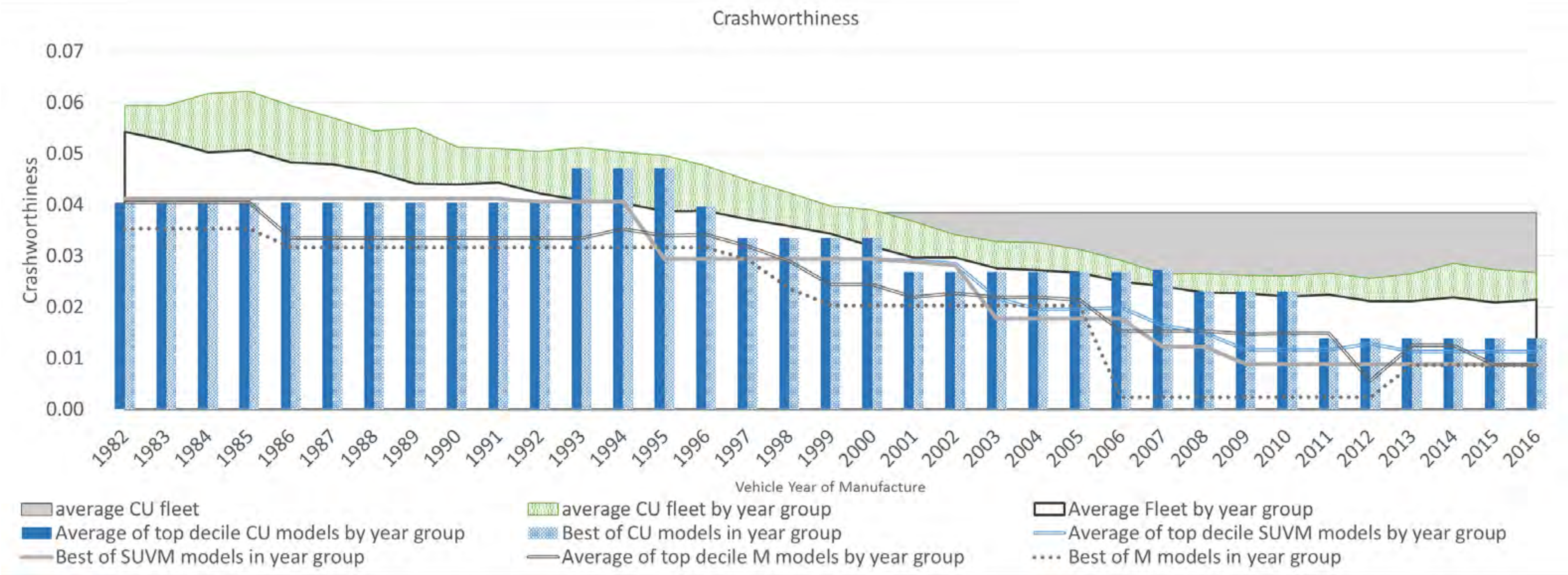

Figure 1: Fleet and model crashworthiness by year of manufacture

(CU=commercial utility, M=medium car, SUVM =medium SUV)

4 METHODS

4.1 Latent potential derived from safer vehicle choices and from shifts in market group composition

A largely deterministic methodology was used to measure the potential for additional road trauma reductions from safer vehicle choices or from shifts in market group composition. The methodology was as follows:

1. A baseline measure of safety performance was established to reflect the safety of the current light vehicles in the fleet by year of manufacture and market group distribution.
2. For each year of manufacture, the safest vehicles within
    - each market group, and
    - across all market groups

   were identified with respect to crashworthiness and total secondary safety from the Used Car Safety Ratings. The safest vehicle ratings were identified not only as those of the top-ranking vehicle but also as the average ratings of the top tenth percentile.
3. For each market group, the safest vehicles were identified with respect to crashworthiness and total secondary safety across all years of manufacture. The safest vehicle across all market groups was also identified across all years of manufacture. Again, the safest vehicle ratings were identified not only as those of the top-ranking vehicle but also as the average ratings of the top tenth percentile.
4. Ratings for the optimal vehicle choice with respect to crashworthiness or total secondary safety (identified at '2' and '3') were applied to all vehicles in the same group as the optimum vehicle as a measure of safety that could be achieved if all people purchased the safest vehicle in the specific group. The optimum group was market group, YOM or YOM and market group or all vehicles. Each different optimum substitution considered was termed a "scenario". When the scenario being considered was modelling market group composition shifts, the optimal ratings for one market group were substituted for all vehicles of another market group.
5. The average safety rating across all vehicles in the fleet calculated for each of the scenarios were then compared with the baseline measure to ascertain the latent potential for improved safety in the fleet. This was expressed as either a percentage reduction in deaths and serious injury or an absolute saving in these outcomes based on current levels of trauma.

4.2 Latent potential derived from ESC fitment or ABS fitment

Further scenarios were analyzed considering the safety benefits of greater penetration of each of the considered proven safety technologies in ESC and AEB. Safety benefits of fitment were taken from analysis of real-world effectiveness in the available literature.

- In the case of AEB, Cicchino (2017) estimated that AEB technology reduced front-to-rear crash rates by 43% and front-to-rear injury crash rates 45%. Budd, Stephens et al. (2019) estimated reductions in fatal and serious injuries of 36%, minor injuries of 19% and 24% in property damage only crashes where the crashed vehicle is the striking vehicle in a rear-end crash and is a model with some variants fitted with AEB, using 2013 to 2016 Australian crash data.
- In the case of ESC, analysis specific to Australian and New Zealand conditions found that ESC reduced the rate of single vehicle crashes by 32% for crashes leading to driver injury (Scully and Newstead 2010).

These scenarios were based on assuming a fraction of crashes could be prevented through increased uptake of ESC and AEB technologies compared to that observed in the 2016 light vehicle fleet. Reductions sourced from the literature were applied to crashes sensitive to the technologies and the proportion that these savings make of the total crash population were then calculated. These scenarios are described in Section 5.2.

For the analyses, vehicles with ESC were identified and assumed to have no potential for further ESC related safety improvements. No vehicles were assumed to have AEB fitted since AEB fitment to the Australian light vehicle fleet fitment was sufficiently low, estimated to be less than 3% of all vehicles, to permit this assumption.

The AEB analysis applied reductions of 36% (fatal and serious injury) and 19% (minor injuries) to the crashes and injuries involving forward moving striking light vehicles which collided with an on-path motor vehicle. These were estimated to amount to 15% of fleet fatal and serious injuries and 36% of fleet minor injuries, consistent with the AEB study of Budd and Newstead (2018). The same Australian injury crash data from 2016 used in the other parts of this analysis were used to estimate the latent potential associated with increased AEB fitment in 2016.

Both the AEB and the ESC crash and injury potential savings were estimated using the following general steps:

1. defining and tabling the crashes involving the light vehicle population amenable to crash mitigation or avoidance with AEB/ESC;
2. defining and tabling the injuries resulting from the identified preventable crash population;
3. calculating crash or injury savings as number of crashes / injuries potentially prevented by the technology by the percentage saving in these crashes by the percent of vehicles not fitted with the technology.

4.3 Key differences between this study and the original study in 2004

The original study (Newstead, Delaney et al. 2004) looked only at the potential for improving total secondary safety through improved consumer choice in the Australian light vehicle fleet. This updated study examined vehicle safety in terms of crashworthiness and total secondary safety. Newstead, Delaney et al. (2004) also used the single vehicle with the best numerical rating as the basis for the scenarios considered. By using the average of the 10th percentile best vehicle safety ratings in the current study, the comparison was more robust.

4.4 Scenarios considered

As described, scenarios were considered based on the substitution of the observed vehicle safety rating for each light vehicle crashes in Australia in 2016 with the safety rating for the optimum safe choice vehicle under that scenario. Optimum safe choices were defined based on either CWR of TSS and were chosen as either the single safest vehicle or the average of the best 10% (decile) of vehicles ranked by safety performance. Safest vehicles and deciles of safest vehicles were defined using rankings of all vehicle models in the 2016 fleet and not just those crashed in 2016.

Potential road safety gains from each scenario were estimated by comparing the average safety rating (CWR or TSS) across all crashed light vehicles in 2016 with the average safety rating across the crashed vehicle set after substitution of the rating of the optimum safe vehicle choice (single vehicle or decile).

Optimum safety choices and subsequent substitutions were considered at various levels being: (i) the entire fleet, (ii) market groups, (iii) year of manufacture within market groups and (iv) year of manufacture. Consequently, the safety optimisation scenarios considered in the analysis were:

i. Within the whole fleet substitute with
   a. the ratings for the vehicle with the best CWR,
   b. the mean ratings for the models of the best CWR decile,
   c. the ratings for the vehicle with the best TSS, or
   d. the mean ratings for the models of the best TSS decile.

ii. Within each market group substitute with
   a. the ratings for the vehicle with the best CWR,
   b. the mean ratings for the models of the best CWR decile,
   c. the ratings for the vehicle with the best TSS, or
   d. the mean ratings for the models of the best TSS decile.

iii. Within each market and year of manufacture groups substitute with
   a. the ratings for the vehicle with the best CWR,
   b. the mean ratings for the models of the best CWR decile,
   c. the ratings for the vehicle with the best TSS, or
   d. the mean ratings for the models of the best TSS decile.

iv. Within each year of manufacture substitute with
   a. the ratings for the vehicle with the best CWR,
   b. the mean ratings for the models of the best CWR decile,
   c. the ratings for the vehicle with the best TSS, or
   d. the mean ratings for the models of the best TSS decile.

v. Substitute commercial utility ratings with
   a. those of the medium SUV model with matching year of manufacture with the best CWR,
   b. the mean ratings for the top CWR decile of medium SUV models with matching year of manufacture,
   c. those of the medium SUV model with matching year of manufacture with the best TSS, or
   d. the mean ratings for the top TSS decile of medium SUV models with matching year of manufacture.

vi. Substitute commercial utility ratings with
   a. those of the medium model with matching year of manufacture with the best CWR,
   b. the mean ratings for the top CWR decile of medium models with matching year of manufacture,
   c. those of the medium model with matching year of manufacture with the best TSS, or
   d. the mean ratings for the top TSS decile of medium models with matching year of manufacture.

Scenarios (ii) to (iv) involve substitution of the best and average best decile safety rating within a market group, within a year of manufacture, or within a market and year of manufacture group. Scenario (i) substitutes the best vehicle or average of the best decile across the whole 2016 fleet. These scenarios model the improvements possible overall and within market group, year of manufacture, and market-year of manufacture groups. Scenarios (v) and (vi) are designed to consider the maximum possible benefits through the elimination of commercial utilities through their substitution with medium SUVs or medium cars respectively.

Two additional scenarios based on increased ESC and AEB fitment were modelled:

vii. Changed market penetration of AEB fitment: All light (passenger) vehicles were fitted with AEB.
viii. Changed market penetration of ESC fitment: All light (passenger) vehicles were fitted with ESC.

4.5 Estimation of scenario impacts on injury counts and associated costs

The above scenarios considered the average change in safety performance across crash involved vehicles. Crash injury reductions, and specifically fatalities and serious injuries, were calculated directly from these estimates after considering the average number of fatalities and serious injuries per vehicle involved in crashes. Injury savings were converted to monetised values using the social costs per injury given in Section 2.4.

5 RESULTS

5.1 Scenarios optimizing secondary safety

Table 1 gives the average secondary safety of the Australian light vehicle fleet as it existed for 2016 (the Baseline Scenario) as well as under each of the 6 broad scenarios considered for optimising the fleet with regards to secondary safety. In Table 1 the '*average top vehicle*' refers to scenarios optimising against the average secondary safety of the 10% of best performing vehicles whilst the '*best vehicle*' refers to scenarios optimising against the single best performing vehicle. For scenarios where the CWR of the fleet is being optimised, the average TSS and AGG have also been calculated under that scenario to reflect the influence of optimising CWR alone on TSS and AGG. Likewise, where fleet TSS is being optimised, average CWR and AGG have been calculated to illustrate the impact of the optimisation on these methods.

In order to illustrate the relative benefits of each optimisation scenario considered in Table 1, Table 2 shows the relative reduction in each average compared to the Baseline Scenario. Negative reductions indicate an increase in the average of the measure relative to the baseline. As described, each secondary safety measure is an estimate of the average risk of death or serious injury in a crash: for CWR this measure relates to the vehicle driver, for AGG this measure relates to people with which a vehicle collides and for TSS this represents the average across all people involved in the crash. As such, the percentage changes given in Table 2 for CWR represent the percentage saving in driver deaths and serious injury, AGG in collision partner deaths and serious injuries and for TSS overall trauma relating from crashes involving light vehicles expected under each scenario. For example, the first row of Table 2 shows that optimising the crashworthiness of the light vehicle fleet through choosing the vehicle with the best crashworthiness across all light vehicles in the fleet in 2016 would have resulted in a 49.4% reduction in driver death and serious injury. However, it would have also resulted in a 4.4% increase in collision partner death and serious injury leading to an overall 30.1% reduction in death and serious injury in crashes involving light vehicles as reflected in the TSS change.

Table 1: Fleet average CWR, TSS and AGG at baseline and for each scenario

	Crashworthiness	Total Secondary Safety	Aggressivity
Baseline	0.0352	0.0382	0.0406
Safest model (i)			
Avg of top CWR vehicle	0.0178	0.0267	0.0424
Avg of top TSS vehicle	0.0205	0.0228	0.0356
Best vehicle CWR	0.0024	0.0158	0.0466
Best vehicle TSS	0.0063	0.008	0.0286
Safest in Market group (ii)	-		
Avg of top CWR vehicle	0.0218	0.0291	0.0389
Avg of top TSS vehicle	0.0233	0.0257	0.0336
Best vehicle CWR	0.013	0.0203	0.0382
Best vehicle TSS	0.0139	0.019	0.033
Safest in Market group and year (iii)	-		
Avg of top CWR vehicle	0.0229	0.0301	0.0394
Avg of top TSS vehicle	0.0268	0.0264	0.0362
Best vehicle CWR	0.021	0.0287	0.039
Best vehicle TSS	0.0259	0.0253	0.0367
Safest in year (iv)	-		
Avg of top CWR vehicle	0.0195	0.0279	0.0432
Avg of top TSS vehicle	0.0235	0.0246	0.0377
Best vehicle CWR	0.0085	0.0193	0.0365
Best vehicle TSS	0.0235	0.0143	0.0407
SUVM for commercial utility (v)	-		
Avg of top SUVM CWR	0.0338	0.0372	0.0401
Avg of top SUVM TSS	0.0341	0.0369	0.0387
Best veh SUVM CWR	0.0335	0.0369	0.0401
Best veh SUVM TSS	0.0338	0.0368	0.0388
M for commercial utility (vi)			
Avg of top M CWR	0.0337	0.0368	0.0388
Avg of top M TSS	0.0338	0.0368	0.0387
Best veh M CWR	0.0329	0.0364	0.039
Best veh M TSS	0.0332	0.0364	0.0384

Table 2: Percentage reduction in fleet average CWR, TSS and AGG for each scenario

	Crashworthiness	Total Secondary Safety	Aggressivity
Safest model (i)			
Avg of top CWR vehicle	49.4%	30.1%	-4.4%
Avg of top TSS vehicle	41.8%	40.3%	12.3%
Best vehicle CWR	93.2%	58.6%	-14.8%
Best vehicle TSS	82.1%	79.1%	29.6%
Safest in Market group (ii)			
Avg of top CWR vehicle	38.1%	23.8%	4.2%
Avg of top TSS vehicle	33.8%	32.7%	17.2%
Best vehicle CWR	63.1%	46.9%	5.9%
Best vehicle TSS	60.5%	50.3%	18.7%
Safest in Market group and year (iii)			
Avg of top CWR vehicle	34.9%	21.2%	3.0%
Avg of top TSS vehicle	23.9%	30.9%	10.8%
Best vehicle CWR	40.3%	24.9%	3.9%
Best vehicle TSS	26.4%	33.8%	9.6%
Safest in year (iv)			
Avg of top CWR vehicle	44.6%	27.0%	-6.4%
Avg of top TSS vehicle	33.2%	35.6%	7.1%
Best vehicle CWR	75.9%	49.5%	10.1%
Best vehicle TSS	33.2%	62.6%	-0.2%
SUVM for commercial utility (v)			
Avg of top SUVM CWR	4.0%	2.6%	1.2%
Avg of top SUVM TSS	3.1%	3.4%	4.7%
Best veh SUVM CWR	4.8%	3.4%	1.2%
Best veh SUVM TSS	4.0%	3.7%	4.4%
M for commercial utility (vi)			
Avg of top M CWR	4.3%	3.7%	4.4%
Avg of top M TSS	4.0%	3.7%	4.7%
Best veh M CWR	6.5%	4.7%	3.9%
Best veh M TSS	5.7%	4.7%	5.4%

Figure 2 shows graphically the impact on TSS of scenarios ii and iii considered by year of vehicle manufacture. The solid green line on the top of the chart represents the actual TSS by year of vehicle manufacture in the data set used for analysis. Each of the other lines in Figure 2 represent the average TSS by year of vehicle manufacture predicted to be achieved under each scenario.

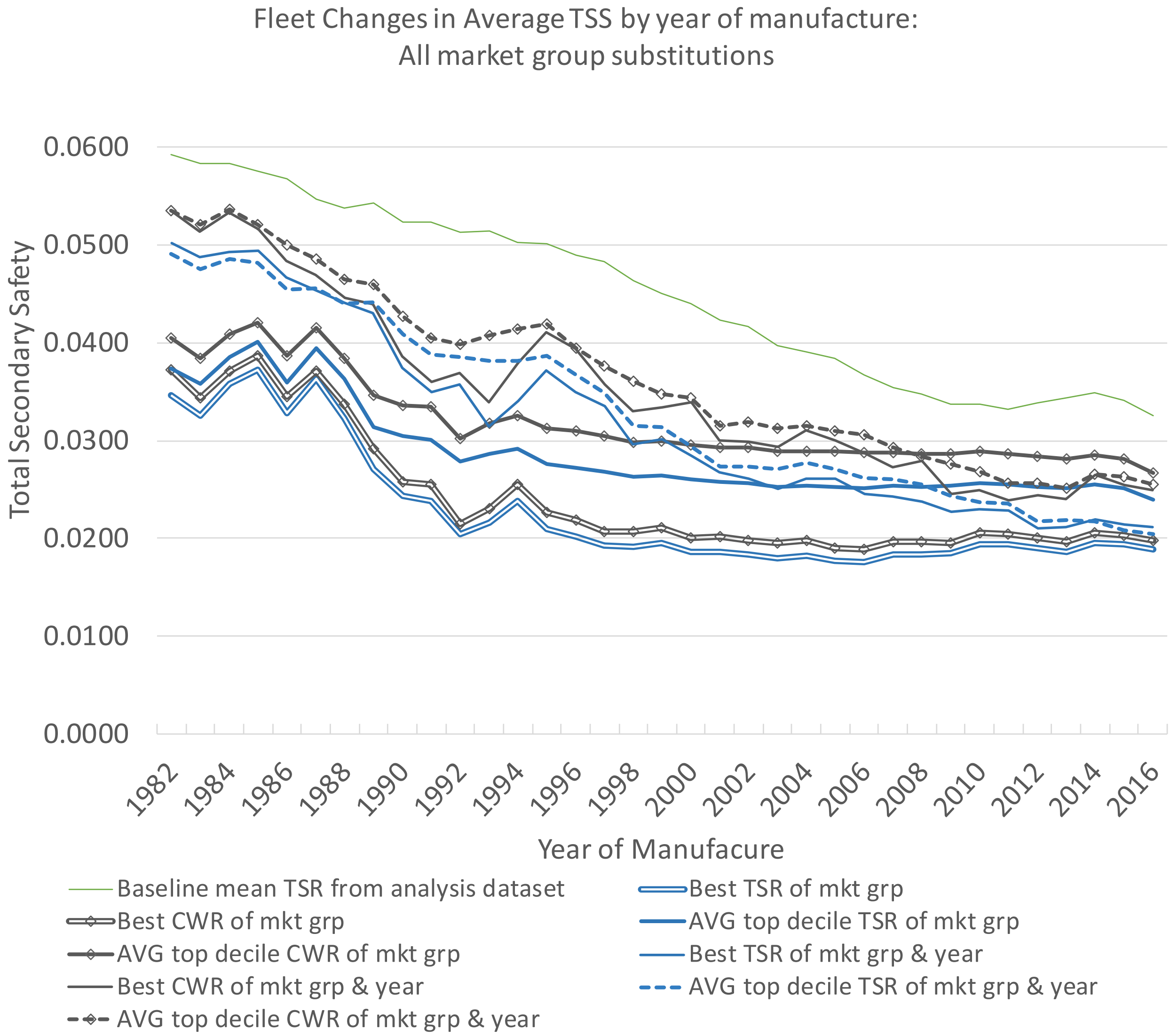

Figure 2: Current 2016 Total Secondary Safety Rating (shading) for each year of manufacture, compared with fleet CWR averages crashworthiness modelled from scenarios ii and iii

To estimate the potential impact of each scenario on absolute serious road trauma levels and their cost to the community, the gains in total secondary safety were converted to combined fatality and serious injury savings by multiplying the observed fatality and serious injury counts in light vehicles manufactured from 1982 onwards during 2016 (940 fatalities and 18,826 serious injuries) by the estimated proportionate change in the total secondary safety rating for that scenario given in Table 2. Estimates represent the savings in fatalities and serious injuries that would have been realised in the year 2016 across crashes involving the light vehicle fleet in Australia had that scenario been implemented. Absolute fatality and serious injury savings have been converted into cost savings to the community associated with each scenario by using the cost per crash estimates described in Section 2.4. The modelled serious trauma and associated cost savings are presented in Table 3. For example, the greatest estimated savings of 774 fatalities and 14,891 serious injuries was from substituting all light vehicles in the 2016 fleet with the single model with the best available TSS corresponding to a saving of $5.2b to the community. Substitutions of commercial utilities with the average top decile of medium SUV models by crashworthiness yielded the smallest savings of 24 fatalities and 489 serious injuries, valued at a cost to society of $170 million dollars.

Table 3: Fatal and serious injury savings and associated economic costs estimated for each scenario

Scenario	Fatality Savings	Serious Injury Savings	Economic Savings
Safest model (i)			
Avg of top CWR vehicle	283	5667	$1,973.43M
Avg of top TSS vehicle	379	7587	$2,642.16M
Best vehicle CWR	551	11032	$3,841.95M
Best vehicle TSS	744	14891	$5,185.98M
Safest in Market group (ii)			
Avg of top CWR vehicle	224	4481	$1,560.38M
Avg of top TSS vehicle	307	6156	$2,143.89M
Best vehicle CWR	441	8829	$3,074.87M
Best vehicle TSS	473	9469	$3,297.79M
Safest in Market group and year (iii)			
Avg of top CWR vehicle	199	3991	$1,389.92M
Avg of top TSS vehicle	290	5817	$2,025.88M
Best vehicle CWR	234	4688	$1,632.50M
Best vehicle TSS	318	6363	$2,216.01M
Safest in year (iv)			
Avg of top CWR vehicle	254	5083	$1,770.18M
Avg of top TSS vehicle	335	6702	$2,334.02M
Best vehicle CWR	465	9319	$3,245.34M
Best vehicle TSS	588	11785	$4,104.20M
SUVM for commercial utility (v)			
Avg of top SUVM CWR	24	489	$170.46M
Avg of top SUVM TSS	32	640	$222.91M
Best veh SUVM CWR	32	640	$222.91M
Best veh SUVM TSS	35	697	$242.58M
M for commercial utility (vi)			
Avg of top M CWR	35	697	$242.58M
Avg of top M TSS	35	697	$242.58M
Best veh M CWR	44	885	$308.14M
Best veh M TSS	44	885	$308.14M

M=medium car, SUVM= medium sports utility vehicle

5.2 Scenarios optimizing primary safety through fitment of ESC and AEB

To estimate potential savings from more widespread fitment of proven safety technologies, two additional scenarios were modelled considering the potential benefits if all vehicles in the 2016 fleet were fitted with electronic stability control (ESC) and autonomous emergency braking (AEB).

5.2.1 AEB

Scenario vii modelled the annual crash injury savings possible if all light vehicles in the Australian fleet in 2016 were fitted with AEB. Estimates of AEB effectiveness were taken from the only existing Australian evaluation of the technology (Budd, et al, 2019) which was based on the primary crash type prevented by current AEB systems being rear-end crashes into another vehicle based on the functionality of the current technology. Budd et al (2019) estimated that AEB fitment to vehicle models which were the striking vehicle in a rear-end crash into a motor vehicle were associated with a 36% (95% CI: 14%-52%) reduction in fatal and serious injuries and 19% (95% CI: 10%-28%) reduction in minor injuries. Appling these to the population of injuries from rear-end crashes involving a light vehicle as the striking vehicle provides the estimated injury savings due to fitting AEB to all light vehicles in the 2016 light vehicle fleet. Estimates are summarised in Table 4 which gives the total fatal + serious and minor injury counts from crashes involving light vehicles in 2016, the proportion of these potentially mitigated by AEB fitment and the percentage, count and community cost of crashes prevented by fitting AEB to all light vehicles.

Table 4: Average annual counts of injuries and potential savings with AEB fitment to all models.

				From rear-end crashes with light vehicle striking a motor-vehicle			
				Potential Saving			
Injury Severity	Total Injuries from crashes involving light vehicles	Total Injuries from rear-end crashes involving light vehicles as the rear impacting vehicle	% of all injuries	% of all injuries saved	Injuries (95%CI:)		Value (A$2018 millions)
Fatal and Serious	19,766	2,965	15	5.4	1,067	(415 to 1,542)	354 (138 to 511)
Minor	45,307	16,311	36	6.8	3,099	(1,631 to 4,567)	7 (3 to 10)

Table 4 shows estimated total saving from fitting all vehicles in the 2016 fleet with AEB of 5.4% of fatal and serious injuries and 6.8% of minor injuries corresponding to absolute savings of 1076 fatalities and serious injuries and 3099 minor injuries. The estimated potential savings in cost to the community equates to an annual saving of around A$361M. It is likely that this estimate is conservative since some AEB variants are claimed to be effective also in mitigating injuries associated with pedestrian and cross-traffic crashes. Estimates from Budd, Stephens et al. (2019) show a further annual average potential saving in community costs of A$231 million potential from 873 fatal and serious injuries (9.8% of the total crash population) and 2,103 minor injuries (11.5% of the total crash population) saved if AEB mitigated these additional crash types.

5.2.2 ESC

Scenario viii modelled potential road trauma savings if 100% of the 2016 light vehicle fleet were fitted with ESC. Crash reduction effectiveness estimates for ESC specific to Australian conditions (Scully and Newstead 2010) estimated that ESC reduced the rate of single vehicle crashes leading to driver injury by 32%.

There were 47 748 reported injury crashes in Australian during 2016 involving light vehicles with a year of manufacture greater than or equal to 1982. Of these 20% were single vehicle crashes. It was estimated that 25.6% of the crash involved light vehicle models had ESC fitted meaning there were 7198 single vehicle injury crashes where the vehicle was not fitted with ESC. 736 of these were involving vehicles manufactured in 2011 or later. Assuming 32% crash reduction associated with ESC, 2303 crashes would have been saved if all vehicles were fitted with ESC or 236 crashes saved if all vehicles manufactured after 2010 were fitted with ESC. This equates to a 4.82% saving across all crashes for all vehicles fitted with ESC and 0.49% of total crashes saved if ESC fitment was limited to a year of manufacture of 2011 or later. If the crashes saved had the same severity profile of the injuries as the total 7198 single vehicle crashes, 108 fatalities, 1163 serious injuries and 1571 minor injuries would be prevented through fitting ESC to all vehicles a total saving in cost to the community of A$533m annually. When only fitting ESC to vehicles with a 2011 or greater year of manufacture, the corresponding community cost saving was estimated at A$54.5m.

5.3 Comparison of latent potential in 2000 with 2016

Newstead et al. (2014) explored the Australian passenger fleet latent potential for safer vehicle choices with respect to the Total Safety Index (TSI) using substitutions of the actual TSI for crashed vehicles in the fleet for the TSI of: the safest vehicle overall and the safest vehicle in each market group. Like the current study, Newstead et al. (2004) explored the substitution of commercial utilities with existing vehicles. However, the previous study explored the substitution of commercial utilities by the safest vehicle amongst all other market groups. In contrast, the current study explored substitution with specific market groups, being medium SUVs and medium cars, that represented perhaps a more realistic alternative vehicle to a commercial utility in terms of likely usage. “Safest” vehicle in both studies was defined as that with the lowest TSS. Another key difference between the current and previous studies is that the current study includes substitution of not only the single safest vehicle but also the average safety of the 10% of safest vehicles to again make the substitution more realistic.

Table 5 compares the latent potential for safer vehicle choices in 2000 with 2016 through assessment of the potential improvement in TSS. Despite the measured improvements in vehicle safety between 2000 and 2016, there still remains significant potential improvement in safer vehicle choices. When considering the impact of commercial utilities, Table 5 shows the potential benefits on whole of fleet TSS in removing this vehicle type are significantly larger in 2016 at between 3.4% and 4.7% than measured from the 2000 vehicle fleet at 1.2%. The greater potential improvement reflects the higher proportion of commercial utilities in the fleet in 2016 compared to 2000. Safety benefits of substituting the safest vehicle in the market group are also significantly greater in 2016 ranging from 32.7% to 50.3% compared with 26% in 2000.

Table 5: Comparison of the latent potential in fleet safety possible through safer vehicle choices in 2000 with 2016

		Percentage difference from baseline			
		2000 TSI		2016 TSS	
	Replacement	**Absolute**	**%**	**Absolute**	**%**
Removal of Commercial Utilities	All other market group	0.001	1.2%		
	Best medium SUV			0.0014	3.7%
	Best medium car			0.0018	4.7%
	Top decile medium SUV			0.0013	3.4%
	Top decile medium car			0.0014	3.7%
Safest vehicle in market group	Best Vehicle	0.0214	26%	0.0192	50.3%
	Average of Top Decile			0.0125	32.7%
Safest vehicle	Best Vehicle	0.0329	39%	0.0302	79.1%
	Average of Top Decile			0.0154	40.3%

6 DISCUSSION AND CONCLUSION

The overall objective of this study was to quantify the potential road safety benefits in terms of reduced deaths and serious injuries that safer vehicle choices could potentially bring in Australia. The Used Car Safety Ratings (Newstead et al, 2018) show that there is significant variation in the secondary safety performance of vehicles within the same year of manufacture across the whole fleet but also within market groups. Variation in the safety performance of vehicles in real world crashes as demonstrated in the UCSR shows clear potential for improving the safety of the fleet through more drivers choosing to drive vehicles with a safer equivalent, or as close as possible to the best available. Ultimately the safety potential of the fleet will only be fully optimised when all drivers choose to drive the safest vehicle.

Analysis presented in this study has measured the difference between secondary safety in the actual 2016 light vehicle fleet and a fleet optimised for safety both across all available vehicles at a point in time and under various constraints. Constraints imposed reflect various levels of pragmatism in what really can be achieved in optimising the safety of the fleet including acknowledging the need for certain vehicle types to fulfil functional requirements (hence optimisation within market groups), continued regeneration of the fleet (hence optimisation within year of manufacture) and having a wider range of optimal vehicles available (hence optimisation against the safest 10% of vehicles rather than a single best vehicle).

Optimisation of secondary safety has been considered against two main measures of secondary safety performance: crashworthiness (CWR) which considers the occupants of vehicles and total secondary safety (TSS) which considers the broader impact of the vehicle across all people involved in the crash. From a societal perspective, TSS is a more relevant measure since safety should be optimised for all road users. Optimising on CWR has also been considered however to demonstrate the impact the narrower consideration of secondary safety has on overall community benefits. Use of the UCSR measures of CWR and TSS also intrinsically optimise safety in terms of fatalities and serious injuries. A lack of reference to minor injuries is not considered problematic since minor injuries represent a relatively small cost burden to society. Furthermore, most Australian road safety strategies are formulated against targets for deaths and serious injuries which is consistent with the focus of this study.

Analysis has also considered the impact of increasing fitment rate of two key crash avoidance technologies in ESC and AEB. The impact of the former is somewhat academic since ESC has been mandated in all light vehicles in Australia since 2015. Despite this the analysis demonstrates the potential benefits of encouraging earlier adoption of such technologies. AEB is more directly relevant since this has not yet been mandated in the Australian light vehicle fleet.

6.1 Latent potential for safer vehicle choices under various scenarios

Analysis has estimated the potential for safer vehicle choices under six broad scenarios with varying levels of constraint on the optimisation related to fixing the market group and year of manufacture of vehicle substitutions in the scenarios considered to be the same as those of the 2016 crashed vehicles. As noted, optimisation of both TSS and CWR has been considered to compare the relative benefits of optimising safety only for vehicle occupants to optimising vehicle safety for all people involved in the crash both inside and outside of the focus vehicle. Safety benefits have been considered in terms of the estimated reductions in fatalities and serious injuries in crashes, the risk metric measured by the Used Car Safety Ratings, the vehicle specific safety metric on which the analysis is based. Robustness of the scenarios has been assessed through comparing the single safest vehicle available under each constraint to the average safety of the 10% of safest vehicles available. The latter is considered to be a more reliable basis to build the scenarios as it represents a wider range of vehicles across which the optimisation can be considered.

The first 2 scenarios considered, scenarios i and ii, consider the possible safety benefits that could be derived if all vehicles in the 2016 fleet were replaced with the safest vehicle or 10% of safest vehicles available in the fleet in 2016. These scenarios are likely unrealistic since they would require instantaneously replacing the entire fleet with the safest single vehicle or a representative mix of the safest 10% of vehicles. This is highly unlikely to ever happen due to economic and practical constraints. Regardless, these scenarios are useful in that they set a theoretical maximum on the benefits safer vehicle choices can make to road trauma. Hence, scenarios i and ii give some indication of future potential for vehicle safety improvement to reduce light vehicle related road trauma. Table 2 shows that if the average total secondary safety of the future vehicle fleet becomes equivalent to the current best 10% of light vehicles, light vehicle related death and SI will reduce by 40%. If the fleet can equal the current benchmark single vehicle, improvement will be around 80%. Even constraining optimising safer vehicle choices to within market group, corresponding benefits of between 33-50% are possible. Historical trends in total secondary safety presented in Newstead et al. (2018) show these benefits are likely to be realised over time. However, optimising safer vehicle choices will realise the benefits much sooner.

Scenarios iii and iv, which consider optimising safe vehicle choices within the same year of manufacture as vehicles were crashed in 2016 are more likely to be achieved compared to scenarios i and ii since they do not rely on replacing the entire fleet, but maintaining the current generational turnover. Scenario iii is most likely to be achieved given it accepts people will also continue to favour certain vehicle types, at least in part due to required functionality. Despite this additional constraint, scenario iii still shows that within the constraints there is still potential to reduce light vehicle related trauma by up to 31-33% through safer vehicle choices, which is substantial. Steering people to more optimal market groups could increase this to between 36-63%. Achieving safer vehicle choice in this way will accelerate the impact of fleet regeneration on safety outcomes well beyond what would be expected without optimised choices.

Comparison of scenarios i and ii shows the sub optimal nature of some market groups in terms of safety through the greater potential safety benefits being achieved through optimising across the whole fleet rather than just within market group. This is supported by information from the UCSRs which shows light vehicles and small SUVs, which have become more prevalent in the Australian light vehicle fleet in recent years, having particularly poor TSS. Steering consumers away from these vehicle types and into safer options such as small vehicles would provide additional benefits to simple choosing the safest options within these market groups. To what degree this can be achieved in practice depends on the necessity of people driving these vehicle types.

TSS is a better measure of overall impact of safety gains on the community as a whole compared to CWR which only measures safety benefits on occupants of the vehicle for which safety is being optimised. As such, the overall benefits of any safety optimisation scenario should be assessed by the impact on TSS. Optimising CWR led to lower overall community benefits that optimising TSS directly. As reflected in Table 2, this is because optimising CWR alone had very limited impact on AGG and in some cases made it worse. These results show that CWR and AGG must be optimised jointly which was the reason for developing the TSS originally. This observation also draws into some question the primary focus of the UCSR being based on CWR which is not consistent with optimising the overall safety of the fleet. The identification of 'safer pick' vehicles in the UCSRs attempts to rectify this to some degree by taking onto account the TSS and other factors to highlight vehicles which perform well in all dimensions. However, a shift to using TSS as the basis for the UCSR would seem warranted. This was attempted some years ago with limited success, possibly because the interpretation of the TSS as a safety measure was not well communicated. Results from this study also provide justification for new vehicle safety rating programs such as ANCAP focusing on the combined CWR and AGG performance in the overall vehicle safety assessment. Future ANCAP testing protocols representing vehicle to vehicle compatibility through using a moving offset test barrier with means to measure intrusion into the barrier face are likely to be better represent both CWR and AGG. In combination with the pedestrian assessment, future ANCAP tests should be better able to measure overall vehicle safety performance which will be critical for achieving the potential safety benefits estimated to be possible in this study.

The proportion of commercial utilities in the Australian fleet has increased around 3-fold in the past 20 years. Analysis presented in this study shows the increased popularity of commercial utilities has had an impact on road trauma through poorer safety. Eliminating these vehicles from the fleet was estimated to result in a 3-5% reduction in light vehicle related serious trauma. It is acknowledged that the functionality of these vehicles is required in some circumstances, but reducing the non-essential use of these vehicles could still have tangible benefits on road safety. Safety benefits of returning to the previous market share commercial utilities used to represent might still reduce serious road trauma by up to around 4%. Analysis shows that medium cars are a slightly safer choice as an alternative to commercial utilities compared to medium SUVs since medium cars have lower average AGG. Whilst there are clear benefits in reducing the proportion of new vehicle sales which are utilities, the relative safety benefits estimated in this study show this objective is secondary to improving overall safety compared to improving safer vehicle choices across all vehicle types.

Economic analysis shows the potential community cost savings to Australia through safer vehicle choices are extremely large valued at between $170M per annum for the least effective scenario and over $5b for the most effective scenario. The most likely savings that could be realised are around $2b per annum based on optimising safety by year of vehicle manufacture within market groups resulting from 290 fatalities and 5817 serious injuries saved. Potential savings of this magnitude could be used to justify significant investment in programs or incentives to improve safer vehicle choices.

6.2 Benefits of crash avoidance technologies

This study has estimated the benefits of ESC being fitted to all existing vehicles. Such a scenario is also somewhat academic since it is impossible to fit ESC to vehicles retrospectively and all new light vehicles in Australia have been required to have ESC since 2015 (2012 for regular passenger vehicles). What analysis represents then is the lost opportunity for trauma reduction through not having achieved higher uptake of ESC in the early years of its availability noting the technology was widely available from around 2008. Additional crash savings of up to 5% were possible if all vehicles had the technology when it first became widely available. This analysis shows the importance of encouraging wide uptake of new effective crash avoidance technologies soon after availability. AEB is not currently mandated in Australian vehicles and analysis suggests additional future fatal / serious injury and minor injury savings of 5 and 7 percent respectively are possible if all new vehicles were now fitted with the technology.

6.3 Changes in latent potential for safer vehicle choices over time

An objective of the current study was to assess if the latent potential for safer vehicle choices in the Australian fleet has changed since the 2004 study of Newstead et al (2004). Whilst the original study considered only a subset of those considered in the current results, there is sufficient overlap to make comment on the change in latent potential over time. Two results in the original study are comparable with main scenario results in this study, as illustrated in Table 5. These are the optimisation of the current fleet against the single vehicle with the best TSS in scenarios i and ii which examine replacing the whole 2016 fleet with the best vehicle overall and the best vehicle within market group respectively. Table 5 shows an estimated 39% potential benefit when optimisation across whole fleet in the previous study. The estimated benefit has now increased to 79% for the single best vehicle and 40% for the average of safest 10% of vehicles, both larger than the original study. When constrained within market group the potential benefit has increased from 26% in the previous study to 50% for the single best vehicle or 33% for the average of the safest 10% of vehicles in the current study. Again, both are significantly larger than the previous estimate. Regardless of comparison, the latent potential for safer vehicle choices has increased over time despite the increased availability and promotion of consumer information to guide safe choices.

Increased latent potential for safer vehicle choices indicate a worsening of the safety of vehicles actually chosen by consumers compared to what could be achieved. There are a number of possible reasons for this. The variation in safety across vehicles in the fleet may have widened over time meaning the average vehicle is now significantly less safe than the best available. In addition, changes in market group preferences have also led to a less optimal fleet with regards to safety with higher proportions of commercial utilities, light and small SUV vehicles in the fleet, all of which have suboptimal safety. The increasing impact of utility sales has been discussed and is further illustrated in Table 5 with total impact increasing from 1.2% in 2000 to up to 3.7% on a comparable basis in 2016. The real reason behind the shift is likely a combination of these factors and potentially others. Regardless of the reason, results from the study show an increased need to continue efforts to improve consumer vehicle choices with respect to safety.

6.4 Conclusion

This study has shown significant savings in fatalities and serious injuries from road crashes are possible through safer vehicle choices particularly optimised with respect to total secondary safety. The largest savings could be derived if all current vehicles in the fleet were replaced with the safest vehicles available with savings of nearly 80% of fatal and serious injuries resulting from crashes involving a light vehicle. Replacing the entire current fleet is unrealistic, however analysis demonstrated that if every vehicle was replaced with the safest vehicle of the same age and within the same market group, fatal and serious injury savings of around 33% would be possible, representing savings to the Australian community of nearly $2b per annum through reduced trauma costs. Safety benefits are maximised not by choosing vehicles that prioritise protection of their own occupants (crashworthiness) but rather through choosing vehicles that provide best possible protection from injury for all people involved in a crash (total secondary safety). Increasing the uptake of electronic stability control in vehicles prior to its mandate in 2012 would have provided an additional 5% crash savings in 2016. Fitment of autonomous emergency braking to all new vehicles would have had the benefit of providing an additional 5% savings in future crashes. Large additional savings were also possible through increased fitment of AEB and ESC and through market group shifts. The latent potential for additional trauma savings through safer vehicle choices was estimated to be larger in 2016 than estimated previously for the year 2000 light vehicle fleet. The additional latent potential available in 2016 merits increased investment in consumer programs and possible incentives which encourage safer vehicle choices.

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APPENDIX A: Vehicles used in substitution scenarios

Appendix A Table 1: Top Decile when ranked by Total Secondary Safety Rating

Code	Make	Model	Market
CIT A01	**Citroen**	**BX**	**S**
MAZ V01	**Mazda**	**CX-3**	**SUVS**
AUD M01	Audi	Q3 / RS Q3 8U	SUVS
ALF C01	Alfa Romeo	Giulietta	S
JAG I01	**Jaguar**	**XF / XFR**	**L**
LEX B01	Lexus	LS430	L
NIS L06	Nissan	Pulsar C12 Hatch	S
RRV A06	**Land Rover**	**Range Rover Sport LS**	**SUVL**
ALF N01	**Alfa Romeo**	**159 / Brera**	**M**
MER O02	Mercedes Benz	B-Class W246	S
MER B04	Mercedes Benz	S-Class R129	L
VOL N01	**Volvo**	**XC60**	**SUVM**
JEE B04	Jeep	Grand Cherokee WK	SUVL
LEX J01	Lexus	GS250/300/350/450h/460	L
JEE D01	Jeep	Commander	SUVL
MER N01	Mercedes Benz	CLS W219	L
NIS Z02	Nissan	Murano Z51	SUVM
MAZ O03	Mazda	6 GJ/GL	M
JEE F01	Jeep	Compass	SUVS
FIA F01	**Fiat**	**Ducato**	**CV**
LDR B03	Land Rover	Discovery 3	SUVL
AUD G01	Audi	Q7	SUVL
HYU O02	Hyundai	ix35	SUVS
MER B05	Mercedes Benz	S-Class W221 / V221	L
KIA P01	**Kia**	**Rondo UN**	**PM**
JEE A03	Jeep	Cherokee KK	SUVM
MER I02	Mercedes Benz	ML / GL -Class W164 / X164	SUVL
HYU G02	Hyundai	Elantra	S
TOY T03	Toyota	Prius 3	S
VKS L01	Volkswagen	Crafter	CV
VKS Q01	Volkswagen	CC	M
MIT N02	Mitsubishi / Peugeot	Outlander / 4007	SUVM
VOL J01	Volvo	XC90	SUVL
BMWX301	BMW	X3 E83	SUVM
SAA C01	Saab	9-May	M
TOY Z01	Toyota	Rukus	S
BMW M02	**Mini**	**MkI Cooper S R53**	**SL**
CIT M01	Citroen	C5	M
LEX I02	Lexus	RX270/350/400h/450h	SUVM
DOD D01	Dodge	Nitro	SUVM
BMWX501	BMW	X5 E53	SUVL
LEX F01	Lexus	GS300	L
VKS O01	**Volkswagen**	**Amarok**	**CU**
POR B04	Porsche	911 996 Series	M
Code	**Make**	**Model**	**Market**
POR F01	Porsche	Cayenne	SUVM
MIT F05	Mitsubishi	Pajero NS / NT / NW / NX	SUVL
NISAB01	Nissan	Dualis	SUVS
HYU H01	Hyundai	Elantra LaVita	S
BMWX502	BMW	X5 E70	SUVL
MAZ S01	Mazda	CX-7	SUVM
NIS N06	Nissan	Navara D23	CU
MAZ Q03	Mazda	3 BM/BN	S
HON M04	Honda	CR-V	SUVM
NIS F04	Nissan	Patrol Y62	SUVL
DOD B01	Dodge	Caliber	SUVS
MIT N03	Mitsubishi	Outlander	SUVM
SUB E05	Subaru	Liberty / Outback / Exiga	M
GTW B01	Great Wall	V240 / V200	CU
HYU R01	Hyundai	iLoad	CV
SUZ J03	Suzuki	Grand Vitara JT	SUVM
SUB E06	Subaru	Liberty / Outback	M
VKS N01	Volkswagen	Tiguan	SUVS
HON G02	Honda	City	SL
VKS F04	Volkswagen	Polo	SL
REN H01	Renault	Megane Cabriolet	S
VKS D01	Volkswagen	Golf VII	S
AUD J01	Audi	Q5/SQ5 8R	SUVM
ROV D02	Land Rover	Freelander 2	SUVM
LDR B02	Land Rover	Discovery	SUVL
NISAA01	Nissan	Tiida	S
TOY V03	Toyota	Landcruiser Prado	SUVL
MIT I07	Mitsubishi	Lancer CJ / CF	S
CHR G01	Chrysler	Grand Voyager RG	PM

Top models by market group are highlighted green. Top model is listed at top.

Appendix A Table 2: Top Decile when ranked by Crashworthiness Rating

Code	Make	Model	Market
ALF N01	**Alfa Romeo**	**159 / Brera**	**M**
CIT A01	**Citroen**	**BX**	**S**
AUD M01	**Audi**	**Q3 / RS Q3 8U**	**SUVS**
MAZ O03	Mazda	6 GJ/GL	M
VOL N01	**Volvo**	**XC60**	**SUVM**
MER I02	**Mercedes Benz**	**ML / GL - Class W164 / X164**	**SUVL**
LEX J01	**Lexus**	**GS250/300/350/450h/460**	**L**
DOD D01	Dodge	Nitro	SUVM
LDR B04	Land Rover	Discovery 4 / Discovery	SUVL
JAG I01	Jaguar	XF / XFR	L
AUD J01	Audi	Q5/SQ5 8R	SUVM
AUD G01	Audi	Q7	SUVL
VKS O01	**Volkswagen**	**Amarok**	**CU**
LDR B03	Land Rover	Discovery 3	SUVL
RRV A03	Land Rover	Range Rover	SUVL
BMWX502	BMW	X5 E70	SUVL
JEE B04	Jeep	Grand Cherokee WK	SUVL
LEX I02	Lexus	RX270/350/400h/450h	SUVM
VKS Q01	Volkswagen	CC	M
HON M04	Honda	CR-V	SUVM
FIA F01	**Fiat**	**Ducato**	**CV**
TOY Z01	Toyota	Rukus	S
BMWX501	BMW	X5 E53	SUVL
MER A05	Mercedes Benz	E-Class W212 / C207 / A207	L
SUB H04	Subaru	Forester	SUVM
JEE F01	Jeep	Compass	SUVS
JEE A03	Jeep	Cherokee KK	SUVM
VKS D01	Volkswagen	Golf VII	S
HON R01	Honda	MDX	SUVM
VOL J01	Volvo	XC90	SUVL
MIT F05	Mitsubishi	Pajero NS / NT / NW / NX	SUVL
NIS Z02	Nissan	Murano Z51	SUVM
LDR B02	Land Rover	Discovery	SUVL
TOY T03	Toyota	Prius 3	S
MER I03	Mercedes Benz	ML / GL / GLE / GLS -Class W166 / X166 / C292	SUVL
TOY V03	Toyota	Landcruiser Prado	SUVL
FOR U02	Ford	Territory SZ MkII	SUVM
VKS N01	Volkswagen	Tiguan	SUVS
VKS I01	Volkswagen	Touareg	SUVL
LEX F01	Lexus	GS300	L
HON L04	**Honda**	**Odyssey**	**PM**
SUB E05	Subaru	Liberty / Outback / Exiga	M
JEE B03	Jeep	Grand Cherokee WH	SUVL
BMW 703	BMW	7 Series E38	L
POR B04	Porsche	911 996 Series	M
VKS A03	Volkswagen	Caravelle / Transporter / Multivan	CV
SUB I01	Subaru	Tribeca	SUVM
HOL E07	Holden	Commodore VF	L
VOL H01	Volvo	S80	L
MER A04	Mercedes Benz	E-Class W211	L
HYU R01	Hyundai	iLoad	CV
BMWX301	BMW	X3 E83	SUVM
MAZ G02	Mazda	MPV	PM
MER E02	Mercedes Benz	CLK C209	M
VOL I01	Volvo	S60	M
KIA G02	Kia	Carnival	PM
FOR K02	Ford	Mondeo	M
REN H01	Renault	Megane Cabriolet	S
AUD D02	Audi	A3	S
MAZ R02	Ford / Mazda	Ranger / BT-50	CU
HYU H01	Hyundai	Elantra LaVita	S
HON L03	Honda	Odyssey	PM
MER L02	Mercedes Benz	Vito / Viano / Valente	CV
DOD B01	Dodge	Caliber	SUVS
TOY W02	Toyota	Kluger / Highlander	SUVM
HOL H01	Holden	Colorado RC	CU
MAZ S01	Mazda	CX-7	SUVM
HYU I02	Hyundai	Santa Fe CM	SUVM

Top models by market group are highlighted green.
Top model is listed at top.

Appendix A Table 3: Top model when ranked by Crashworthiness Rating for other market groups

Code	Make	Model	Market
HON G02	Honda	City	SL
HON L04	Honda	Odyssey	PM

Appendix A Table 4: Top models by year of manufacture when ranked by Crashworthiness Rating

Code	Year of manufacture	Make	Model	Market
ROV A01	1982	Rover	3500	L
ROV A01	1983	Rover	3500	L
ROV A01	1984	Rover	3500	L
ROV A01	1985	Rover	3500	L
CIT A01	1986	Citroen	BX	S
CIT A01	1987	Citroen	BX	S
CIT A01	1988	Citroen	BX	S
CIT A01	1989	Citroen	BX	S
CIT A01	1990	Citroen	BX	S
CIT A01	1991	Citroen	BX	S
CIT A01	1992	Citroen	BX	S
CIT A01	1993	Citroen	BX	S
CIT A01	1994	Citroen	BX	S
BMW 703	1995	BMW	7 Series E38	L
BMW 703	1996	BMW	7 Series E38	L
LEX F01	1997	Lexus	GS300	L
LEX F01	1998	Lexus	GS300	L
LEX F01	1999	Lexus	GS300	L
LEX F01	2000	Lexus	GS300	L
BMWX501	2001	BMW	X5 E53	SUVL
RRV A03	2002	Land Rover	Range Rover	SUVL
RRV A03	2003	Land Rover	Range Rover	SUVL
RRV A03	2004	Land Rover	Range Rover	SUVL
MER I02	2005	Mercedes Benz	ML / GL -Class W164 / X164	SUVL
ALF N01	2006	Alfa Romeo	159 / Brera	M
ALF N01	2007	Alfa Romeo	159 / Brera	M
ALF N01	2008	Alfa Romeo	159 / Brera	M
ALF N01	2009	Alfa Romeo	159 / Brera	M
ALF N01	2010	Alfa Romeo	159 / Brera	M
ALF N01	2011	Alfa Romeo	159 / Brera	M
ALF N01	2012	Alfa Romeo	159 / Brera	M
AUD M01	2013	Audi	Q3 / RS Q3 8U	SUVS
AUD M01	2014	Audi	Q3 / RS Q3 8U	SUVS
AUD M01	2015	Audi	Q3 / RS Q3 8U	SUVS
AUD M01	2016	Audi	Q3 / RS Q3 8U	SUVS

Appendix A Table 5: Top models by year of manufacture when ranked by Total Secondary Safety Rating

Code	Year of manufacture	Make	Model	Market
ALF C01	1982	Alfa Romeo	Giulietta	S
ALF C01	1983	Alfa Romeo	Giulietta	S
ALF C01	1984	Alfa Romeo	Giulietta	S
ALF C01	1985	Alfa Romeo	Giulietta	S
CIT A01	1986	Citroen	BX	S
CIT A01	1987	Citroen	BX	S
CIT A01	1988	Citroen	BX	S
CIT A01	1989	Citroen	BX	S
CIT A01	1990	Citroen	BX	S
CIT A01	1991	Citroen	BX	S
CIT A01	1992	Citroen	BX	S
CIT A01	1993	Citroen	BX	S
CIT A01	1994	Citroen	BX	S
MER B04	1995	Mercedes Benz	S-Class R129	L
MER B04	1996	Mercedes Benz	S-Class R129	L
MER B04	1997	Mercedes Benz	S-Class R129	L
MER B04	1998	Mercedes Benz	S-Class R129	L
MER B04	1999	Mercedes Benz	S-Class R129	L
LEX B01	2000	Lexus	LS430	L
LEX B01	2001	Lexus	LS430	L
LEX B01	2002	Lexus	LS430	L
LEX B01	2003	Lexus	LS430	L
LEX B01	2004	Lexus	LS430	L
RRV A06	2005	Land Rover	Range Rover Sport LS	SUVL
RRV A06	2006	Land Rover	Range Rover Sport LS	SUVL
RRV A06	2007	Land Rover	Range Rover Sport LS	SUVL
JAG I01	2008	Jaguar	XF / XFR	L
JAG I01	2009	Jaguar	XF / XFR	L
JAG I01	2010	Jaguar	XF / XFR	L
JAG I01	2011	Jaguar	XF / XFR	L
AUD M01	2012	Audi	Q3 / RS Q3 8U	SUVS
AUD M01	2013	Audi	Q3 / RS Q3 8U	SUVS
AUD M01	2014	Audi	Q3 / RS Q3 8U	SUVS
MAZ V01	2015	Mazda	CX-3	SUVS
MAZ V01	2016	Mazda	CX-3	SUVS

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