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ACCIDENT RESEARCH CENTRE

The Potential Benefits of Autonomous Emergency Braking Systems in Australia

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The Potential Benefits of Autonomous Emergency Braking Systems in Australia

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Abstract:
Monash University Accident Research Centre conducted an evaluation of the potential benefits of AEB in light and heavy vehicles in Australia. Crash and crash injury benefits were modelled on police reported crash data on crashes occurring in Australia between 2013-2016 inclusive. The classification of sensitive crashes, those potentially mitigated by AEB, was based on four existing real world evaluations of AEB and applied to crashes occurring in Australia. Crashes were considered as narrowly sensitive, broadly sensitive and pedestrian sensitive. Narrowly and broadly sensitive crashes involved car to vehicle incidents, with either a high degree of confidence (narrow sensitivity) or where there was some evidence (broadly sensitive) that AEB would alleviate or mitigate the crash. Pedestrian crashes included car to pedestrian and car to bicycle, unless otherwise stated. Up to 30% of light vehicle crashes were found to be sensitive to AEB. The addition of broad and pedestrian sensitivity increased this to 61% or 64% if only low speed zone crashes were considered (≤60km/h). When injuries from crashes, rather than crashes were considered, up to 70% of injuries sustained in car to vehicle crashes (considering narrow and broad crashes combined) and up to 5% of injuries from car to pedestrian crashes were sensitive to AEB. In low speed zones, 74% of car to vehicle trauma was sensitive to AEB and 7% of pedestrian crashes. Therefore, in low speed zones the fitment of AEB to light passenger vehicles has the potential to impact the outcome in 63% of all light vehicle crashes; and to potentially avoid or mitigate up to 81% of the trauma incidents occurring in light vehicle crashes.

Analysis of police reported crash data from Australia using induced exposure methods showed strongly significant estimates of relative risk reductions associated with light vehicle models where some variants are fitted with AEB. In low speed zones, reductions in the risk of trauma from narrowly sensitive crashes were estimated at 28% for fatal and serious injuries and 18% for minor injuries. In broadly sensitive crashed vehicles, risk reductions were 12% for fatal and serious injuries and 13% for minor injuries; 18% and 32% respectively for pedestrian sensitive crashes. Therefore, if all light passenger vehicles in narrowly, broadly and pedestrian sensitive crashed vehicles in Australia were models where some variants had AEB fitted, these estimates of injury reduction in sensitive crashes would translate to injury reductions across all crashes of: **9.69%** for fatalities and serious injuries and **8.80%** of minor injuries. In low speed zones, these reductions constitute **12.36%** of all light vehicle crash fatalities and serious injuries, and **13.41%** of all light vehicle minor injuries.

Fifteen percent of all heavy vehicle crashes were classified as sensitive to avoidance or mitigation with AEB. The effectiveness of AEB in heavy vehicles was determined from empirical literature as equivalent data to allow direct estimation of crash reductions associated with the technology from Australian heavy vehicle crash data was not available. Crash reductions in sensitive crashes associated with heavy vehicle AEB fitment estimated from existing international literature were between 22% to 57%, using a range that considers current AEB technology (lower bound) and future technology (upper bound). Potential average savings across all crash types from full heavy vehicle fleet fitment of AEB were estimated at between **2.11% to 5.09%** of fatalities and **4.74% to 11.52%** of serious injuries. In addition, **8.69% to 21.67%** of all minor injuries resulting from crashes involving heavy vehicle crashes could be avoided or mitigated with AEB.

The results highlight significant benefits of AEB technology in the reduction of trauma incidents as a results of light vehicle or heavy vehicle involved crashes.

Key Words:	**Disclaimer**
AEB; Advanced Autonomous Automatic Emergency Braking Systems; induced exposure; rear-end crashes; real-world Australian crash data	This report is disseminated in the interest of information exchange. The views expressed here are those of the authors, and not necessarily those of Monash University

Preface

Project Manager / Team Leader:

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Research Team:

- Ms Laurie Budd
- Dr Amanda Stephens

Contributor Statement

- Stuart Newstead: Project oversight and analysis design
- Laurie Budd: Statistical design and analysis and associated report sections
- Amanda Stephens: Preparation of the final report

Ethics Statement:

Ethics approval was not required for this project.

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EXECUTIVE SUMMARY

The Vehicle Safety Standards Branch of the Department of Infrastructure, Transport, Regional Development and Communications approached MUARC to provide statistical analysis services to support the development of a Regulatory Impact Statement to consider a case to mandate Advanced Emergency Braking Systems, specifically Autonomous Emergency Braking (AEB), in light and heavy vehicles.

Method

The analyses conducted for this project focussed on estimation of the crash and crash injury benefits associated with AEB in both light and heavy vehicles in Australia based on analysis of police reported crash data over the four-year period from 2013 to 2016. The potential benefits were measured with the assumption of AEB fitment to all light and heavy vehicles; and with the assumption of nil fitment during the reference data period of 2013 to 2016. In the light vehicle fleet, during 2013 to 2015, less than 0.1% of crashed light vehicles were models with AEB fitment certainty (fitted to all variants of the model). Thus, an assumption of 0% fitment seems reasonable and unlikely to bias the sensitive vehicle potential benefit.

Light vehicles were defined as all vehicles with a vehicle weight less than or equal to 3.5 tonnes. Heavy vehicles were classified into six broad categories, which included, rigid trucks <= 12 tonnes, articulated trucks (i.e. prime movers, semi-trailers and road trains, large heavy vehicles >12 tonnes), rigid trucks with unknown weight, large buses (vehicles with 9 or more seats or weighing > 4.5 tonnes), smaller buses (vehicles with 9 or more seats and either weighing 4.5 tonnes or less, or a seat capacity under 25), and buses with unknown weight. Heavy vehicles were selected to match as closely as possible the vehicle set to which UNR131 applies.

The evaluation methods used to determine the potential benefits of AEB are detailed comprehensively in Section 5 of the report. AEB effectiveness estimates for heavy vehicles were sourced from available published literature and applied to the heavy vehicle sensitive crashes (that is crashes likely to be prevented or their severity lessened by AEB). A 16-40% reduction in sensitive crashes due to AEB fitment was modelled, which is likely to underestimate AEB effects. For light vehicles, the effectiveness estimates were determined directly using induced exposure methods through analysis of police reported crash data in Australia. Crash or injury counts within crashed vehicles considered not sensitive to AEB were used to induce exposure. Broadly, induced exposure methods estimate the crash reduction effects of AEB by comparing the ratio of AEB sensitive to AEB non-sensitive crashes in vehicles fitted with AEB to the same ratio for vehicles without AEB, with this ratio expected to be smaller for AEB equipped vehicles if AEB is effective in reducing crash (or injury) risk.

Crashes defined as sensitive to AEB contained a number of attributes. For light vehicle crashes, the light vehicle induced exposure analysis of crash injuries included only injury-crash data (crashes in which at least one person was injured). An analysis of light vehicle non-injury crashes was carried out in a separate induced exposure analysis. Speed zone was used as a proxy for vehicle travel speed for light vehicles and separated across 60km/h or lower and above 60km/h for analysis. The entire range of speed zones was used to estimate the potential benefits of AEB in heavy vehicles. Crash sensitivity was considered as narrow - a high degree of certainty that AEB would mitigate or avoid the crash - or broad, situations where AEB might mitigate of avoid the crash. Pedestrian-to-vehicle crashes were also considered.

Fitment of AEB to light vehicles was determined using a process of decoding vehicle identification numbers to identify make and model of vehicle and then matching vehicle specification information from RedBook to the decoded data. Almost no vehicles manufactured before 2013 were identified as having AEB fitted in the crash data hence analysis was limited to vehicles manufactured from 2013 to eliminate a vehicle age bias in the analysis.

A Poisson regression model was fitted to the crash data to estimate the relative proportion of AEB sensitive crashes in AEB equipped light vehicles compared to those without AEB. The analysis was conducted in two ways. The primary model utilised narrowly sensitive crashes compared against non-sensitive crashes. The secondary model compared pedestrian and broadly sensitive crashes with the non-sensitive crash set. AEB fitment status was also modelled in two ways due to limited resolution in determining AEB fitness through the VIN decoding process. The first analysis considered AEB effectiveness for light vehicles where all variants if a vehicle model group were determined as having AEB fitted. The second analysis considered light vehicle model groups where only some of the variants in the group may have had AEB fitted. The second group of models was much larger providing greater statistical analysis power but also likely more conservative estimates of AEB effectiveness.

AEB Sensitive crashes – light passenger vehicles

Twenty-eight percent of light vehicle crashes in speed zones of 60km/h or less were classified as narrowly sensitive to AEB. An additional 33% were classified as broadly sensitive to AEB, and 3% as pedestrian crashes sensitive to AEB. Based on the narrowly sensitive data, AEB could therefore impact the crash outcome in up to 28% of light vehicle crashes in low speed zones. When broadly sensitive and pedestrian sensitive crashes are also considered, AEB could impact the crash outcome in up to 64% of light vehicle crashes in lower speed zones.

When proportioned across all crash injuries, up to 68% of all fatal and serious injuries from light passenger vehicle crashes were sensitive to AEB and 78% of all minor injuries were sensitive. These injury proportions are derived from injuries in narrow, broad and pedestrian sensitive crashes. When considering all speed zones, up to 75% of all trauma incidents were sensitive to AEB, slightly less than for the lower speed zones alone. These findings show that a greater percentage of crashes sensitive to AEB occurred in speed zones of 60km/h or lower; and consequently, the mandating of AEB in light passenger vehicles is likely to benefit a greater percentage of crashes occurring in lower speed zones.

AEB Effectiveness – light passenger vehicles

The analyses showed potential benefits of AEB fitment in reducing the risk of crashes and resulting injuries. However, due to the small number of light vehicle model groups where with all variants were fitted with AEB fitted, estimated crash reductions associated with AEB were only statistically significant from the analysis considering vehicle model groups where some variants were fitted with AEB. Only these results are reported in the following. For narrowly sensitive crashes, the injury risk reductions associated with vehicle model groups with some variants fitted with AEB were much greater for serious and fatal injuries than for minor injuries. Specifically, an estimated injury risk reduction of 22% (95%CI: 13%, 30%) was found for all injuries resulting from narrowly sensitive crashes; a corresponding 36% (95%CI: 14%, 52%) reduction in fatal and serious injuries; and a 19% (95%CI: 10%, 28%) reduction in minor injuries (not requiring hospital admission).

When considered across speed zones, the estimated potential benefits of AEB for injury risk reduction were greatest in higher speed zones. AEB fitment was associated with a 45% (95%CI: 14%, 64%) reduction in the risk of fatal and serious injury in narrowly sensitive crashes in speed zones above 60km/h. The corresponding risk reductions were 22% (95%CI: 4%, 36%) for minor injuries and 27% (95%CI: 13%, 30%) for all injuries. In all cases these injury risk reductions were higher than the risk reductions in speed zones of 60km/h or lower. However, when broadly sensitive crashes or pedestrian sensitive crashes were considered, greater risk reductions were found for the speed zones of 60km/h or less. For broadly sensitive crashes, a minor injury risk reduction of 13% (95%CI: 3%, 22%) was found. While for pedestrian sensitive crashed vehicles, a 32% (95%CI: 7%, 50%) minor injury risk reduction was found. Results from other injury severities were not statistically significant due to limited data quantities.

AEB Crash and Injury benefits in the light vehicle fleet

Considering estimated AEB effectiveness in all narrowly, broadly and pedestrian sensitive crashes and the proportion of all crashes that these sensitive crash types represent, if all light passenger vehicles in vehicles in Australia were fitted with AEB, the estimated reduction in total injuries would be 10% for fatalities and serious injuries and 9% for minor injuries. Considering only narrowly sensitive crashes, the estimated percentage injury reduction from AEB fitment to all vehicles would be 5% for fatalities and serious injuries and 4% for minor injuries. It should be noted that these estimates are likely conservative since they are based on estimates of AEB effectiveness in vehicle model groups where only some of the vehicles were fitted with the technology.

AEB in heavy vehicles

Crashes defined as narrowly sensitive to AEB made up 14.78% of the total crashes involving the heavy vehicle fleet. Of the heavy vehicle crashes that have occurred in Australia between 2013 to 2016, 15% of all crashed heavy vehicles were considered to be striking vehicles in crashes sensitive to AEB. This percentage varied by heavy vehicle type. For buses this was 9.5% large buses, 12% for smaller buses and 12% for buses of unknown weight. For trucks it was 15% for rigid trucks under 12 tonne, 16% for large rigid and articulated trucks and 16% for trucks of unknown weight.

Given the paucity of local data on AEB fitment in heavy vehicles it was not possible to estimate AEB crash effects directly from local heavy vehicle crash data. Consequently, effectiveness values were taken from published international literature and a range used which accommodated current AEB technology effectiveness in heavy vehicles (lower value) and the likely future effectiveness AEB technologies in heavy vehicles (upper value) based on the anticipated future development of the technology. The overall range of heavy vehicle crash reduction effects associated with AEB taken form the literature and applied to the Australian crash context was between 22% to 57% for fatalities and 21% to 57% for serious and minor injuries.

Based on estimated effectiveness from the literature, the heavy vehicle analysis showed potential significant benefits of AEB technology in sensitive heavy crashed vehicles. If all sensitive crashed heavy vehicles had AEB fitted, there would be, on average, between 3 to 6 less fatal injuries per year; 68 to 165 less serious injuries per year and 270 to 673 less minor injuries. These figures represent approximately 2% to 5% of all annual fatalities and 5% to 12% of all annual serious injuries resulting from heavy vehicle AEB sensitive crashes based on 2013-2016 averages.

Conclusions

Analyses using real-world crash data from Australia form the years 2013 to 2016 showed significant potential benefits of AEB fitment in reducing crashes involving light and heavy vehicles. Estimates of the potential future benefits of AEB in this study for light vehicles are likely to be conservative due to constraints on identifying AEB equipped light vehicles as well as the constant development of the technology being seen to address more crash types in higher speed zones.

1 BACKGROUND

The Vehicle Safety Standards Branch of the DIRD has approached MUARC to provide statistical analysis services to support the development of a Regulatory Impact Statement for the mandate of Advanced Emergency Braking Systems, specifically Autonomous Emergency Braking (AEB), in light and heavy vehicles. AEB, and particularly AEB functional at speeds above 80km/h has been identified in prospective evaluations as the driver assistance technology for both light and heavy vehicles most likely to have the greatest impact on crash risk and subsequent road trauma reductions (see Anderson, Hutchinson et al. 2010). The limited number of real world evaluations available for AEB have provided early confirmation of the crash reduction benefits of the technology (Fildes, Keall et al. 2015, Cicchino 2017), estimating an overall crash reduction of 12% due to the technology. These early evaluations have been based largely on vehicles with functionality only in low speed environments (generally less than 50km/h).

Current statistics on AEB fitment to light vehicles recently published by ANCAP show that 31% of new light vehicle sales have AEB of some form standard whilst a further 40% have the technology available as an option. The majority of AEB systems currently available are designated as having city functionality with crash avoidance possible only up to speeds of between 30 and 80km/h with only speed reduction possible before impact above these speeds. Similar statistics for heavy vehicles are not readily available although it is anticipated that very few heavy vehicles currently have AEB fitted.

Similar to the introduction of previous crash avoidance technologies such as ESC, market forces and programs such as ANCAP will drive uptake of the technology only to a certain point. To achieve fitment of the technology to all new vehicles requires appropriate regulations to be implemented mandating fitment to all new vehicles entering Australia.

The purpose of the analysis under this study is to inform the calculation of the likely road safety benefits that can be derived through the mandated fitment of AEB systems to all new light and heavy vehicles entering Australia. Data analysis in this regard was conducted across distinct stages, referred to as project milestones. These were:

1. Design of the evaluation study including the definition of AEB sensitive crash types, appropriate induced exposure (non-sensitive) crash types and potential confounding factors such as crash year, crash jurisdiction, crash location (urban/rural) and road surface type (sealed/unsealed). In addition, the methodology to present results across crash severity (i.e. fatal, serious injury, minor injury and property damage only) and crash type (heavy/light, single/multi vehicle) was established.
2. Collation of AEB crash situation sensitivity statistics based on analysis of data supported by research evidence. In particular:
    a. Crash situation applicability / sensitivity of UN R131 AEB for heavy vehicles;
    b. Crash situation applicability / sensitivity of up to 60kph AEB for light vehicle crashes with other vehicles and with pedestrians;
    c. An estimation of the percentage of trauma that could be mitigated by AEB, i.e. downgraded from fatality to serous and/or minor injury and/or avoided for heavy vehicle AEB and light vehicle AEB.
3. Calculation of effectiveness statistics for AEB in light passenger vehicles and in also heavy vehicles. In particular,
    a. Effectiveness of UN R131 type heavy vehicle against trauma. It was noted that UN R131 does not set requirements for vehicle to infrastructure nor vehicle to

vulnerable road user AEB technology and therefore these components were not included;

   b. Effectiveness of light vehicle AEB operating up to 60kph with up to 40kph velocity differential against
      i. vehicle to vehicle, and
      ii. vehicle to pedestrian trauma.

4. Collation of AEB crash demographic statistics, based on research evidence and used to support the provision of data analysis. These included:
   a. Typical (mode) age of persons killed or injured by heavy vehicle crash situations that could have been mitigated via AEB, if not non-significantly different to typical age at death for all heavy vehicle fatalities.
   b. Typical (mode) age of persons killed or injured by light vehicle crash situations that could have been mitigated via AEB, if not non-significantly different to typical age at death for all light vehicle fatalities.

This report forms the final milestone of the project and summarises the findings across each stage. Milestone 1, design of the evaluation study is presented in section 5. The analysis of potential benefits of AEB in light passenger vehicles, and the sensitivity statistics are presented in Section 6. Section 9 discusses the findings related to heavy vehicles and the effectiveness of AEB fitment in the fleet as well as sensitivity statistics. These sections address the requirements for milestones 2 and 3. Milestone 4 is addressed in Section 11, where the AEB crash demographics are presented.

2 PREVIOUS RESEARCH ON AEB EFFECTIVENESS: A BRIEF OVERVIEW

To facilitate the analysis, a review of the literature was conducted. This was necessary to determine which crashes were sensitive to AEB, and the level of sensitivity across crash types. This method provides the most robust understanding of crash sensitivity based on a large range of crash types. Reported studies are based on real-world crash data and simulations. The effectiveness determined in these prospective evaluations is described below and sensitivity reported in the method section of this report.

2.1 LIGHT PASSENGER VEHICLES

Table 1 highlights four real-world crash evaluations of AEB effectiveness in light vehicles. Despite using different data sources, the four studies have produced similar findings regarding the overall potential reductions in rear end crash involvement due to AEB fitment. Fildes, Keall et al. (2015) and Cicchino (2017) showed that vehicles fitted with low speed AEB had 38% and 43%, respectively less rear end crashes compared to similarly matched make and model vehicles without AEB fitment. When injury crash reductions were considered, AEB fitment was associated with between 35% to 41% (Rizzi, Kullgren et al. 2014) and 45% (Cicchino 2017) less injury related rear end crashes.

TABLE 1: SUMMARY OF FOUR REAL-WORLD CRASH EVALUATIONS OF AEB IN LIGHT VEHICLES

Author	Data source	Period of data	Country of crash data	Exposure	Vehicle restrictions	Speeds evaluated
Isaksson-Hellman and Lindman (2016)	454 vehicle insurance claims	2012-2015	Sweden	The number of insured vehicle years (IVY), 48,089 and 52,634 for AEB and no-AEB cars, respectively.	Volvo V70 only.	Impact speed <5, 5-15 and >15km/has defined by repairs needed and equated to crash severity
Rizzi, Kullgren et al. (2014)	Of the 3,922 Police reported injury crashes, 660 rear-end crashes were used	2010-2014	Sweden	Rear end crash struck vehicle	Vehicles matched by weight and manufacturer	50km/h speed zones
Cicchino (2017)	23,649 Police reported crashes (7055 injury crashes)	2010-2014	U.S.A, 22 states	the number of insured vehicle days (IVY)	Vehicles matched by make and model, yom 2009-2012	≤56km/h, 64-72km/h and 80+km/h speed zones
Fildes, Keall et al. (2015)	3,326 Police reported crashes (not specified to be injury crashes)	2009 onwards	6 countries Meta-analysis	Rear end crash struck vehicle	Vehicles matched by make and model	Any speed zone

2.1.1 Effectiveness of AEB in light passenger vehicles considered across different speed zones

The summary of previous light vehicle crash analyses in Table 2 also gives the speed zone or travelling speed restrictions for these analyses. Table 2 shows that when considered across lower speed zones, the effectiveness of low speed AEB was shown to be stronger, than when considered across all speeds. For example, Rizzi, Kullgren et al. (2014) showed an injury crash reduction of 54% to 57% in speed zones of 50km/h or less and a reduction of 22% to 32% in speed zones above 50km/h; however the latter was not significant. Likewise, Cicchino (2017) showed a 40% reduction in injury crashes in speed zones of 35 mph or less (equivalent of 56km/h or lower) and a 59% reduction in zones 40 to 45mph (equivalent of 72km/h to 80km/h) which were both higher than the 30% reduction suggested for zones of 50mph or higher (80km/h or greater). Cicchino (2017) suggest the greater percentage injury reduction found for the medium speed zone may be explained by the increased opportunity for rear-end collisions based on the road infrastructure in these speed zones (i.e. more intersections).

TABLE 2: EFFECTIVENESS OF AEB ACROSS REAL-WORLD CRASH EVALUATIONS OF AEB IN LIGHT VEHICLES

	All severity (or severity not specified)		Injury crashes	
Author	All speed zones	Separated across speed zones	All speed zones	Separated across speed zones
Isaksson-Hellman and Lindman (2016)	27% of all crashes striking in all speed zones	37% in all crashes striking in <5km/h impact speed		
Rizzi, Kullgren et al. (2014)			35% to 45%	Halving in ≤ 50km/h zones, 57%± 36% Volvos, 54%± 37% non-Volvos No statistically significant reductions in speed zones > 50km/h
Cicchino (2017)	43% (39%, 47%)	40% (35%,45%) ≤ 56km/h speed zones 53% (50%,57%) 64-72km/h speed zones 31% (24%, 38%) 80km/h + speed zones	45% (40%, 48%) striking vs 15% (9%, 21%) struck	43% (34%, 51%) in striking in ≤ 56km/h speed zones 59% (53%, 64%) in striking in 64-72km/h speed zones 30% (22%, 38%) in striking in 80+km/h speed zones
Fildes, Keall et al. (2015)	38%			

2.2 HEAVY VEHICLES

There have been few recent evaluations of the effectiveness of AEB in heavy vehicles. There have been some in-depth evaluations of cases paired with simulations and there have been field operations studies (Kessler 2012, Grove, Atwood et al. 2016). The NHTSA one year field operation study of 169 drivers in 150 class 8 prime mover + semi-trailer combinations generated data to enable the production of a safety benefit model. As recently as 2018, a published benefit cost analysis of AEB in large trucks (Camden, Medina-Flintsch et al. 2018) reviewed AEB effectiveness from which a 16% to 28% (Woodrooffe, Blower et al. 2012, Woodrooffe, Blower et al. 2013, Woodrooffe, Blower et al. 2013) effectiveness rate for sensitive crashes was selected as the base for the potential benefit measure. This reduction rate was based on test track performance, national crash databases and naturalistic driving performance.

Woodrooffe, Blower et al. (2012) disaggregated effectiveness by truck type, injury type and crash type, and made calculations for current, next generation and future generations of AEB technologies, using knowledge of current developments that were not yet in production (Table 3). The jump in effectiveness from 2012 current to 2012 future generations was attributed to the ability of the next generations able to react in situations where the struck vehicle is stationary, which Woodrooffe, Blower et al. (2012) estimate to be a situation for one third of all rear-end heavy vehicle sensitive fatal crashes.

The range over device types has been used to estimate the potential benefits possible in Australia. In the analysis reported here, effectiveness estimates have been applied using current generation as the lower bound estimate and future generation as the upper bound estimate to incorporate anticipated advances in AEB technology. Therefore, for all heavy vehicle types, excluding articulated truck >12t, the effectiveness of AEB in mitigating injuries has been calculated at 22% to 55% for fatalities and 21% to 57% for injuries. For articulated trucks this is 25% to 54% for injuries and 24% to 57% for fatalities.

TABLE 3: EFFECTIVENESS ESTIMATES FROM WOODROOFFE (2012) - INJURY SEVERITY REDUCTIONS FOR ALL OCCUPANTS APPLIED TO AUSTRALIAN DATA

	Device	Fatalities	Injuries	Targeted rear-end crashes
Rigid Trucks	Current Generation	22%	21%	
	Next Generation	43%	46%	
	Future Generation	55%	57%	
Articulated trucks (semi-trailers + prime mover)	Current Generation	24%	25%	16%
	Next Generation	44%	47%	28%
	Future Generation	57%	54%	40%

Another study using real world crash data (Jermakian 2012) reduced the rear-end striking vehicles, selecting only 37% as relevant, and yielding 8% of all large truck involved crashes as relevant (7% in non-fatal injury crashes and 3% of fatal crashes) to having a potential to be avoided or mitigated. The application of the range (

Table 25) of Woodrooffe, Blower et al. (2012) effectiveness estimates produced similar overall proportions to the relevant crashes of Jermakian (2012) in the lower to middle end of the range. In an earlier report of AEB benefits in heavy vehicles, TRL (Grover, Knight et al. 2008) analysed and reviewed the effectiveness of AEB and found for sensitive crashes that 25% to 75% of fatalities could be mitigated to serious injuries; 25% to 75% of serious injuries could be mitigated to minor injuries and 0 to 10% of minor injuries could be avoided. The lower end of these ranges is similar to, however the upper exceed the efficacies of Woodrooffe, Blower et al. (2012) used in the approach of Camden, Medina-Flintsch et al. (2018).

3 SUMMARY OF THE EVALUATION ANALYSIS METHODOLOGY - SCOPE OF ANALYSIS

The analyses conducted for this project focussed on estimation of the crash and crash injury benefits, in terms of trauma reduction, associated with Advanced Emergency Braking Systems, specifically Advanced Emergency Braking (AEB) in crashed light and heavy vehicles in Australia over the four-year period from 2013 to 2016. The potential benefits were measured with the assumption of AEB fitment to all heavy vehicles and all light vehicle models; and with the assumption of nil fitment during 2013 to 2016. The operational definitions for light passenger and heavy vehicles are presented below.

3.1 VEHICLE TYPES AND DEFINITION INCLUDED IN THE ANALYSIS

3.1.1 Heavy Vehicles

Heavy vehicles were selected to match as closely as possible to the vehicle set to which UN R131 (2013) applies. UN R131 applies to N2 and N3 vehicles (designed to carry goods that have a vehicle weight of 3.5 tonnes and greater) and M2 and M3 vehicles (designed to carry 9 or more occupants).

In Australian crash data, heavy vehicles are generally identified using vehicle weights equal to or greater than 4.5 tonnes and buses are identified with a 10 seat, or greater, occupancy. This classification posed a problem for data from some jurisdictions where only general vehicle classes were categorised, with no information regarding for seat capacity or vehicle weight. Specifically, vehicle weights were unavailable for NSW and SA data, as well as for cases with missing registration sourced data in other jurisdictions. In addition, the sizing of buses proved difficult to identify in WA and QLD data.

Generally, the jurisdictions provided categories which could be used to distinguish buses, rigid and articulated vehicles (as road-train, prime movers and semi-trailers). The following six broad categories were used in the analyses:

- rigid trucks <=12 tonnes;
- articulated trucks[1] consisting of prime-movers, semi-trailers and road trains, and large heavy vehicles with weights greater than 12 tonnes;
- unknown weight rigid trucks;
- large buses: consisting of vehicles with ≥ 9 seats or with a vehicle weight larger than 4.5 tonnes;
- smaller buses: consisting of vehicles with ≥ 9 seats and with either a vehicle weight ≤ 4.5 tonnes or a seat capacity under 25; and
- unknown weight buses.

[1] Generally rigid trucks with trailers such as dog trailers, could not be distinguished and classed as articulated, however if the vehicle weight was recorded, and greater than 12 tonnes, then trucks with dog trailers were included in this category.

Where possible to identify (when not included in the jurisdictional 'truck' classes), emergency vehicles and special purpose vehicles such as tow trucks and cranes were included in the rigid heavy vehicle classes.

3.1.2 Light Vehicles

Light passenger vehicles were defined as all vehicles with a vehicle weight less than or equal to 3.5 tonnes. These were identified by vehicle class, vehicle weight and VIN (vehicle identification number) when manufactured after 1981, and where the data set of vehicles used for the used safety car ratings, made up of cars (M1), and utilities and light vans (N1).

3.1.3 Other Vehicles

As the analyses pertained only to the estimation of potential benefits of AEB in light and heavy vehicles, other vehicles were excluded from the analysis. These included plant equipment, agricultural vehicles, non-motorised vehicles, bicycles and motorcycles.

3.2 CRASH YEARS INCLUDED IN THE ANALYSIS

Figure 1 shows the penetration of AEB technology into the crashed Australian light vehicle fleet. As can be seen in the Figure, discernible market penetration did not begin until 2012 and therefore, the potential benefit analysis did not consider crash data before this period. In total, crash data from 2013-2016 was included in the analysis. This provided sufficient detail to obtain meaningful average estimates, given that at least three years of data are required to make inferences from the findings.

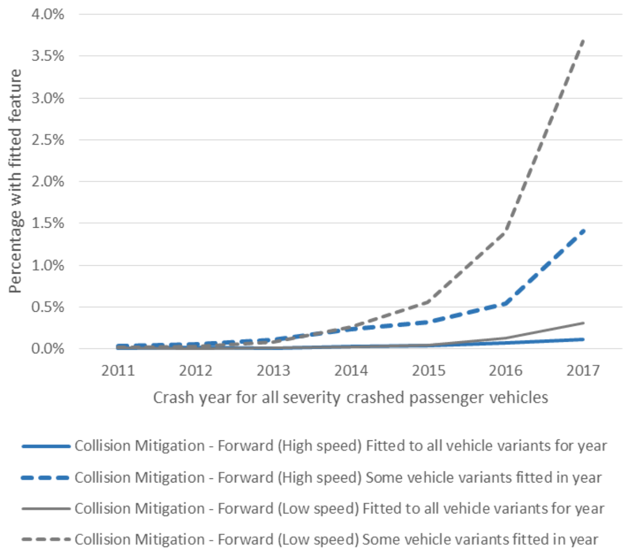

FIGURE 1: MARKET PENETRATION OF TWO TYPES OF AEB SYSTEMS IN THE AUSTRALIAN LIGHT VEHICLE FLEET, BY CRASH YEAR[2]

[2] See below for description of Redbook data to explain these classes.

4 DATABASE TO SUPPORT THE ANALYSIS

Three complementary data sources were used to estimate the potential injury savings associated with AEB fitment in light passenger and heavy vehicles. These were, police reported crash data, make, model and market groups of light vehicle assigned to the crash data using methods established in the Used Car Safety Ratings program (Newstead, Watson et al, 2018), and Redbook safety feature fitment data merged onto the UCSR make and model groups for light vehicles.

Police reported crash data were sourced from Australian jurisdictions from which data are collected for calculation of the Used Car Safety Ratings (Newstead, Watson et al. 2018). This data covers the five largest Australian States: New South Wales, Queensland, Victoria, South Australia and Western Australia (see Table 4). Although not having total national coverage in Australia (Tasmania, the Australian Capital Territory and Northern Territory data are not included) the database had sufficient coverage of the Australian crash population (95%) to be representative of the national situation. Based on national fatal crash coverage of the states represented in the database, tables of data produced from the database were then inflated to represent national counts. An inflation factor of 1.05 was used to inflate minor and serious injuries of the five jurisdictions to represent the whole of Australia and similarly and inflation factor of 1.08 was used on fatalities. An inflation factor of 2.06 was used to inflate non-injury crash counts to represent national totals which are available from only three jurisdictions: NSW, SA and WA. An explanation of these inflation factors is included as Appendix 0.

TABLE 4: UCSR LIGHT AND HEAVY VEHICLES IN ALL-SEVERITY AUSTRALIAN POLICE REPORTED CRASHES (2013-2016)

	Heavy Vehicles		Light Vehicles	
	N	%	N	%
New South Wales	22,257	48	203,672	29
Victoria	3,838	8	80,172	11
Queensland	5,231	11	92,509	13
Western Australia	10,654	23	227,905	32
South Australia	4,145	9	109,646	15
TOTAL	**46,125**	**100**	**713,904**	**100**

Crashes were disaggregated into the severity classes: no-injury, minor injury not requiring admission to hospital, serious injury where hospital admission is required and fatal (death within 30 days of the crash). These classes are defined by at least one crash involved person having sustained injuries meeting the class severity (e.g. a fatal crash is one where at least one person is killed). Data for no-injury crashes were only available from jurisdictions other than Victorian and Queensland[3].

Crash details held in the database are extensive and include variables to facilitate the requested analyses. This includes person details of those involved in the crash, road user types and a broad range of crash circumstance information. Crash causation and fault are not included.

The light passenger and heavy vehicles were analysed over the crash period from 2013 to 2016.

4.1 MODEL AND MARKET GROUP ENHANCEMENT

MUARC enhances the UCSR database with specific makes, models and market groups of light vehicles appearing in the crash data through a proprietary process of Vehicle Identification Number (VIN) decoding. Information on light vehicles involved in crashes can be presented with a high degree of specificity. Information on heavy vehicles is available only at a coarser level of classification dictated by the information available in the crash data. This is still sufficient to classify heavy vehicles by broad types (bus, rigid tuck, articulated truck, etc.).

4.2 REDBOOK DATA

The light vehicle models group identified in the UCSR database were further enhanced with information on whether the following safety features were fitted: ESC, Brake Assist, and both low speed and high speed Forward Collision Mitigation (FCM) Systems. FCM is a sub-group of AEB systems that target forward collisions only. The definition of low and high speed varies by manufacturer and system type. For the purposes of this study, low speed systems were expected to perform best in speed zones of 60 km/h and under, and high speed systems were thought to be optimal in speed zones greater than 60 km/h.

The Redbook model identification was matched to that of the MUARC VIN decoder. However, RedBook data identifies feature fitment at the model variant level whereas the MUARC system cannot identify variant level information defining model groups across a number of variants. This means that some MUARC VIN decoder defined model groups may have a mix of variants in them, some with and some without a specific safety feature. If all model variants in a model group were fitted with the safety system, the fitment status of "*all*" was awarded to the model. If not all of the model variants were fitted with the safety system, the fitment status became, "*some*". The remaining light vehicles were classified as "*no fitment or unknown fitment*".

[3] Queensland 'property damage only' records ceased in 2010.

5 METHODS FOR EVALUATION ANALYSIS

The potential benefits of AEB are the product of the effectiveness of the technology in reducing the target crash population and the proportion of all crashes that are the target population. For this project, effectiveness is defined as the percentage reduction in Australian Police reported target crashes and associated injuries associated with AEB fitment in crashes involving light or heavy vehicles. The target crash population is the group of crashes in which AEB is likely to, or has already shown to have, an effect. The effect in this instance is not just activation of AEB, but activation which results in target population crash avoidance or mitigation.

The process of estimating potential benefits involved the following steps:

1. defining and tabling the light and heavy *vehicle* population in crashes sensitive to mitigation or avoidance with AEB;
2. defining and tabling the injuries from sensitive light and heavy *vehicle* crashes;
3. determining the proportion of sensitive crashes the whole crash population;
4. determining the proportion of injuries from sensitive crashes in the whole crash injury population;
5. estimating the crash and associated injury reduction effects associated with AEB in light vehicles or obtaining the crash reduction risk from literature for heavy vehicles;
6. calculating the proportion of crash or injury benefits within the entire set of Police reported crashes:

Crash Benefits = Effectiveness at reducing AEB sensitive crashes x proportion of total crashes which are AEB sensitive crashes (Equation 1)

Injury Benefits = Effectiveness at reducing injuries in AEB sensitive crashes x proportion of all injuries which occur in AEB sensitive crashes (Equation 2)

The calculations for AEB potential crash and injury benefits (Step 6 of this methodology) makes the assumptions that the potential benefits are obtained with 100% AEB fitment to light and heavy vehicles, and that there are currently no sensitive crashes involving vehicles fitted with AEB Systems, so the crash reduction can be applied to all sensitive crashes. In the heavy vehicle fleet, true AEB fitment is unknown, but assumed to be lower than in the light vehicle fleet. In the light vehicle fleet, during 2013 to 2015, less than 0.1% of crashed light vehicles were models with AEB fitment certainty (fitted to all variants of the model). Thus, an assumption of 0% fitment seems reasonable and unlikely to bias the sensitive vehicle potential benefit. This is not only because the potential bias would be proportionally extremely small, but also because the over-estimate of crash benefits that may be produced by the assumption of zero fitment is balanced by the under-estimate of total sensitive crashes produced by crashes already reduced by AEB fitment.

The effectiveness estimates for heavy vehicles, described in equations (1) and (2), have been sourced from available published literature and applied to the sensitive crashes involving heavy vehicles. For light vehicles, the effectiveness estimates have been determined using induced exposure analysis applied to Australian crash data. The analyses used to determine the potential effectiveness of AEB in heavy vehicles in Australia, modelled potential *crash* benefits of AEB in heavy vehicles using the approach used by Camden (2018), which, after a thorough review, elected to use the reductions of sensitive heavy vehicle crashes and injuries calculated by Woodrooffe, Blower et al. (2012). The rear-end crash reduction range of 16% to 40% will be used for property damage only crash reductions.

The effect measured in the light vehicle induced exposure analysis was the reduction in property damage crashes or the reduction in injuries, associated with AEB fitment in the crashed vehicle, where the crash is sensitive to AEB. Sensitivity indicates that it is thought that the crash could be avoided or mitigated by AEB fitment to the striking vehicle. For the light vehicle analysis, crash or injury counts not sensitive to AEB were used as the *induced exposure*. This non-sensitive set acts as a comparison group, so that the effects of AEB in sensitive crashes may be separated from the effects due to exposure. To minimise bias, the non-sensitive group needs to match the sensitive group in as many attributes as possible, including in time and location. Furthermore, a brief review of recent literature (Anderson 2011, Rizzi, Kullgren et al. 2014, Fildes, Keall et al. 2015, Grove, Atwood et al. 2016, Isaksson-Hellman and Lindman 2016, Cicchino 2017, Glassbrenner, Morgan et al. 2017) identified some covariates of interest, and possible confounding variables were explored within both the heavy and light vehicle fleets through comparison of crash variable distribution within the sensitive and non-sensitive crashed vehicles.

Details of the methods employed follow under the appropriate subheadings.

5.1 CRASH VARIABLE EXCLUSION AND INCLUSION CRITERIA

This section details the attributes of a sensitive crash for step 1 of the method.

In addition to the data criteria described in the scope of analysis above, this analysis required identification and tabling of the crashes that were sensitive to AEB.

5.1.1 Severity of crash

The light vehicle induced exposure analysis of *injuries* resulting from crashes included only injury-crash data because there is no risk of injury in a no-injury crash.

The analysis of light vehicle no-injury crashes was carried out in a separate induced exposure analysis. This was done because no-injury crash data were not available for all jurisdictions.

5.1.2 Speed Zone

AEB systems vary in their effectiveness according to travelling speed (Rizzi, Kullgren et al. 2014, Isaksson-Hellman and Lindman 2016, Cicchino 2017, Glassbrenner, Morgan et al. 2017), an attribute not consistently collected within Australian crash data. Speed zone was used to approximate travelling speed.

The UN R131 regulation (UN 2013) specifies that the heavy vehicle AEB is tested at 80km/h, and that the aim of the regulation is to reduce highway crashes. Because effectiveness at reducing crashes for heavy vehicles fitted with AEB has no benchmarked speed zone, the entire range of speed zones was used to estimate the potential benefits of AEB in heavy vehicles.

The speed range for light vehicle crash inclusion reflects the research brief requirement of crashes in zones up to 60km/h. As both low speed and high speed AEB fitment data were available, analyses were carried out over the entire speed range and for data disaggregated by speed zone: ≤ 60 km/hr and >60 km/hr. This division of speed zoning was chosen because it separates high speed, highway and freeway locations from lower speed urban regions and because current literature (Rizzi, Kullgren et al. 2014, Cicchino 2017) has evaluated low speed AEB (effective at speeds up to 50km/h) in light passenger vehicle crashes primarily in speed zones under 60km/h. The summary of previous light vehicle crash analyses in Table 1 gives the speed zone or travelling speed restrictions for these analyses.

5.1.3 Sensitive crashes

Classification of crash sensitivity was based on recent published literature of prospective evaluations of the potential effectiveness of AEB technology. These studies rely on real world crash data or simulations and have determined crash types sensitive to avoidance or mitigation through AEB. These represent the best evidence of crash sensitivity on which to base classification. This method of classification allows a range of crash types.

Table 5 shows the evaluation studies used to determine AEB sensitivity in crashes. Crashes strongly sensitive to AEB have been defined in previous studies as predominately rear-end type crashes. As can be seen in Table 5, some researchers consider only crashes involving twos vehicles in their definition (Rizzi, Kullgren et al. 2014, Fildes, Keall et al. 2015), while other studies have also included crashes involving multiple vehicles (Cicchino 2017). Crashes involving reversing vehicles have also been excluded from some AEB sensitive crashes (Cicchino 2017).

In addition to crashes sensitive to AEB, Anderson (2011) defined crash types as broadly sensitive to forward collision technologies. These are situations where a vehicle crosses the path of a vehicle fitted with AEB and that AEB might mitigate the crash. While less effective, AEB may mitigate certain intersection crashes, opposite direction crashes, overtaking crashes and U turn crashes.

Table 5 also shows definitions for vehicle roles involved in the sensitive crashed. These are the striking vehicle in sensitive crashes, which would be sensitive to crash risk reduction through AEB technology (Anderson 2011, Rizzi, Kullgren et al. 2014, Fildes, Keall et al. 2015, Isaksson-Hellman and Lindman 2016, Cicchino 2017, Glassbrenner, Morgan et al. 2017). In rear end crashes these are generally defined as the vehicles with frontal damage (see Table 5). Likewise, the struck vehicle is the vehicle (not reversing) that receives rear end damage.

TABLE 5: IDENTIFICATION OF SENSITIVE AND NON-SENSITIVE CRASHES OR CRASHED VEHICLES FOR LIGHT VEHICLES

Author	Sensitive Crashed vehicles	Non-Sensitive Crashed vehicles	Excluded Crashes
Isaksson-Hellman and Lindman (2016)	Striking vehicles (cars) in rear-end crashes	Not studied	
Rizzi, Kullgren et al. (2014)	Striking vehicles (cars) in rear-end crashes	Struck vehicles(cars) in rear-end crashes	Crashes with more than two vehicles No-injury crashes
Cicchino (2017)	Striking vehicles (cars) in front to rear-end crashes. (If more than 2 vehicles, this is all vehicles with front end damage)	Struck vehicles (cars) in front to rear-end crashes. (if more than 2 vehicles, this is the vehicle with rear end damage)	All vehicles in crashes involving reversing. Parked vehicles
Fildes, Keall et al. (2015)	Striking vehicles(cars) in rear-end crashes	Struck vehicles (cars) in rear-end crashes	Crashes with more than two vehicles

Table 6 shows a summary of the NHTSA in-depth study into the definition of the target AEB population of sensitive crashes involving heavy vehicle vehicles (>4.5 t GVM), in which the set of criteria that would provide a highly probable crash benefit were determined. They examined limitations of the current heavy vehicle technologies, assessed whether they were likely to be overcome in the near future and came up with a list summarised in the following table. Therefore, the vehicle roles in sensitive crashes used in previous studies, such as Woodrooffe, Blower et al. (2012) were not just rear-end striking vehicles, but were further reduced by exclusions of specific crash events such as fog, snow and water on the road, as recommended by the NHTSA (Glassbrenner, Morgan et al. 2017). In 2017 NHTSA published a definition of their target heavy vehicle (>4.5t single unit rigid trucks incl. prime movers) population for AEB fitment, however NHTSA have not yet published models of crash benefits expected within this population. This study was used in the current analyses to identify potential confounders for the analysis and to define sensitive crashes for the evaluation of the potential of AEB in the heavy vehicle fleet (see Section 5.3).

TABLE 6: IDENTIFICATION OF SENSITIVE CRASHES AND STRIKING VEHICLES IN LITERATURE ON HEAVY VEHICLES

Author	Sensitive Crashes and Vehicles	Non-Sensitive Crashes and Vehicles	Excluded Crashes
Glassbrenner et al (NHTSA)	First harmful crash event is a frontal impact in which the heavy vehicle strikes the rear of another on path (lead) moving vehicle or into any part of a parked vehicle. Front vehicle may be changing lanes but striking vehicle must be going straight. Striking vehicle view of lead vehicle is not blocked by a rise, curve or road feature.	Not studied	Crashes at travelling speeds <24km/h, crashes involving HV turning movements, crashes in snow, sleet or fog weather events Crashes with pedestrians, bicyclists and motorcyclists. Crashes on roads that are not paved or free from snow or ice or standing water.

Based on the empirical evidence presented above, three types of sensitivity were considered for this analysis: narrowly sensitive, pedestrian sensitive and broadly sensitive.

The **narrowly sensitive** crash group for this analysis has therefore been defined similarly as crashes in which a forward moving vehicle strikes an on-path vehicle which may be moving in the same direction (any speed, accelerating or decelerating), stopped, parked, double-parked or broken down. The defining feature of the collision is that the front of the striking vehicle, impacted the other vehicle (in the rear if it was moving forward) in a manner similar to the VicRoads DCA descriptions of 130, 131, 132, 141, 145, 160, 161, and 162. The jurisdictional DCA or RUM charts are included in Appendix A1 (section 14). The struck vehicle must be a motor vehicle, and the striking vehicle must be a light or a heavy vehicle for the crash to be considered narrowly sensitive.

Some AEB systems in light vehicles are designed to reduce the risk of pedestrian-to-vehicle crashes. Pedestrian-to-vehicle crashes were considered as **pedestrian sensitive** when the crash type was a single vehicle-to-pedestrian crash of the type described in the VicRoads DCA descriptions as 100 to 105 and 108 to 109, where the pedestrian was on-path and not on the footpath or median.

In addition to foot (pedestrian) traffic, for the purposes of this analysis, bicycle-to-vehicle collisions were considered as equivalent to a pedestrian if the bicycle was on path. In these cases, the struck vehicle was a bicycle and it was on-path in a similar manner to the narrowly sensitive crashes (with Victorian DCA's of 130, 131, 132, 141, 160, 161, and 162; see Appendix A.1). Both the motor vehicle and bicycle were the first event (primary impact) of the crash and the light motor vehicle had to be moving. Collisions of bicycles with parked or stopped vehicles were not considered sensitive crashes.

There is evidence that AEB systems may sometimes mitigate other crash types where a vehicle crosses the path of the AEB fitted vehicle. AEB is less effective in these situations. Typical crash types (with Victorian DCA groups) broadly sensitive to AEB are adjacent direction intersection crashes (110-119), opposite direction crashes including head-on crashes (120-129, 150), same direction U-turn (140), pulling out (152, 154) and cutting-in (153), leaving and entering parking (142 and 143), emerging from a driveway or footpath (147 and 148) and striking a train/plane/tram (192). These crash types were identified as **broadly sensitive** to forward collision technologies by Anderson (2011). These broadly sensitive *multi-vehicle* crashes were restricted to motor vehicle-to-motor vehicle collisions; motor vehicle collisions with bicycles of these types are considered not likely to be mitigated by AEB in the striking motor vehicle. However, crashes with motorcycles, heavy vehicles and other motor vehicles were included in the analysis.

There is also evidence that AEB systems may sometimes mitigate other crash types where an object smaller than a vehicle is in front of the AEB fitted vehicle, although AEB is less effective in these situations. These are *single-vehicle* crashes and will be restricted to the light vehicle analysis because the NHTSA (2017) determined that AEB technology developments for heavy vehicle systems are unlikely to mitigate collisions with small vehicles or objects. Typical single vehicle crash types (with Victorian DCA groups) **broadly sensitive** to AEB are on-path struck object/animal crashes (164-167,193), missile crashes (191) and off end of road/T-intersection (175). These crash types were identified as broadly sensitive to forward collision technologies by Anderson et al (2011).

While light vehicles crashes were classified across different sensitivity types (i.e. narrowly, broadly, pedestrian or not sensitive), heavy vehicle crashes were restricted to narrowly sensitive crashes (or not sensitive) only. Despite previous studies using the broadly sensitive classification, recent evidence from the NHTSA (Glassbrenner, Morgan et al. 2017) determined that AEB technology developments for heavy vehicle systems are unlikely to mitigate collisions with motorcycles, bicycles and pedestrians in the future. Heavy vehicle narrowly sensitive crashes were therefore restricted to collisions of heavy vehicles with light vehicles only. Further, the NHTSA (Glassbrenner, Morgan et al. 2017) determined that AEB technology developments for heavy vehicle systems are unlikely to mitigate collisions involving cross-traffic, so the heavy vehicle analysis did not include any broadly sensitive crashes.

5.2 VEHICLE EXCLUSION AND INCLUSION CRITERIA

The following section details the attributes of a sensitive crashed vehicle for step 3 of the method.

The vehicle sets in sensitive and non-sensitive crashes consisted only of striking light or heavy vehicles as defined above. Vehicle exclusions were based on crash sensitivity to AEB and market penetration of AEB fitment, not make or model.

5.2.1 Vehicle Year of Manufacture

As can be seen in FIGURE 2, the market penetration of AEB in vehicles manufactured prior to 2013 was not discernible. Therefore, the induced exposure analysis of the effects of AEB in the light vehicle fleet was restricted to vehicles manufactured in 2013 and beyond, so that the vehicles without AEB fitment matched the age of those with. The induced exposure analysis looks at the crash involvement and injuries in vehicles with AEB fitment and compares it to vehicles without such fitment. In order for the evaluation to produce an unbiased estimate of the injury benefits associated with AEB, the two sets of vehicles must be as similar as possible.

5.2.2 Model code

As only vehicles with a UCSR model code could be identified as having AEB fitment, the sensitive and non-sensitive vehicles included in the light vehicle induced exposure study were limited to vehicles with UCSR model codes. Generally, all light vehicles meeting the crash year and year of manufacture inclusion criteria were coded.

The induced exposure analysis aimed to estimate injury reduction benefits associated with AEB in the light vehicle fleet. The percentage reduction was applied, along with the heavy vehicle percentage reduction (based on current literature), to vehicles in sensitive crashes of models of all years of manufacture (in the method step 6) to estimate the potential benefits across the entire fleet.

5.2.3 Striking vehicles

The forward moving vehicle striking the rear of another vehicle in a narrowly sensitive crash was defined as the striking vehicle from which crash risk reduction could be achieved through AEB technology. Striking vehicles were restricted to only light or heavy vehicles.

5.2.4 Pedestrian striking vehicles

The *light,* forward moving, striking vehicle of a pedestrian sensitive crash was considered a pedestrian striking vehicle.

5.2.5 Broadly sensitive striking vehicles

Light, forward moving, vehicles in a broadly sensitive crash were considered broadly sensitive crash striking vehicles.

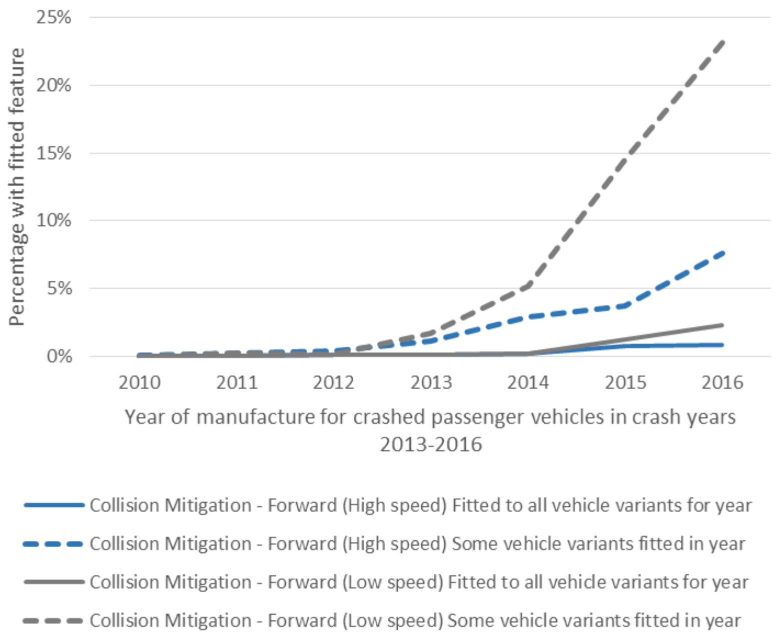

FIGURE 2: MARKET PENETRATION OF AEB IN THE 2013-2016 AUSTRALIAN LIGHT VEHICLE FLEET BY YEAR OF MANUFACTURE

5.2.6 Non-striking crashed vehicles

Non-striking vehicles were forward moving, stationary, reversing, stopped or parked. They were directly in the path of the striking vehicle.

5.3 OTHER CRASH VARIABLE RESTRICTIONS

On the basis of the NHTSA (2017) study, sensitive heavy vehicle crashes were further restricted to collisions where the striking heavy vehicle was travelling straight (and not turning) and the heavy vehicle collision was not occurring in conditions of snow, sleet or fog weather events, nor on road surfaces covered in snow or ice.

5.4 INDUCED EXPOSURE RELATIVE RISK OF CRASH INJURIES REGRESSION MODEL

Following the methodology of previous induced exposure AEB crash risk studies (Rizzi, Kullgren et al. 2014, Fildes, Keall et al. 2015) , a Poisson regression model was fitted to the light vehicle sensitive crash data to estimate crash risks in the sensitive vehicles relative to the control (non-sensitive) vehicles. Having established the need to stratify the analysis by speed zone and vehicle size, the form of the analysis model is given by Equation 3.

$$\ln(y_{cvs}) = \propto + \beta_{sf} + \gamma_{sc} + \delta_{sfc} \qquad \text{...(Equation 3)}$$

In Equation 3,

y is the crash injury count

c is the crash type index (sensitive / non-sensitive)

f is the AEB fitment status (fitted / not fitted)

s is the stratum indicator

α,β,γ,δ are parameters of the model.

The crash index type is modelled in two ways. The primary model utilised narrowly sensitive crashes compared against non-sensitive crashes. The secondary model compared pedestrian and broadly sensitive crashes with the non-sensitive crash set.

The fitment status was modelled in two ways and with two levels of fitment, *some* and *all* variants of a model fitted with a forward AEB system. The primary model indicated fitment for all forward AEB systems regardless of whether they were designed for high or for low speed conditions. Some other modelling was explored which considered only the fitment status of high speed systems in high speed zone crashes.

The primary stratification used a binary speed zone (≤60 km/h and >60 km/h) disaggregated by three levels of vehicle type (car, SUV or light commercial vehicle - LCV). The cars included all passenger vehicle types that were not commercial utilities or vans and were not large or medium sports utility vehicles. The SUVs consisted of large and medium sports utility vehicles. The LCVs were commercial utilities and vans. Alternative strata that were explored replaced the vehicle size disaggregation with weather, road surface, intersection location, drivers' sex or drivers' age (so that effectiveness disaggregated by these variables could be explored). The model allowed only two variables in the stratification; regression models with more stratification levels than 2 failed to converge.

The relative crash risks for each concessional vehicle type are estimated from the δ parameters of the model. By replacing δ_{sfc} with δ_{fc}, the overall effect for AEB fitment may be estimated. In addition this term was modified to estimate condensed levels of the stratum since the fully saturated model did not converge.

Tests for over-dispersion found that no Pearson's scaling of the estimate confidence intervals were required.

5.5 INDUCED EXPOSURE RELATIVE RISK OF CRASH REGRESSION MODEL

A similar modelling approach was used with the no-injury crash data of New South Wales, South Australia and Western Australia to estimate the risk of a no-injury crash. In this model, y is the crashed vehicle count.

5.6 INDUCED EXPOSURE SEVERITY ODDS RATIO REGRESSION MODEL

In addition to the relative risk, an analysis of the odds of a more severe outcome in a light vehicle injury crash was performed. The model is similarly structured (equation 4) however this model has sufficient power to allow for greater levels of stratification or additional covariates.

$$\ln(\pi_{cvs}/(1-\pi_{cvs})) = \propto + \beta_{sf} + \gamma_{sc} + \delta_{sfc} + \zeta + \eta + \theta \qquad \text{...(Equation 4)}$$

π is the probability that a crash for a crashed vehicle is more severe (fatal or hospital admission versus minor injury)

c is the crash type index (sensitive / non-sensitive)

f is the AEB fitment status (fitted / not fitted)

s is the stratum indicator

β,γ,δ are stratified parameters of the model

α,ζ, η ,θ are non-stratified parameters of the model

6 SUMMARY OF FINDINGS FOR LIGHT AND HEAVY VEHICLES

6.1 SUMMARY STATISTICS FOR LIGHT VEHICLE CRASHES SENSITIVE TO AEB

Based on the Australian light vehicle crash data (Table 9), in low speed zones:

- 28% (27.77%) of light vehicle crashes were narrowly sensitive to AEB
- 33% (33.06%) of light vehicle crashes were broadly sensitive to AEB
- 3% (2.83%) of light vehicle crashes were pedestrian sensitive to AEB

Therefore, AEB has the potential to impact the outcome in up to 64% of light vehicle crashes occurring in low speed zones.

In speed zones higher than 60km/h:

- 36% (36.20%) of light vehicle crashes were narrowly sensitive to AEB
- 17% (17.46%) of light vehicle crashes were broadly sensitive to AEB
- 2% (2.13%) of light vehicle crashes were pedestrian sensitive to AEB

Therefore, AEB has the potential to impact the outcome in up to 55% of light vehicle crashes occurring in high speed zones.

Average annual inflated crash injuries were also classified across sensitivity (Table 12). In low speed zones:

- 9.18 fatalities were narrowly sensitive to AEB (3.92% of all fatalities in low speed zones)
- 1,685.51 serious injuries were narrowly sensitive to AEB (15.21% of serious injuries in low speed zones)
- 11,516.40 minor injuries were narrowly sensitive to AEB (35.29% of minor injuries in low speed zones)

In high speed zones:

- 14.04 fatalities were narrowly sensitive to AEB (2.18% of all fatalities in high speed zones)
- 1,358.44 serious injuries were narrowly sensitive to AEB (16.09% of serious injuries in high speed zones)
- 6,148.01 minor injuries were narrowly sensitive to AEB (38.06% of minor injuries in high speed zones)

When considered across both zones, AEB has the potential to avoid or mitigate 30% (29.96) of trauma incidents occurring from crash types that are classified as narrowly sensitive to AEB.

6.2 SUMMARY OF THE ESTIMATED EFFECTIVENESS OF AEB IN LIGHT PASSENGER VEHICLES

There was no evidence of statistically significant reductions in the relative risk of an injury found to be associated with models with all variants fitted with AEB. This was due to the lack of vehicles currently available for analysis, as observed in Figures 1 and 2, presented above. However, there was sufficient power in the analysis to yield strongly significant estimates of relative risk reductions associated with models with some model variants fitted with AEB.

Given the low number of fatalities, fatal and serious injuries were combined for the analysis. Therefore, the reduction has been applied equally to fatal and serious injuries.

For narrowly sensitive crashed vehicles (Table 15), the injury risk reductions associated with models with some AEB fitment were much greater for serious and fatal injuries than for minor injuries, across low and high speed zones.

In low speed zones, large, strongly evidenced overall reductions in the risk of an *injury* were estimated in **narrowly** sensitive crashes (with some models variants with AEB fitment) at:

- 19% (95% CI: 8 to 29, p =.001) for all injury types;
- 28% (95% CI: -6 to 51, p= .09) for fatal and serious injuries; and
- 18% (95% CI: 6 to 29, p=.004) for minor injuries (no hospital admission).

In high speed zones, overall reductions in the risk of an *injury* were estimated for **narrowly** sensitive crashes (with some models variants with AEB fitment) at:

- 27% (95% CI: 8 to 29, p =.001) for all injury types;
- 45% (95% CI: 14 to 74, p=.008) for fatal and serious injuries; and
- 22% (95% CI: 4 to 36, p=.02) for minor injuries (no hospital admission).

The data presented above are summarised in .

TABLE 7.

TABLE 7: ESTIMATED AEB EFFECTIVENESS IN LIGHT PASSENGER VEHICLES ACROSS INJURY SEVERITY AND HIGH AND LOW SPEED ZONES

	Crashes in 60km/h zones that are sensitive to AEB					
	Fatalities		**Serious injuries**		**Minor injuries**	
	Av. Annual fatalities	**reduction with AEB (effectiveness)**	**Av. Annual serious injuries**	**reduction with AEB (effectiveness)**	**Av. Annual minor injuries**	**reduction with AEB (effectiveness)**
Narrowly sensitive Car to motor vehicle	9.18	28%	1685.51	28%	11516.40	18%
Narrowly sensitive Car to pedestrian	78.32	18%	1389.84	18%	1528.85	32%
Broadly sensitive Car to motor vehicle	92.88	12%	5363.14	12%	13837.16	13%
	Crashes in speed zones higher than 60km/h that are sensitive to AEB					
	Fatalities		**Serious injuries**		**Minor injuries**	
	Av. Annual fatalities	**reduction with AEB**	**Av. Annual serious injuries**	**reduction with AEB**	**Av. Annual minor injuries**	**reduction with AEB (effectiveness)**

		(effectivenes s)		(effectivenes s)		
Narrowly sensitive **Car to motor vehicle**	14.04	45%	1358.44	45%	6148.01	22%
Narrowly sensitive **Car to pedestrian**	37.19	-6%	158.16	-6%	104.66	-32%
Broadly sensitive **Car to motor vehicle**	318.60	9%	3294.90	9%	4958.36	10%

6.3 SUMMARY OF THE POTENTIAL REDUCTIONS IN TRAUMA FROM FITTING AEB TO LIGHT PASSENGER VEHICLES

In summary, if all light passenger vehicles in narrowly, broadly and pedestrian sensitive crashes in Australia had AEB fitted, these estimates of injury reduction would translate to average annual potential reductions of (see

Table 22):

- 1,976.72 (95%CI: -730.97 to 4,166.29) fatal and serious injuries; and
- 4,291.64 (95%CI: 1,752.60 to 6,735.72) minor injuries.

These make up **9.69%** of all light vehicle crash fatalities and serious injuries, and **8.80%** of all light vehicle minor injuries.

If only low speed crashes ≤ 60km/h are considered, the average annual injury savings from AEB fitment are estimated at:

- 1,398.20 (95%CI: -1,936.86 to 3,482.10) fatal and serious injuries; and
- 4,378.10 (95%CI: 1,217.85 to 7,175.12) minor injuries,

These make up **12.36%** of all light vehicle crash fatalities and serious injuries, and **13.41%** of all light vehicle minor injuries from crashes in these speed zones.

Regression analysis provided no evidence of a more (or less) severe outcome from an injury crash associated with AEB fitment.

6.4 SUMMARY STATISTICS OF HEAVY VEHICLE CRASHES SENSITIVE TO AEB

Crashes defined as narrowly sensitive to AEB made up 14.78% of the total crashes in the heavy vehicle fleet.

Average annual crash injuries inflated to be nationally representative showed that (Table 23).

- 10.80 fatalities resulted from heavy vehicle crashes narrowly sensitive to AEB (9.52% of all heavy vehicle fatalities)
- 296.89 serious injuries resulted from heavy vehicle crashes narrowly sensitive to AEB (20.73% of all serious injuries from heavy vehicle crashes)
- 1203.83 minor injuries resulted from heavy vehicle crashes narrowly sensitive to AEB (38.75% of all minor injuries from heavy vehicle crashes)

6.5 SUMMARY OF THE ESTIMATED POTENTIAL BENEFITS FROM FITTING AEB TO HEAVY VEHICLES

Given the paucity of local data on AEB in heavy vehicles, as reported above, the following effectiveness values were used to calculate the potential benefits of AEB in heavy vehicles:

	AEB Generation	Reduction in Fatalities	Reduction in Serious Injuries	Reduction in Minor Injuries
Rigid Trucks	Current to future Generation	22% to 55%	21% to 57%	21% to 57%
Articulated trucks (semi-trailers + prime mover)	Current to future Generation	24% to 57%	25% to 54%	25% to 54%

Full fitment of AEB to the heavy vehicle fleet has the potential to prevent 258 to 646 property damage only crashes per year. This is approximately **4%** of heavy vehicle involved property damage only crashes. In addition, full heavy vehicle fleet fitment of AEB has the potential to annually prevent (see Table 24):

- 2.53 to 6.10 fatalities (**2.11% to 5.09%** of all heavy vehicle involved fatalities)
- 67.90 to 165.05 serious injuries (**4.74% to 11.52%** of heavy vehicle involved serious injuries)
- 269.96 to 673.31 minor injuries (**8.69% to 21.67%** of all heavy vehicle involved minor injuries)

This reduction in injuries was based on an average injury reduction assumed to be equal for serious and minor injuries, however it is likely that serious injury reductions would be greater than for minor injuries due to injury mitigation from fatal and serious to minor.

The data presented above are summarised in Table 8.

TABLE 8: ESTIMATED AEB EFFECTIVENESS IN HEAVY VEHICLES ACROSS INJURY SEVERITY

Crashes narrowly sensitive to AEB		
Fatalities	**Serious injuries**	**Minor injuries**

	Av. Annual fatalities	reduction with AEB (effectivenes s)	Av. Annual serious injuries	reduction with AEB (effectivenes s)	Av. Annual minor injuries	reduction with AEB (effectiveness)
All HV	10.80	22% to 57%	296.89	21% to 57%	1203.83	21% to 57%
All bus	0.00	22% to 55%	15.49	21% to 57%	111.30	21% to 57%
Large bus	0.00	22% to 55%	4.99	21% to 57%	33.86	21% to 57%
Small bus	0.00	22% to 55%	0.00	21% to 57%	2.36	21% to 57%
Unknown bus	0.00	22% to 55%	10.50	21% to 57%	75.08	21% to 57%
All truck	10.80	22% to 55%	281.40	21% to 57%	1092.53	21% to 57%
Rigid ≤ 12t	1.89	22% to 55%	100.80	21% to 57%	471.71	21% to 57%
Articulated >12t	7.83	24% to 57%	138.86	25% to 54%	428.93	25% to 54%
Unknown weight	1.08	22% to 55%	41.74	21% to 57%	191.89	21% to 57%

7 EVALUATION OF SENSITIVE CRASHES IN THE AUSTRALIAN LIGHT VEHICLE CRASH DATA

7.1 LIGHT VEHICLE SENSITIVE CRASH TYPES

Table 9 shows the percentage of sensitive crashes in all light vehicle crashes. Twenty-eight percent of crashes in speed zones of 60km/h or less were classified as narrowly sensitive to AEB. An additional 33% were classified as broadly sensitive to AEB, and 3% as pedestrian sensitive. Based on the narrowly sensitive data, AEB could therefore impact the crash outcome in up to 28% of light vehicle involved crashes in low speed zones. When broadly sensitive and pedestrian sensitive crashes are also considered, AEB could impact the crash outcome in up to 64% of light vehicle involved crashes in low speed zones.

TABLE 9: PERCENT OF LIGHT VEHICLE CRASHES SENSITVE TO AEB, ACROSS LOW AND HIGH SPEED ZONES

	Narrowly Sensitive	Pedestrian sensitive	Broadly sensitive
Low speed zone: ≤60 km/h zone	27.77%	2.83%	33.06%
High speed zone: >60 km/h zone	36.20%	0.62%	17.46%
Total	30.46%	2.13%	28.09%

To conduct the potential benefit analysis, crashed vehicles were also considered in terms of striking or struck vehicles. Fifty-one (51.12%) percent of light crashed vehicles were considered to be striking vehicles in crashes sensitive to AEB, however only 17.07% were involved in crashed that were narrowly sensitive (1.76% were pedestrian sensitive and 31.82% were broadly sensitive) to AEB.

- Of the narrowly sensitive crashes, 62.58% were from crashes in 60 km/h or lower speed zones.
- Of the pedestrian sensitive crashes 90.57% were from crashes in 60 km/h or lower speed zones.
- Of the broadly sensitive crashes, 76.08% were from crashes in 60 km/h or lower speed zones.

Twenty-one (20.77%) percent of the light vehicles were the struck vehicles in narrowly sensitive crashes (where the striking vehicle was a light vehicle).

The light vehicle regression analysis conducted to determine the potential injury reductions was based on 29,369 vehicles (4% of total); 34% were struck vehicles in narrowly sensitive crashes, 19% were striking vehicles in narrowly sensitive crashes, 4% struck pedestrians and 43% were the striking vehicle in broadly sensitive crashes. Sixty-nine percent of the regression analysis vehicles crashed in low speed zones (60km/h or less).

7.2 AEB FITMENT OF LOW AND HIGH SPEED SYSTEMS IN CRASHED LIGHT VEHICLES

AEB fitment was similarly present across all analysis groupings apart from light vehicles in the narrowly sensitive crash group, in which fitment rates were lower (see Table 10). This statistic is supportive of a crash avoidance association with AEB fitment.

TABLE 10: PERCENT FITMENT OF LOW AND HIGH SPEED AEB SYSTEMS IN LIGHT VEHICLE MODEL (ALL OR SOME VARIANTS), ACROSS ANALYSIS GROUPS

	Crash Sensitivity – Striking Vehicle				Non-sensitive Crashes		
% fitment	Narrow Sensitivity	Pedestrian Sensitivity	Broad Sensitivity-multivehicle	Broad Sensitivity-single vehicle	Struck Vehicle	Other vehicles	**All vehicles**
Low Speed	8.24	12.70	10.61	7.80	11.09	10.16	10.29
High speed	3.31	5.23	5.10	5.25	4.91	4.72	4.71

The proportion of fatalities amongst serious and fatal injuries is reported in Table 11. These are separated across vehicles in non-sensitive and sensitive crashes, whereby AEB fitment is likely to mitigate or avoid the fatality. The lower proportions of fatalities for vehicles in narrowly sensitive crashes may be evidence of crash mitigation associated with AEB or may be indicative of a crash type associated with less serious injuries.

TABLE 11: PROPORTION OF FATAL INJURIES IN THE GROUP OF FATAL AND SERIOUS INJURIES, ACROSS ANALYSIS GROUPS

	Vehicles in sensitive crashes			Non-sensitive crashes		
Speed Zone	Narrow Sensitivity	Pedestrian Sensitivity	Broad Sensitivity	Struck Vehicle	Other vehicles	**All vehicles**
Low Speed	0.010	0.191	0.079	0.008	0.070	0.062
High speed	0.005	0.054	0.014	0.005	0.025	0.018
All	0.008	0.072	0.040	0.006	0.046	0.037

Figure 3 shows the distribution of light vehicles by age at time of crash. As can be seen, 6% of all narrowly sensitive crashed light vehicles in all severity crashes were aged 8 years at the time of the crash. A larger percentage of the crashed vehicles in pedestrian sensitive crashes were younger at the time of crash with the largest percent (7%) being five years at the time of the crash. Tabled data are listed in Appendix A.2 and consist of distributions for all crash severities (Table 26) and separated across fatal crashes (Table 27) serious injury crashes (Table 28), minor crashes (Table 29) and no-injury crashes (Table 30).

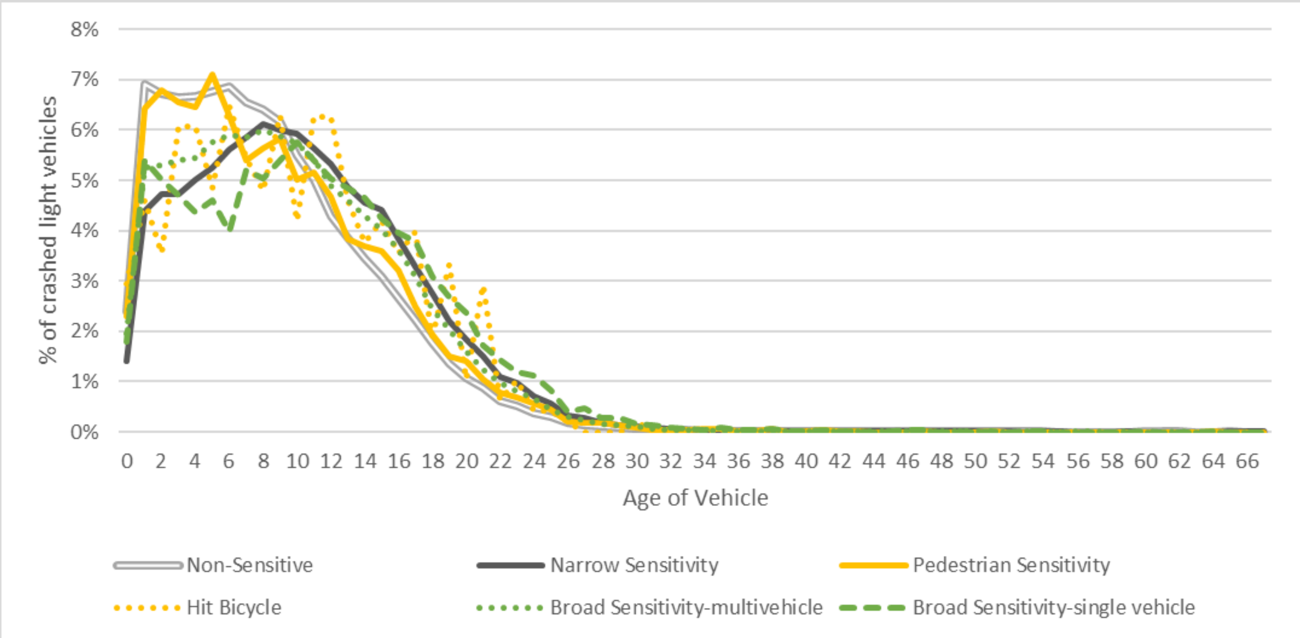

FIGURE 3: LIGHT VEHICLE AGE AT CRASH DISTRIBUTION BY CRASH AEB SENSITIVITY

7.3 ANNUAL INFLATED CRASH INJURIES SENSITIVE TO AEB

Table 12 shows the inflated (to national counts) crash-related injuries across the total light vehicle crashes and also separated across AEB crash sensitive groups. As can be seen in Table 12, up to 67.88% of all fatal and serious incidents were sensitive to AEB and 78.21% of all minor injuries. Up to 29.96% of trauma was estimated, with a high degree of confidence, to be sensitive to AEB (i.e. narrowly sensitive crashed vehicles). When injuries in broadly sensitive crashes were considered, up to 70.23% of injuries resulting from car to vehicle incidents and 75.16% of injuries when vehicle to pedestrian incidents were sensitive to AEB.

When considered across low and high speed zones, up to 76.42% of all fatal and serious injuries from crashes in low speed zones were sensitive to AEB and 82.52% of all minor injuries from crashes in low speed zones. Up to 80.96% of all trauma incidents in low speed zones and 69.48% of all trauma incidents in high speed zones were sensitive to AEB. This includes narrow, broadly and pedestrian sensitive crashed vehicles.

TABLE 12: AVERAGE ANNUAL INFLATED COUNTS OF INJURIES FROM AND PROPERTY DAMAGE ONLY LIGHT VEHICLE INVOLVED CRASHES (2013-2016) OVERALL AND BY AEB SENSITIVE GROUPS

			Sensitive set only*							
							% of all			
Crash injuries		ALL Fleet	Narrow	Pedestrian*	Broad	***Total maximum sensitive***	Narrow	Pedestrian*	Broad	***Total***
Fatal and Serious	**All**	**20,400.47**	**3,067.17**	**1,711.66**	**9,069.52**	***13848.35***	**15.03**	**8.39**	**44.46**	***67.88***
	≤60km/hr	11,312.91	1,694.69	1,494.26	5,456.02	***8,644.97***	14.98	13.21	48.23	***76.42***
	>60 km/hr	9,087.56	1,372.48	217.40	3,613.50	***5,203.38***	15.10	2.39	39.76	***57.26***
Fatal	All	879.39	23.22	119.07	411.48	***553.77***	2.64	13.54	46.79	***62.97***
	≤60km/hr	234.36	9.18	79.38	92.88	***181.44***	3.92	33.87	39.63	***77.42***
	>60 km/hr	645.03	14.04	39.69	318.60	***372.33***	2.18	6.15	49.39	***57.73***
Serious	All	19,521.08	3,043.95	1,592.59	8,658.04	***13,294.58***	15.59	8.16	44.35	***68.10***
	≤60km/hr	11,078.55	1,685.51	1,414.88	5,363.14	***8,463.53***	15.21	12.77	39.63	***76.40***
	>60 km/hr	8442.53	1,358.44	177.71	3,294.90	***4,831.05***	16.09	2.10	39.03	***57.23***
Minor	**All**	**48,790.61**	**17,664.41**	**1698.64**	**18,795.53**	***38,158.58***	**36.20**	**3.48**	**38.52**	***78.21***
	≤60km/hr	32,638.20	11,516.40	1,582.35	13,837.16	***26,935.91***	35.29	4.85	42.40	***82.52***
	>60 km/hr	16,152.41	6,148.01	116.29	4,958.36	***11,222.66***	38.06	0.72	30.70	***69.48***
Total Trauma	***All***	***69,191.08***	***20,731.58***	***3,410.30***	***27,865.04***	***52,006.92***	***29.96***	***4.93***	***40.27***	***75.16***
	≤60km/hr	***43,951.11***	***13,211.09***	***3,076.61***	***19,293.18***	***35,580.88***	***30.06***	***7.00***	***43.90***	***80.96***

	>60 km/hr	***25,239.97***	***7,520.49***	***333.69***	***8,571.86***	***16,426.04***	***29.80***	***1.32***	***33.96***	***65.08***
Crashed vehicles										
No injury crashes	**All**	**96,902.92**	**33,748.47**	**294.58**	**54,607.51**	***88,650.56***	**34.83**	**0.30**	**56.35**	***91.48***
	≤60km/hr	67,099.35	20,769.44	268.32	43,637.50	***64,675.25***	30.95	0.40	65.03	***96.39***
	>60 km/hr	29,803.57	12,979.03	26.27	10,970.02	***23,975.31***	43.55	0.09	36.81	***80.44***

*pedestrian crashes include cyclists

The pedestrian sensitive crashes included in Table 12 also include car to bicycle crashes. Table *13* shows pedestrian sensitive crashes, with only car to pedestrian crashes involved.

TABLE 13: AVERAGE ANNUAL INFLATED COUNTS OF INJURIES IN PEDESTRIAN AEB SENSITIVE CRASHES INVOLVING LIGHT VEHICLES (2013-2016)

Crash injuries		ALL Fleet	Number	%
Fatal and Serious	**All**	**20,400.47**	**1,663.50**	**8.15**
	≤60km/hr	11,312.91	1,468.16	12.98
	>60 km/hr	9,087.56	195.35	2.15
Fatal	All	879.39	115.50	13.13
	≤60km/hr	234.36	78.32	33.41
	>60 km/hr	645.03	37.19	5.77
Serious	All	19,521.08	1,548.00	7.93
	≤60km/hr	11,078.55	1,389.84	12.54
	>60 km/hr	8,442.53	158.16	1.87
Minor	**All**	**48,790.61**	**1,633.48**	**3.35**
	≤60km/hr	32,638.20	1,528.85	4.68
	>60 km/hr	16,152.41	104.66	0.65
Total Trauma	***All***	***69,191.08***	***3,296.98***	***4.77***
	≤60km/hr	***43,951.11***	***2.997.01***	***6.82***
	>60 km/hr	***25,239.97***	***300.01***	***1.18***

8 DERIVING BENEFITS OF MANDATED AEB: ESTIMATED TRAUMA REDUCTIONS ASSOCIATED WITH AEB IN LIGHT VEHICLES

8.1 ESTIMATING AEB EFFECTIVENESS

8.1.1 Method considerations

In identifying the potential benefits of AEB in the Australian fleet within any speed zone, regardless of the low/high speed nature of the fitted AEB system, it was not necessary to quantify the effectiveness of AEB according to its "low speed/ high speed" nature of operation. Therefore, the results reported in this section are from analyses where the effects of the two types of systems are combined. The analyses were based on the presence of a system in a model (all or some variants) regardless of type. Furthermore, penetration of high speed AEB into the market place was poor, so analyses of independent systems were unlikely to yield strongly significant results associated with the high speed AEB alone. Some results specific to high speed AEB in high speed zones and low speed AEB in low speed zones have been included in Appendix 0. For the most part, and where well evidenced by low p-values or tight confidence intervals, these '*speed zone-to-AEB type*' matched results are similar to those presented in this section.

Due to limited quantities of data, the analysis only permitted two levels of stratification. It was decided on the basis of the confounder analysis (reported in the Appendix A7), that the vehicle size was more likely to introduce bias into the estimate than were the other likely confounders of driver age, driver sex or intersection location, thus overall results have only been presented for analysis using vehicle size and speed zone strata. It is possible that the overall risks presented here for narrowly sensitive crashes have been slightly inflated due to possible small confounding effects from differential driver age distributions between vehicles in the sensitive and narrowly sensitive crash set. Confounding bias analysis was not performed for broadly and pedestrian sensitive crashes because the non-sensitive set was chosen only to match the narrowly sensitive crash set. Confounding effects in the narrowly sensitive crash analyses were considered likely to be small and insignificant, especially when paired with the fact that the benefits presented in this section chiefly arise from models with only some variants fitted with AEB. It is therefore more likely that the results for AEB effectiveness presented here under-estimate the true effectiveness. If all variants for a fitted model had AEB, the estimated benefits are likely to be larger.

Results by attributes other than speed zone and vehicle size arise from analyses using an alternative stratification. In order to reduce the vehicle size bias when using the alternative stratification, commercial vehicles were omitted from these analyses. Furthermore, AEB fitment in commercial vehicles was rare, and removing them from the analysis presented in Table 14 had no effect on overall estimators.

Given the low number of fatalities in the data, analyses were conducted on combined fatal and serious injuries.

8.1.2 Overall AEB effectiveness on reducing injuries in crashes

Estimated AEB effectiveness is based on the reductions in injury resulting from crashes. With respect to the following tables of results, the first table presents overall results by injury and crash AEB sensitivity (see Table 14). Table 15 presents data by injury and crash AEB sensitivity across speed zones 60km/h or lower and above 60km/h and only for vehicles models with some variants with AEB fitment. The following tables (Table 16 to Table 21) show data for narrowly AEB sensitive crashes only, and again only for "some" model variant fitment of AEB. The "all" variants fitted with AEB category was insufficiently populated to produce useful estimates on disaggregation and the disaggregated pedestrian and broadly sensitive crash analyses produced only a couple of well evidenced estimators which were additionally potentially biased by an inefficient exposure set.

TABLE 14: OVERALL RELATIVE INJURY RISK ASSOCIATED WITH AEB IN VEHICLES MANUFACTURED BETWEEN 2013 TO 2016 (INCLUSIVE) WITH ALL OR SOME MODEL VARIANTS FITTED WITH AEB

Fitment	All Injuries	Fatal and Serious Injuries	Minor Injuries
	Narrowly sensitive crashes		
ALL	0.80 (0.53 1.21) p=0.29	0.37 (0.08 1.67) p=0.20	0.86 (0.56 1.32) p=0.49
SOME	0.78 (0.70 0.87) p=<.0001	0.64 (0.48 0.86) p=0.002	0.81 (0.72 0.90) p=0.0002
	Pedestrian sensitive crashes		
ALL	1.68 (0.96 2.96) p=0.07	1.98 (0.84 4.70) p=0.12	1.20 (0.48 3.02) p=0.70
SOME	0.90 (0.74 1.09) p=0.28	1.02 (0.77 1.36) p=0.89	0.72 (0.53 0.97) p=0.03
	Broadly sensitive crashes		
ALL	1.22 (0.92 1.62) p=0.17	1.37 (0.72 2.60) p=0.33	1.17 (0.84 1.62) p=0.35
SOME	0.90 (0.83 0.97) p=0.006	0.90 (0.76 1.06) p=0.19	0.88 (0.80 0.96) p=0.006

As can be seen in Table 15, large reductions in injuries of all severities from narrowly sensitive crashes were associated with AEB in vehicles in both low and high speed zones. Injury risk reductions in narrowly sensitive crashes, particularly fatal and serious injury risk reductions, were greater in higher speed zones, which points to a yet untapped potential for fatal and serious injury reduction from high speed AEB with future market penetration. These fatal and serious injury reduction estimates in narrowly sensitive crashes were as great as 45% (p=0.008) for speed zones of greater than 60 km/h.

AEB was found to be associated with reductions in minor injury risk in low speed zones in pedestrian and broadly sensitive crashes. Minor injuries arising from pedestrian sensitive crashes were estimated to be reduced by 32% (p=0.02) if the crashes were in speed zones of 60 km/h and under.

TABLE 15: RELATIVE INJURY RISK ASSOCIATED WITH AEB BY SPEED ZONE

	All Injuries	Fatal and Serious Injuries†	Minor Injuries
	Narrowly sensitive crashes		
≤60 km/h zone	0.81 (0.71 0.92) p=0.001	0.72 (0.49 1.06) p=0.09	0.82 (0.71 0.94) p=0.004
>60 km/h zone	0.73 (0.61 0.88) p=0.001	0.55 (0.36 0.86) p=0.008	0.78 (0.64 0.96) p=0.02
	Pedestrian sensitive crashes		
≤60 km/h zone	0.88 (0.72 1.09) p=0.24	0.82 (0.38 1.79) p=0.62	0.68 (0.50 0.93) p=0.02
>60 km/h zone	1.01 (0.55 1.84) p=0.98	1.06 (0.77 1.47) p=0.70	1.32 (0.49 3.57) p=0.59
	Broadly sensitive crashes		
≤60 km/h zone	0.89 (0.81 0.98) p=0.015	0.88 (0.69 1.12) p=0.30	0.87 (0.78 0.97) p=0.01
>60 km/h zone	0.91 (0.79 1.04) p=0.17	0.91 (0.73 1.14) p=0.42	0.90 (0.76 1.07) p=0.23

†Analysis performed without commercial vehicles.

8.1.3 Additional analyses for AEB effectiveness for crash injury reduction, stratified by vehicle size, driver age and gender and road surface

Table 16 shows the relative injury risk associated with light passenger vehicles AEB fitment in with some variants separately for cars and SUVs. As is shown, fatal and serious injury risk reduction estimates were greatest for SUVs and minor injury risk reduction estimates were greatest for cars with fatal and serious injury reductions greater than those for minor in. Estimates of fatal serious injury risk reductions were 12% units greater for SUVs than for cars in narrowly sensitive crashes, however the differences were not statistically significant. Results by vehicle type were limited to narrowly sensitive crashes involving cars and SUVs. The minor injury reductions associated with SUVs was 9% units lower than that for cars (also not a significant difference).

TABLE 16: RELATIVE INJURY RISK ASSOCIATED WITH AEB IN NARROWLY SENSITIVE CRASHES BY VEHICLE SIZE†

	All Injuries	Fatal and Serious Injuries	Minor Injuries
	Narrowly sensitive crashes		
Car	0.75 (0.66 0.87) p=<.0001	0.70 (0.49 1.00) p=0.0499	0.77 (0.66 0.89) p=0.0005
SUV	0.82 (0.69 0.97) p=0.019	0.58 (0.36 0.93) p=0.02	0.86 (0.72 1.03) p=0.11

†Commercial vehicles not included in the analysis.

Table 17 shows AEB associated crash injury risk across age groups of 25 years and younger, 26 to 54, 55 to 74 and 75 years and older. The AEB associated crash injury risk reduction increased with driver age for narrowly sensitive crashes. However, the results for the extreme (old and young) age groups were poorly evidenced. The exception was that fatal and serious injury reductions for the drivers aged 75 and older showed a strongly significant reduction of 82% with a p=value of 0.02.

TABLE 17: RELATIVE INJURY RISK ASSOCIATED WITH AEB IN NARROWLY SENSITIVE CRASHES BY DRIVER AGE†

	All Injuries	Fatal and Serious Injuries	Minor Injuries
	Narrowly sensitive crashes		
75 and older	0.64 (0.35 1.18) p=0.15	0.18 (0.04 0.73) p=0.02	0.92 (0.46 1.83) p=0.80
55-74	0.75 (0.55 1.00) p=0.05	0.67 (0.34 1.31) p=0.24	0.76 (0.55 1.07) p=0.11
26-54	0.83 (0.73 0.94) p=0.004	0.71 (0.49 1.01) p=0.05	0.85 (0.75 0.98) p=0.02
25 and younger	1.07 (0.79 1.43) p=0.67	0.91 (0.40 2.09) p=0.83	1.08 (0.79 1.48) p=0.63

†Analysis performed without commercial vehicles.

The relative injury risk associated with AEB equipped vehicles in narrowly sensitive crashes estimated by driver sex is shown in Table 18. All severity injuries were estimated to reduce by 25% for male drivers, however for female drivers, AEB was associated with lower reductions in minor injuries and greater in fatal and serious injuries. AEB was associated with a 48% reduction (p=0.003) in fatal and serious injuries for female drivers.

TABLE 18: RELATIVE INJURY RISK ASSOCIATED WITH AEB IN NARROWLY SENSITIVE CRASHESBY DRIVER SEX†

	All Injuries	Fatal and Serious Injuries	Minor Injuries
	Narrowly sensitive crashes		
Female	0.82 (0.7 0.95) p=0.008	0.52 (0.34 0.80) p=0.003	0.88 (0.75 1.03) p=0.10
Male	0.75 (0.65 0.87) p=0.0002	0.75 (0.51 1.10) p=0.14	0.75 (0.64 0.89) p=0.0006

†Analysis performed without commercial vehicles.

Table *19* and

Table *20* show the relative injury risk associated with AEB in narrowly sensitive crashes at intersections and not at intersection (Table 19) and on wet and dry/unknown condition roads (

Table 20). AEB was associated with large fatal and serious injury reductions in narrowly sensitive crashes at intersections: 59% (p=0.005) and on dry roads 37% (p=0.003).

TABLE 19: RELATIVE INJURY RISK ASSOCIATED WITH AEB IN NARROWLY SENSITIVE CRASHESBY INTERSECTION LOCATION†

	All Injuries	Fatal and Serious Injuries	Minor Injuries
	Narrowly sensitive crashes		
No or unknown	0.78 (0.68 0.90) p=0.0004	0.75 (0.54 1.03) p=0.075	0.79 (0.68 0.92) p=0.002
Intersection	0.84 (0.71 0.99) p=0.04	0.41 (0.22 0.77) p=0.005	0.89 (0.75 1.06) p=0.20

†Analysis performed without commercial vehicles.

TABLE 20: RELATIVE INJURY RISK ASSOCIATED WITH AEB IN NARROWLY SENSITIVE CRASHESBY ROAD SURFACE†

	All Injuries	Fatal and Serious Injuries	Minor Injuries
	Narrowly sensitive crashes		
Wet	0.82 (0.60 1.12) p=0.21	0.76 (0.33 1.78) p=0.53	0.83 (0.59 1.16) p=0.28
Dry or unknown	0.80 (0.71 0.89) p=<.0001	0.63 (0.46 0.85) p=0.003	0.83 (0.74 0.94) p=0.003

†Analysis performed without commercial vehicles.

Regression analysis of AEB effects associated with sensitive and non-sensitive no-injury crashes provided no evidence of a crash benefit associated with AEB in broadly sensitive and pedestrian sensitive crashes. However, a significant crash benefit associated with AEB in narrowly sensitive crashes was observed (see Table 21). A crash reduction of 24% (95% CI: 0 to 42, p=0.047) was associated with AEB in vehicle models with some variant fitment. The potential benefits were greater in low speed zones (31%, p=0.03).

No commercial vehicles were fitted with AEB in the property damage only set which consisted of vehicles from only three jurisdictions.

TABLE 21: RELATIVE CRASH RISK FOR NARROWLY SENSITIVE PROPERTY DAMAGE ONLY ASSOCIATED WITH AEB †

AEB FITMENT	All speed zones	<=60 km/h zones	>60 km/h zones
	Narrowly sensitive		
ALL VARIANTS FITTED	0.84 (0.29 2.39) p=0.74	0.56 (0.15 2.04) p=0.38	2.56 (0.36 18.3) p=0.35
SOME VARIANTS FITTED	0.76 (0.58 1.00) p=0.047	0.69 (0.50 0.96) p=0.03	0.94 (0.58 1.53) p=0.80

†Analysis performed without commercial vehicles.

8.2 POTENTIAL TRAUMA SAVINGS ASSOCIATED WITH AEB IN LIGHT PASSENGER VEHICLES

The overall relative risk reductions associated with AEB fitment to some model variants were applied to the average annual, inflated, sensitive property damage only crashes, and to the average annual, inflated, injuries in sensitive crashes of Table 12, to estimate the potential average annual savings over 2013 to 2016. The estimated injury and property damage only crash savings potentially possible with AEB fitment to all light vehicle models, regardless of year of manufacture, are presented in

Table 22. Alongside, is the proportion that these savings represent of the entire injury and property damage crash population.

Significant minor injury savings are possible from preventing narrowly sensitive crashes in all speed zones, amounting to about 4% of all minor injuries sustained in road crashes in Australia. Potentially, this can be augmented by an additional 5% when low speed zone pedestrian and broadly sensitive crash savings are factored into the total. Since the regression model estimates consider fatal and serious injury crash savings combined, fatal and serious injury savings have been combined in the table.

Fatal and seriously injury effectiveness estimates were only statistically significant in narrowly sensitive crashes with benefits primarily in high speed zones. Overall, 10% of all fatal and serious injuries were found to potentially be reduced by AEB fitment in all light vehicle models.

TABLE 22: POTENTIAL AVERAGE ANNUAL SAVINGS OF INJURIES AND PROPERTY DAMAGE ONLY CRASHES (2013-2016) OVERALL AND BY CRASH SENSITIVITY IF ALL MODELS REGARDLESS OF YEAR OF MANUFACTURE WERE FITTED WITH AEB

		Savings			% of all injuries/crashed vehicles			
Injuries		Narrow	Pedestrian	Broad	Narrow	Pedestrian	Broad	All
Fatal and Serious	**All***	1,104.18 (429.40 to 1,595.93)	-34.23 (-616.20 to 393.68)	906.95 (-544.17 to 2,176.68)	5.41 (2.10 to 7.82)	-0.17 (-3.02 to 1.93)	4.45 (-2.67 to 10.67)	9.69 (-3.58 to 20.42)
	≤ 60	474.51 (-101.68 to 864.29)	268.97 (-1,180.46 to 926.44)	654.72 (-654.72 to 1,691.37)	4.19 (-0.90 to 7.64)	2.38 (-10.43 to 8.19)	5.79 (-5.79 to 14.95)	12.36 (-17.12 to 30.78)
	> 60	617.61 (192.15 to 878.39)	-13.04 (-102 .18 to 50.00)	325.22 (-505.89 to 975.65)	6.80 (2.11 to 9.67)	-0.14 (-1.12 to 0.55)	3.58 (-5.57 to 10.74)	10.23 (-4.58 to 20.95)
Minor	**All***	2,188.12 (1,151.64 to 3,224.59)	443.06 (47.47 to 743.70)	1,660.46 (553.49 to 2,767.43)	4.48 (2.36 to 6.61)	0.91 (0.10 to 1.52)	3.40 (1.13 to 5.67)	8.80 (3.59 to 13.81)
	≤ 60	2,072.92 (691.98 to 3,339.76)	506.35 (110.76 to 791.18)	1,798.83 (415.11 to 3,044.18)	6.35 (4.28 to 20.68)	1.55 (0.69 to 4.90)	5.51 (2.57 to 18.85)	13.41 (7.53 to 44.42)
	>60	1,352.56 (245.92 to 2,213.28)	-37.21 (-298.68 to 59.31)	496 (-347.09 to 1,190.01)	8.37 (1.52 to 13.7)	-0.23 (-1.85 to 0.37)	3.07 (-2 .15to 7.37)	11.21 (-2.48 to 21.44)
Crashed vehicles								
No injury crashes	**All***	8,099.63 (0 to 14,174.36)			8.36 (0 to 14.63)			8.36 (0 to 14.63)
	≤ 60	6,438.52 (830.78 to 10,384.72)			9.60 (1.24 to 15.48)			9.60 (1.24 to 15.48)

>60	778.74 (-6878.89 to 5,451.19)	2.61 (-23.08 to 18.29)	2.61 (-23.08 to 18.29)

*The estimated savings overall is based on regression model estimates of the overall effect and the estimated savings by speed zone is based on regression model estimates by speed zones. As such the sum of the savings for each speed zones is not the overall savings. Rounding errors apply.

9 EVALUATION OF SENSITIVE CRASHES INVOLVING HEAVY VEHICLES

9.1 AGE AND TYPE DISTRIBUTION OF HEAVY VEHICLES IN SENSITIVE CRASHES

Crashes defined as narrowly sensitive to AEB made up 14.78% of the total crashes in the heavy vehicle fleet. Fifteen (15.21%) percent of crashed heavy vehicles were considered to be striking vehicles in narrowly sensitive crashes of all severity, which includes crashes where the injury level was not classified.

When considered across heavy vehicle type, the following types of vehicles were considered to be striking vehicles in narrowly sensitive crashes across all severity:

- Large bus 9.53%
- Small bus 11.86%
- Unknown weight bus 11.52%
- Rigid truck ≤ 12t 15.10%
- Articulated trucks and >12t 16.13%
- Unknown weight trucks 16.53%

FIGURE ***4*** and FIGURE 5 show the vehicle age distributions at the time of crash for goods vehicles (trucks) and buses respectively in sensitive and non-sensitive crashes. Distributions are also table in Appendix 0 and considered across all severity (Table 33), fatal crashes (Table 34), serious injury crashes (Table 35), minor injury crashes (Table 36) and no injury crashes (Table 37).

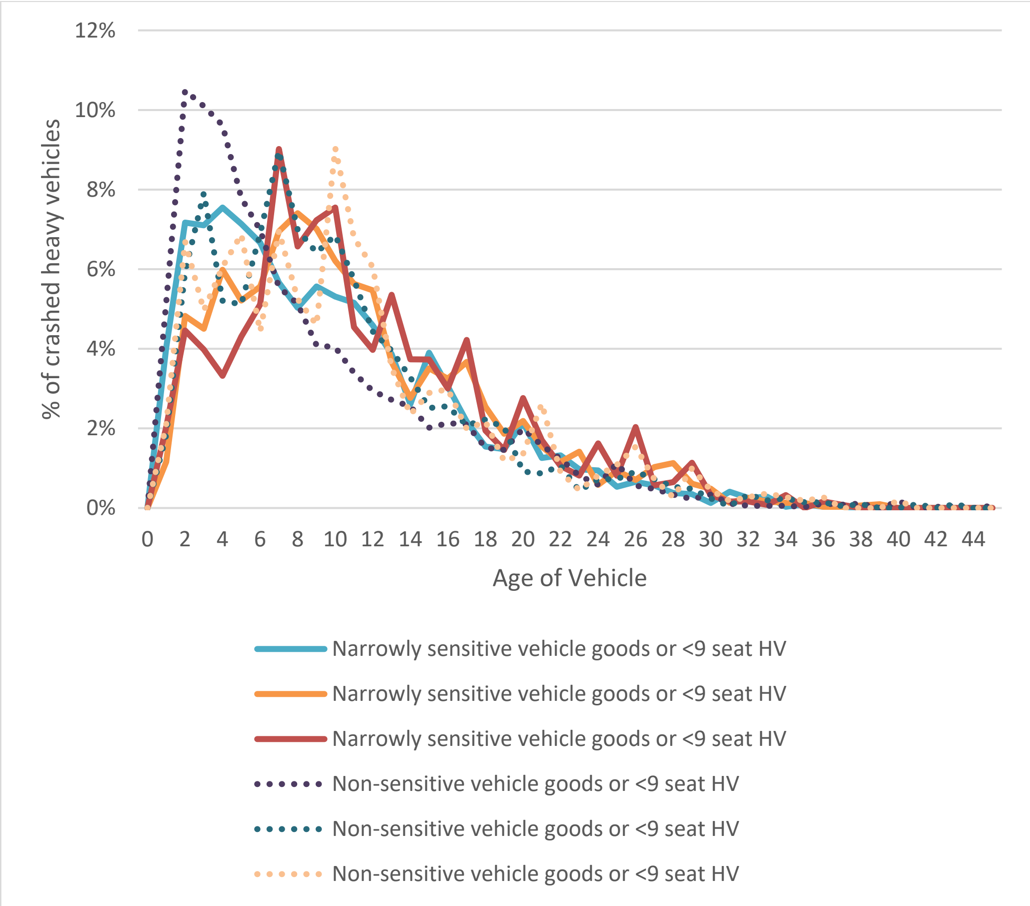

FIGURE 4: AGE (AT CRASH) DISTRIBUTION OF HEAVY GOODS VEHICLES INVOLVED IN ALL SEVERITY CRASHES, BY CRASH SENSITIVITY

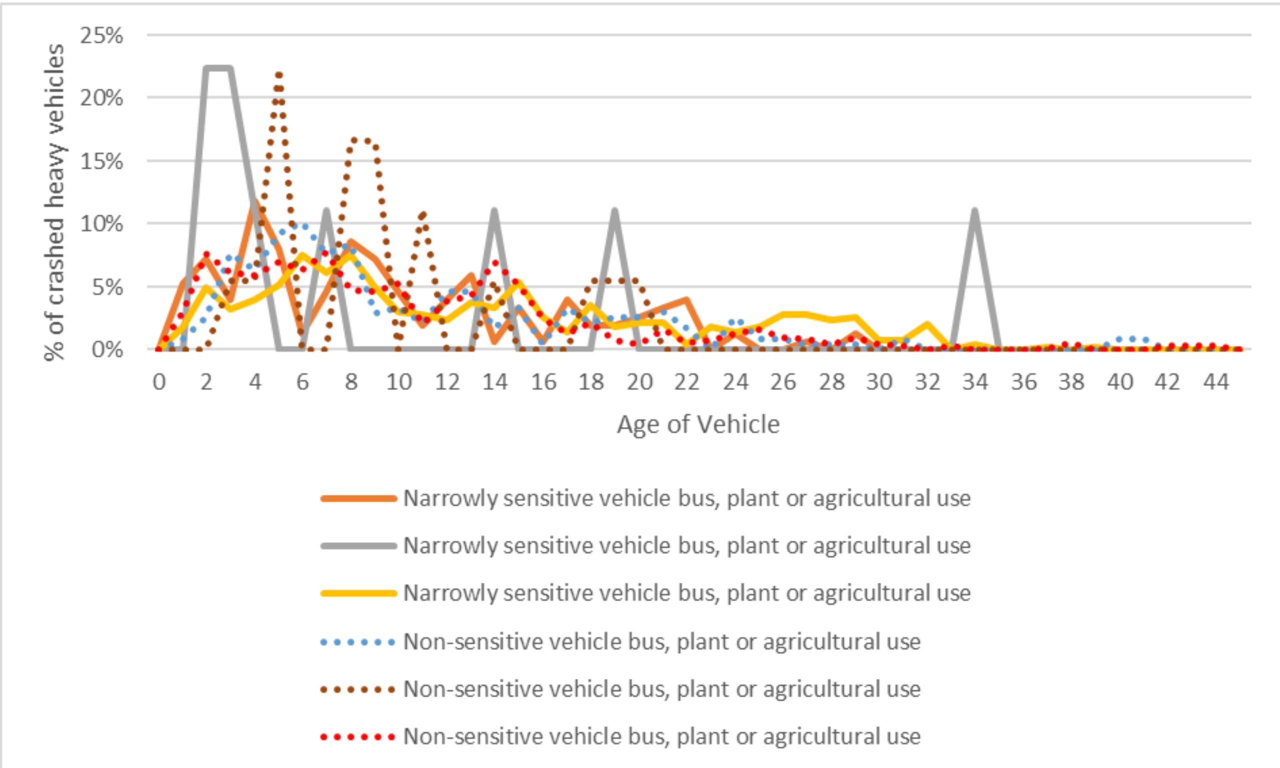

FIGURE 5: AGE (AT CRASH) DISTRIBUTION OF BUSES INVOLVED IN ALL SEVERITY CRASHES, BY CRASH SENSITIVITY

9.2 ANNUAL INFLATED INJURIES IN HEAVY VEHICLE CRASHES SENSITIVE TO AEB

Table 23 summarises the average annual crash injuries by severity and the average annual count of no-injury crashes for all crash involved heavy vehicles and for heavy vehicles involved in AEB sensitive crashes by heavy vehicle type. The row percentages that narrowly sensitive injuries or crashes make-up of the total are presented in the final column. An inflation factor of 1.05 was used to inflate minor and serious injuries of the five jurisdictions to represent the whole of Australia and similarly and inflation factor of 1.08 was used on fatalities. An inflation factor of 2.12 was used to inflate the three jurisdictions of property damage only crashes to represent that of the entire nation. An explanation of these inflation factors is included as Appendix 0. The injuries and no-injury crashes were averaged over the year 2013 to 2016 and then inflated. Data are presented for fatal and serious injuries combined, as well as separated across fatal and serious injuries. Given the small number of fatalities in the crash data, fatal and serious injuries were grouped together for the risk reduction analyses.

The average annual heavy vehicle crashes and of fatal, serious and minor injury crashes involving heavy vehicle occurring between 2013 and 2016 are presented in Appendix 0.

TABLE 23: AVERAGE ANNUAL INFLATED COUNTS OF INJURIES FROM HEAVY VEHICLE CRASHES AND PROPERTY DAMAGE ONLY HEAVY VEHICLE CRASHES (2013-2016) BY CRASH SENSITIVITY AND HEAVY VEHICLE GROUP

Crash injuries		All crash injuries	Injuries in narrowly sensitive crashes	% of all injuries that are in AEB sensitive crashes
Fatal and Serious	Large bus	37.61	4.99	13.26
	Small bus	3.15	0.00	0.00
	Unknown bus	93.83	10.50	11.19
	All Bus	**134.58**	**15.49**	**11.51**
	Rigid ≤ 12t	569.34	102.69	18.04
	Articulated and >12t	662.96	146.69	22.13
	Unknown weight	185.46	42.82	23.09
	All truck	**1417.16**	**292.20**	**20.61**
	All heavy vehicle	**1552.34**	**307.69**	**19.82**
Fatal	Large bus	2.43	0.00	0.00
	Small bus	0.00	0.00	0.00
	Unknown bus	4.05	0.00	0.00
	All Bus	**6.48**	**0.00**	**0.00**
	Rigid ≤ 12t	36.99	1.89	5.11
	Articulated and >12t	62.10	7.83	12.61
	Unknown weight	14.31	1.08	7.55
	All truck	**113.40**	**10.80**	**9.52**
	All heavy vehicle	119.88	10.80	9.01
Serious	Large bus	35.18	4.99	14.18
	Small bus	3.15	0.00	0.00
	Unknown bus	89.79	10.50	11.70
	All Bus	**128.10**	**15.49**	**12.09**
	Rigid ≤ 12t	532.35	100.80	18.93
	Articulated and >12t	600.86	138.86	23.11
	Unknown weight	171.15	41.74	24.39
	All truck	**1304.36**	**281.40**	**21.57**
	All heavy vehicle	1432.46	296.89	20.73
Minor	Large bus	129.15	33.86	26.22
	Small bus	7.35	2.36	32.14
	Unknown bus	228.11	75.08	32.91
	All Bus	**364.61**	**111.30**	**30.53**
	Rigid ≤ 12t	1261.58	471.71	37.39
	Articulated and >12t	1022.70	428.93	41.94
	Unknown weight	457.54	191.89	41.94
	All truck	**2741.81**	**1092.53**	**39.85**
	All heavy vehicle	**3106.43**	**1203.83**	**38.75**
Crashed vehicles		**All crashed vehicles**	**Vehicles in narrowly**	**% of all crashes that**

			sensitive crashes	are in AEB sensitive
No injury crashes	Large bus	372.59	36.57	9.82
	Small bus	7.42	1.06	14.29
	Unknown bus	1100.28	127.20	11.56
	All Bus	**1480.29**	**164.83**	**11.13**
	Rigid ≤ 12t	3363.38	434.60	12.92
	Articulated and >12t	4779.01	741.47	15.52
	Unknown weight	1981.67	272.95	13.77
	All truck	**10124.06**	**1449.02**	**14.31**
	All heavy vehicle	**11604.35**	**1613.85**	**13.91**

10 DERIVING BENEFITS OF MANDATED AEB: ESTIMATED TRAUMA REDUCTIONS ASSOCIATED WITH AEB IN HEAVY VEHICLES

10.1 HEAVY VEHICLE POTENTIAL SAVINGS TABLES

Given the paucity of information regarding the fitment of heavy vehicle AEB in the Australian crash data and hence the ability to directly estimate heavy vehicle AEB crash an injury reduction effects from Australia crash data, it was necessary to apply reductions based on published international data (Woodrooffe et al., 2012). Based on the published literature, injury reductions in AEB sensitive heavy vehicle crashes of 21% to 57% were applied to serious and minor injuries for all heavy vehicles except articulated trucks where a 25% to 54% injury reduction from sensitive crashes was applied. Likewise, for fatalities in all heavy vehicle AEB sensitive crashes, a 22% to 55% reduction was applied to all vehicles, except articulated trucks where a reduction of 24% to 57% was applied. These reductions were based on Woodrooffe et al., (2012) who estimated AEB effectiveness based on currently available AEB technology (lower bound) and as well as predicted AEB effectiveness based on future generations of the AEB technology (upper bound). These reductions estimated for heavy vehicle AEB in AEB sensitive crashes were applied to the average annual inflated counts of property damage only crashes and injuries in crashes sensitive to heavy vehicle AEB shown in Table 23 to estimate the potential average annual savings based on the years 2013 to 2016. The estimated potential crash and injury savings are presented below in Table 24 and

Table 25. In addition, the proportion of the total injuries in all injury crashes and total property damage crashes that these savings represent is also listed. Potential benefits in terms of crash and fatal and serious injury reductions were found to be statistically significant for heavy vehicles (reported in Table 24).

TABLE 24: POTENTIAL AVERAGE ANNUAL SAVINGS IN <u>INJURIES</u> (2013-2016) IN HEAVY VEHICLE CRASHES OVERALL AND BY HEAVY VEHICLE TYPE IF ALL HEAVY VEHICLES WERE FITTED WITH AEB

		Injury Savings						% of all injuries saved					
		Fatal		Serious		Minor		Fatal		Serious		Minor	
		Min (current)	Max (future)	Min (current)	Max (future)	Min (current)	Max (future)	Min (current)	Max (future)	Min (current)	Max (future)	Min (current)	Max (future)
Bus	large	0.00	0.00	1.05	2.84	7.11	19.30	0.00	0.00	2.98	8.08	5.51	14.95
	Small	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	6.75	18.32
	Unknown	0.00	0.00	2.21	5.99	15.77	42.79	0.00	0.00	2.46	6.67	6.91	18.76
	All	**0.00**	**0.00**	**3.25**	**8.83**	**23.37**	**63.44**	**0.00**	**0.00**	**2.54**	**6.89**	**6.41**	**17.40**
Truck	Rigid ≤ 12t	0.42	1.04	21.17	57.46	99.06	268.88	1.12	2.81	3.98	10.79	7.85	21.31
	Articulated and >12t	1.88	4.46	34.72	74.99	107.23	231.62	3.03	7.19	5.78	12.48	10.49	22.65
	Unknown weight	0.24	0.59	8.76	23.79	40.30	109.38	1.66	4.15	5.12	13.90	8.81	23.91
	All	**2.53**	**6.10**	**64.65**	**156.23**	**246.59**	**609.87**	**2.23**	**5.38**	**4.96**	**11.98**	**8.99**	**22.24**
All		**2.53**	**6.10**	**67.90**	**165.06**	**269.96**	**673.31**	**2.11**	**5.09**	**4.74**	**11.52**	**8.69**	**21.67**

TABLE 25: POTENTIAL AVERAGE ANNUAL SAVINGS IN HEAVY VEHICLE CRASHES (2013-2016) OVERALL AND BY HEAVY VEHICLE TYPE IF ALL VEHICLES WERE FITTED WITH AEB

		Crash Savings					% of all crashes saved				
		Fatal and serious	Fatal	Serious	Minor	No injury	Fatal and serious	Fatal	Serious	Minor	No injury
Bus	large	0.63 to 1.58	0.00 to 0.00	0.63 to 1.58	3.40 to 8.51	5.85 to 14.63	0.69 to 1.73	0.00 to 0.00	0.75 to 1.88	1.90 to 4.74	1.57 to 3.93
	Small	0.00 to 0.00	0.00 to 0.00	0.00 to 0.00	0.21 to 0.53	0.17 to 0.42	0.00 to 0.00	0.00 to 0.00	0.00 to 0.00	3.08 to 7.69	2.29 to 5.71
	Unknown	1.26 to 3.15	0.00 to 0.00	1.26 to 3.15	6.05 to 15.12	20.35 to 50.88	0.81 to 2.03	0.00 to 0.00	0.86 to 2.15	2.48 to 6.21	1.85 to 4.62
	All	**1.89 to 4.73**	0.00 to 0.00	**1.89 to 4.73**	**9.66 to 24.15**	**26.37 to 65.93**	**0.75 to 1.88**	0.00 to 0.00	**0.80 to 2.01**	**2.25 to 5.62**	**1.78 to 4.45**
Truck	Rigid ≤ 12t	13.70 to 34.25	0.30 to 0.76	13.40 to 33.50	55.44 to 138.60	69.54 to 173.84	1.50 to 3.76	0.42 to 1.05	1.59 to 3.99	3.24 to 8.10	2.07 to 5.17
	Articulated and >12 t	15.44 to 38.61	1.08 to 2.70	14.36 to 35.91	42.97 to 107.42	118.64 to 296.59	1.61 to 4.02	0.80 to 1.05	1.74 to 4.35	3.54 to 8.84	2.48 to 6.21
	Unknown weight	5.63 to 14.08	0.17 to 0.43	5.46 to 13.65	22.13 to 55.34	43.67 to 109.18	1.82 to 4.55	0.45 to 1.13	2.01 to 5.03	3.83 to 9.58	2.20 to 5.51
	All	**34.78 to 86.94**	**1.56 to 3.89**	**33.22 to 83.06**	**120.54 to 301.35**	**231.84 to 579.61**	**1.59 to 3.98**	**0.63 to 1.58**	**1.71 to 4.29**	**3.44 to 8.60**	**2.29 to 5.73**
All		**36.67 to 91.67**	**1.56 to 3.89**	**35.11 to 87.78**	**130.20 to 325.50**	**258.22 to 654.54**	**1.51 to 3.77**	**0.60 to 1.49**	**1.62 to 4.04**	**3.31 to 8.27**	**2.23 to 5.56**

11 AEB CRASH DEMOGRAPHICS

11.1 A COMPARISON OF FATALITIES FROM CRASHES INVOLVING HEAVY AND LIGHT VEHICLES IN AEB SENSITIVE CRASHES

Fatalities from AEB sensitive heavy vehicle crashes were more often drivers or riders[4] (controllers) than passengers (FIGURE 6), and fatalities from all AEB sensitive light vehicle crashes were more often controllers, than for all crashes nationally over the same period.

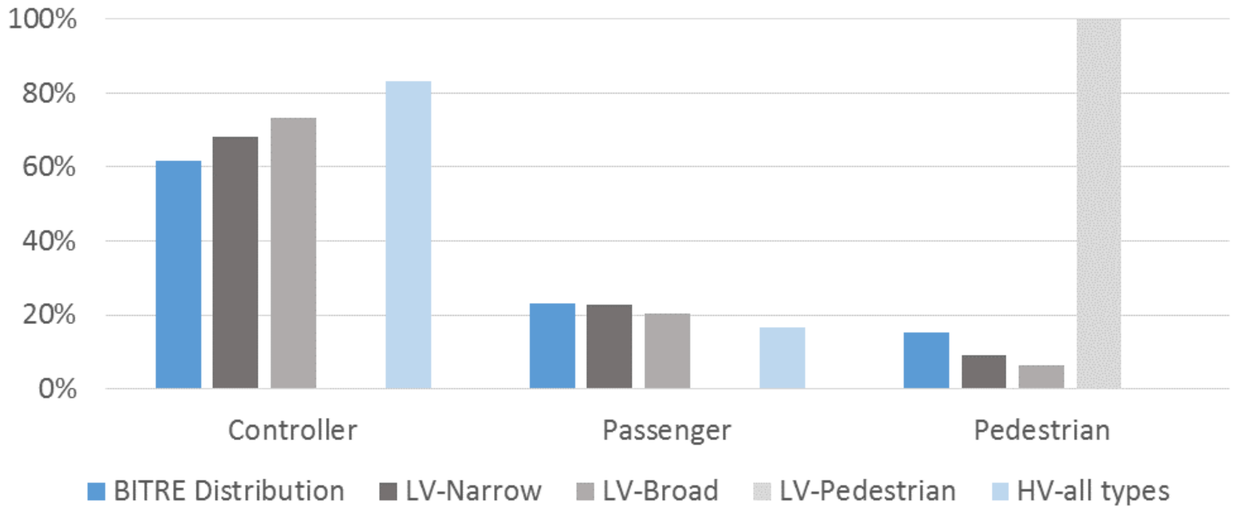

FIGURE 6: PERCENTAGE OF 2013-2015 FATALITIES BY ROAD USER TYPE IN SENSITIVE CRASHES INVOLVING EITHER LIGHT (LV) OR HEAVY (HV) SENSITIVE VEHICLES COMPARED WITH NATIONAL ROAD FATALITY DISTRIBUTION BY ROAD USER (BUREAU OF INFRASTRUCTURE TRANSPORT AND REGIONAL ECONOMICS [BITRE] 2018)

Fatalities from AEB sensitive heavy vehicle crashes were more often aged 26 to 55 years than for AEB sensitive light vehicle crashes or for all road fatalities (FIGURE 7). Fatalities from light vehicle AEB sensitive crashes were more often aged over 55 than for AEB sensitive heavy vehicle crashes and for all road fatalities over the same period.

[4] Motorcycle to heavy vehicle collisions and motorcycle-to-pedestrian collisions were not included in the sensitive vehicle set.

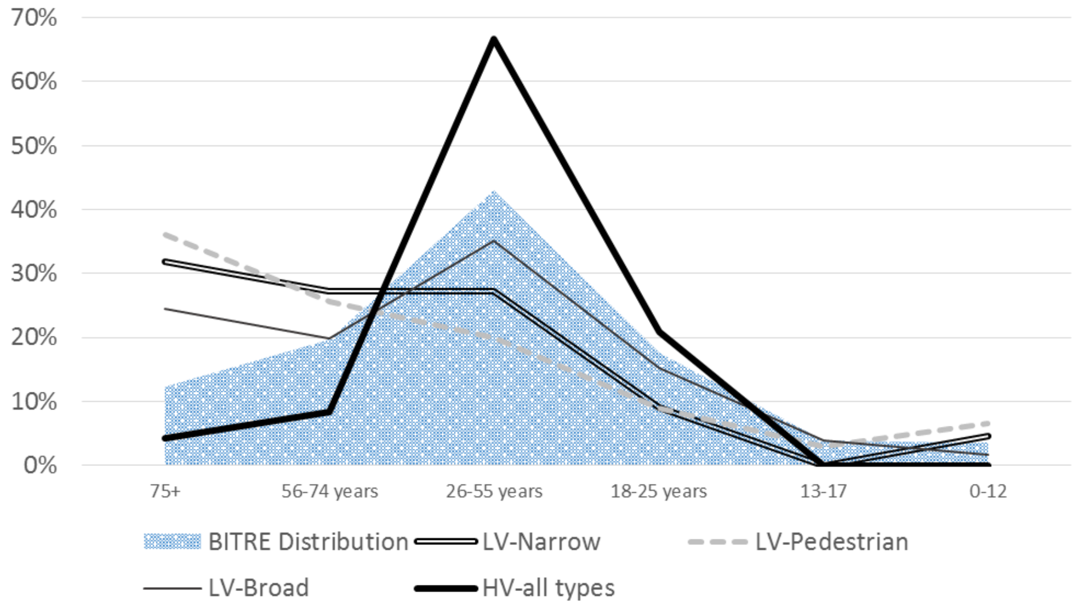

FIGURE 7: PERCENTAGE OF 2013-2015 FATALITIES BY AGE IN AEB SENSITIVE CRASHES INVOLVING EITHER LIGHT (LV) OR HEAVY (HV) COMPARED WITH NATIONAL ROAD FATALITY DISTRIBUTION BY AGE (BUREAU OF INFRASTRUCTURE TRANSPORT AND REGIONAL ECONOMICS [BITRE] 2018)

For all crashes occurring between 2013 to 2015, the modal fatality age was 20. By road user modal age was 19 for controllers, 17 for passengers and 74 for pedestrians.

- Overall, the modal fatality age was slightly more than 20 for all AEB sensitive light vehicle crashes: 27 for narrowly AEB sensitive light vehicle crashes, 31 for broadly AEB sensitive light vehicle crashes and 41 for heavy vehicle AEB sensitive crashes.
- For controller fatalities, the modal fatality age was also older: 26 for narrowly AEB sensitive light vehicle crashes, 31 for broadly AEB sensitive light multi-vehicle crashes and 41 for heavy vehicle AEB sensitive crashes. An exception to this trend was for broadly AEB sensitive single vehicle crashes which was closer to the all crash mode at 21.
- For passenger fatalities, the modal age was 8 for the five narrowly AEB sensitive light vehicle crash fatalities, 82 for the 44 broadly AEB sensitive light multi-vehicle crash fatalities and 26 for four heavy vehicle AEB sensitive crash fatalities.
- The modal fatality age for pedestrian AEB sensitive light vehicle crashes was the same as for all crashes (74), but older at 86, for the 14 pedestrians killed in broadly AEB sensitive light multi-vehicle collisions. There were no pedestrian fatalities for AEB sensitive heavy vehicle crashes and only two for light vehicle AEB sensitive crashes.

12 DISCUSSION AND CONCLUSIONS

The purpose of the study was to calculate the likely road safety benefits that could be derived through the mandated fitment of AEB systems to all new light and heavy vehicles sold in Australia. The analyses were considered separately for light passenger vehicles and for heavy vehicles reflecting differences in the effectiveness of AEB and associated crash involvement as well as different resolutions of available data. Overall, the findings showed significant crash and associated injury risk reductions resulting from AEB fitment in both the light and heavy vehicle fleet. These are discussed below separately for light passenger vehicles and heavy vehicles.

12.1 THE POTENTIAL EFFECTIVENESS OF AEB FITMENT IN LIGHT PASSENGER VEHICLES

Analysis of Australian crash data showed a greater percentage of AEB sensitive crashes involving light vehicles occurred in lower speed zones. This is to be expected given the crash types considered to be sensitive. Overall, 69% of all light vehicles included in the analysis were involved in AEB sensitive crashes occurring in speed zones of 60km/h or lower. This was also evident across vehicles with a different role in AEB sensitive crashes. For example, when striking vehicles in the crash were considered, 63% in crashes narrowly sensitive to AEB, 91% in pedestrian AEB sensitive crashes and 76% in crashes broadly sensitive to AEB were in crashes occurring in 60km/h zones or lower. Currently most AEB systems in light passenger vehicles are limited to crash mitigation at low speeds (less than 80km/h). However, AEB technologies are constantly advancing to be able to function at higher speeds with many new systems now offering impact speed mitigation to speeds over 100km/h.

Different AEB types operate at different maximum speeds depending on the specification of the technology. Of the light vehicles involved in crashes analysed in the study, 5% of vehicles had high speed (operational at >60km/h) AEB fitted while 10% had low speed AEB systems. Only 3% of vehicles involved in crashes narrowly sensitive to AEB had high speed AEB fitted, compared to 5% across other crash types. In comparison, 8% of light vehicles in crashes narrowly sensitive to AEB were fitted with low speed AEB, compared to 13%, 11% and 8% of vehicles fitted in pedestrian sensitive AEB crashes, broadly AEB sensitive multivehicle and broadly AEB sensitive single vehicle crashes. In addition, of all striking vehicles in crashes sensitive to AEB, 17% were in crashes considered to be narrowly sensitive to AEB, while 32% were in crashes considered to be broadly sensitive to AEB.

Regression analysis of injury risk reductions associated with AEB fitment in light vehicles showed significant benefits associated with AEB in reducing trauma. However, results were only statistically significant when considering vehicles model groups where possibly only some model variants were fitted with AEB. For model groups where all variants were fitted with AEB, there were not enough exposure in the available crash data to produce sufficient power for the analysis. This is a likely result of the only recent market penetration of AEB. This means that the significant trauma effects associated with AEB which relate to model groups with only some variants fitted with AEB are likely to be an underestimate of the effects of the technology.

Significant reductions in crashes and associated injury risk were found to be associated with AEB fitment in light vehicles. Analysis results broadly showed that injury risk reductions associated with AEB were much greater for serious and fatal injuries than for minor injuries. In addition, injury mitigation associated with AEB was estimated to be largest in crashes narrowly sensitive to AEB, compared to crashes broadly sensitive to AEB. Overall, a 36% reduction in the risk of fatal and serious injuries and a 19% risk reduction in minor injuries was associated with AEB fitment in crashes narrowly sensitive to AEB (primarily rear end crashes into other vehicles). In low speed zones (60km/h or lower), the corresponding risk reductions were 28% for fatal and serious injury and 18% for minor injuries. In contrast, the estimated associated injury risk reductions were greater for crashes in higher speed zones (above 60km/h) where AEB was associated with a 45% reduction in the risk of fatal and serious injury and 22% reduction in the risk of minor injuries. Overall, AEB fitment has been estimated to be associated with substantial injury reductions across both low and high speed zones. However, the greatest benefit in terms of injury risk reduction is estimated in high speed crashes. It should be noted that these analyses estimated the combined effects of both low speed and high speed AEB systems in the crash involved vehicles, due to the low numbers of each in the dataset, and did not specifically examine the impacts of high speed AEB in high speed crashes. Nevertheless, with greater potential for serious and fatal injuries associated with higher speed zones, these findings point to a yet untapped potential for fatal and serious injury reduction from high speed AEB as it progressively appears on new vehicles.

AEB fitment in broadly AEB sensitive crashes was associated with an overall all-injury risk reduction of 10%, a 12% risk reduction for minor injuries, and 10% for fatal injuries, although the latter was not significant. AEB fitment was also associated with injury risk reductions in pedestrian AEB sensitive crashes vehicles but only with respect to minor injuries, where a 28% reduction in injury risk was estimated. This latter result might be due to the current AEB technology, which is currently limited in capacity to detect pedestrians in many vehicles. With improved AEB technology, the benefits of pedestrian AEB are likely to be increased.

If all light passenger vehicles in Australia had AEB fitted, the estimated injury reductions in AEB narrowly sensitive crashes would translate to average annual reductions of 1,104 fatal and serious injuries and 2,188 minor injuries. This constitutes 5% and 4% of total average annual fatalities and serious injuries and minor injuries in light vehicle involved crashes, respectively. Likewise, if all light passenger vehicles were fitted with AEB, estimated reductions in narrowly, broadly and pedestrian AEB sensitive crashes would result in annual savings of 1,977 fatal and serious injuries and 4,292 minor injuries. This equates to 10% of total fatalities and serious injuries and 9% of all minor injuries resulting from crashes involving light vehicle.

12.2 THE POTENTIAL EFFECTIVENESS OF HEAVY VEHICLE AEB

The light vehicle analysis estimated the crash and associated injury reductions associated with AEB in light vehicles directly from the available crash data based on known fitment of AEB in crashes light vehicles. In contrast, the heavy vehicle analysis modelled the potential crash and injury benefits of AEB fitment in heavy vehicles based on AEB effectiveness on sensitive crashes measured from published studies undertaken internationally. In the Australian crash data for heavy vehicles, 15% of all heavy vehicle crashes were sensitive to AEB based on the sensitive crash types identified in the literature. Further, 15% of crashed heavy vehicles were considered to be striking vehicles in crashes sensitive to AEB. Different proportions of large vehicle involved crashes were AEB sensitive by large vehicle type: 9.5% of crashed large buses; 12% of crashed small buses; 12% of crashes unknown size buses, and trucks: 15% of crashed rigid trucks under 12 tonne; 16% of crashed large rigid and articulated trucks and 16% of crashed trucks of unknown size.

Analysis estimated significant crash savings associated with the fitment of AEB to heavy vehicles in Australia. Because the true fitment of AEB in the heavy vehicle fleet is unknown, an assumption of nil fitment during the years 2013 to 2016 was made and compared to 100% fitment to estimate potential crash and injury savings. Resulting estimates of crash savings showed that AEB has the potential to avoid or mitigate 37 to 92 fatal and serious injury crashes, 130 to 326 minor crashes and 258 to 646 no-injury crashes per year with the lower an upper estimates relating to current and predicted future capability of the technology. Corresponding injury savings associated with AEB fitment in heavy vehicles were estimated at three to six fatalities per year, 68 to 165 serious injuries per year and 270 to 673 minor injuries. This equates to 2-5% of all fatalities and 5% to 12% of all serious injuries resulting from crashes involving heavy vehicles that occur annually in Australia.

12.3 CONCLUSIONS

Analysis presented in this report has estimated crash and injury reductions associated with AEB fitment in light and heavy vehicles in crashes likely to be sensitive to the technology, From these estimates, the analysis has derived subsequent estimates of percentage and absolute savings in overall road trauma if all light and heavy vehicles in the Australian fleet were fitted with AEB. Analyses showed significant potential benefits associated with AEB fitment in reducing crashes sensitive to the technology involving light and heavy vehicles based on real-world crash data from Australia over the years 2013 to 2016.

Analysis results broadly showed that injury risk reductions associated with AEB were much greater for serious and fatal injuries than for minor injuries. In addition, injury mitigation associated with AEB was estimated to be largest in crashes narrowly sensitive to AEB (rear end crashes with other vehicles) compared to crashes broadly sensitive to AEB (such as pedestrian fixed object and other vehicle to vehicle crashes). Overall, a 36% reduction in the risk of fatal and serious injuries and a 19% risk reduction in minor injuries was associated with AEB fitment in crashes narrowly sensitive to AEB. In low speed zones (60km/h or lower), the corresponding risk reductions were 28% for fatal and serious injury and 18% for minor injuries. In contrast, the estimated associated injury risk reductions were greater for crashes in higher speed zones (above 60km/h) where AEB was associated with a 45% reduction in the risk of fatal and serious injury and 22% reduction in the risk of minor injuries. If all light passenger vehicles in Australia had AEB fitted, the estimated annual injury reductions associated with AEB across the broader set of crash types potentially mitigated by the technology were estimated to be 1,977 fatal and serious injuries and 4,292 minor injuries. This equates to 10% of total fatalities and serious injuries and 9% of all minor injuries resulting from crashes involving light vehicle.

Analysis of AEB effectiveness in heavy vehicles also showed significant potential benefits of the technology in Australia based on reductions in AEB sensitive crashes involving heavy vehicles reported in the literature. If all heavy vehicles had AEB fitted in Australia, estimates of crash savings showed that AEB has the potential to avoid or mitigate 37 to 92 fatal and serious injury crashes, 130 to 326 minor crashes and 258 to 646 no-injury crashes per year with the lower an upper estimates relating to current and predicted future capability of the technology. Corresponding injury savings associated with AEB fitment in heavy vehicles were estimated at three to six fatalities per year, 68 to 165 serious injuries per year and 270 to 673 minor injuries. This equates to 2-5% of all fatalities and 5% to 12% of all serious injuries resulting from crashes involving heavy vehicles that occur annually in Australia.

The results show clear benefit for AEB fitment across light passenger vehicles and heavy vehicles. However, these rely on drivers choosing new vehicles including this technology. Previous research has shown not all drivers may readily adopt AEB (Rahman, Strawderman et al. 2018) demonstrating the need for a mandate to include the technology in all vehicles to maximise its potential benefit. As AEB technologies advance, more crash types are likely to become narrowly sensitive to AEB (Sander 2017) and therefore the potential benefits of AEB will increase. The growing market penetration of AEB systems and increased functionality in the technology means that further evaluation of the road safety benefits of AEB is warranted in the future.

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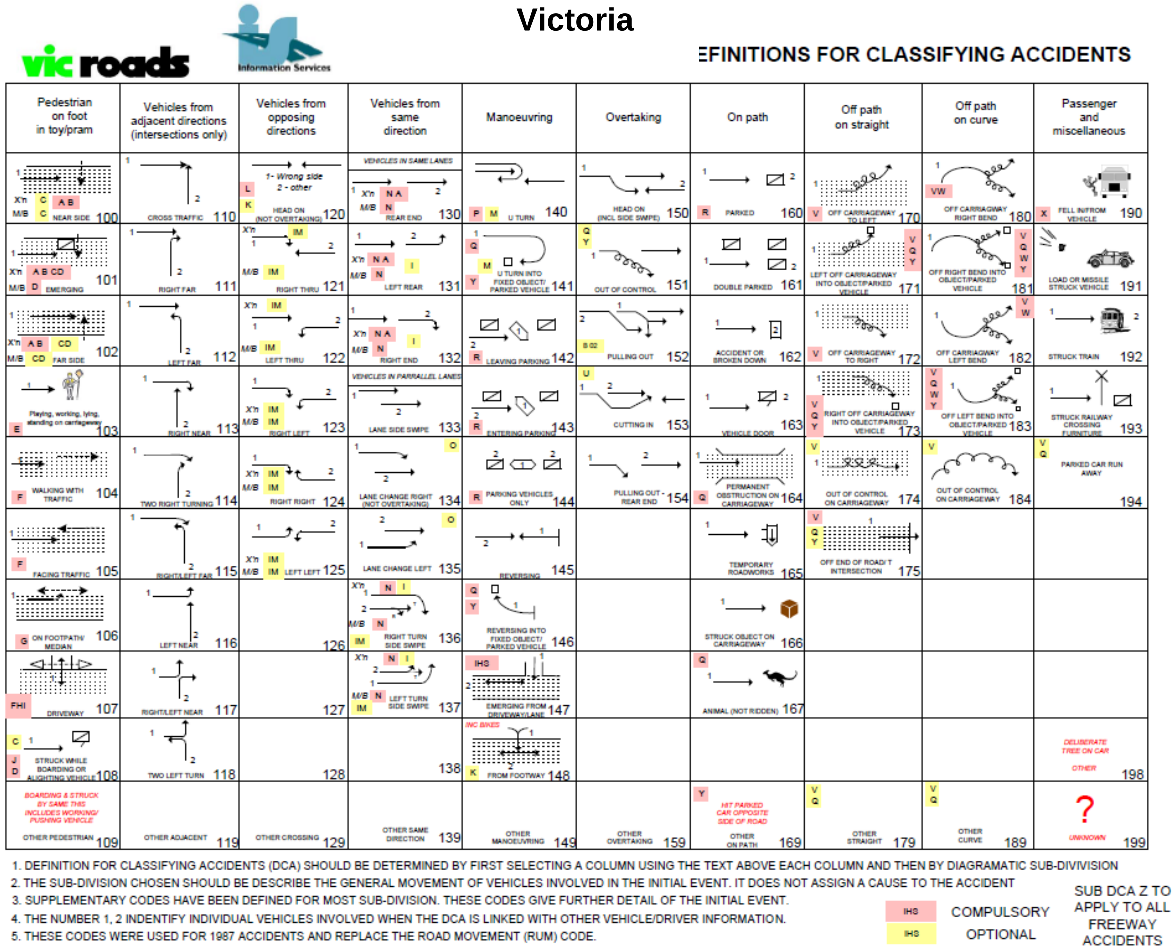
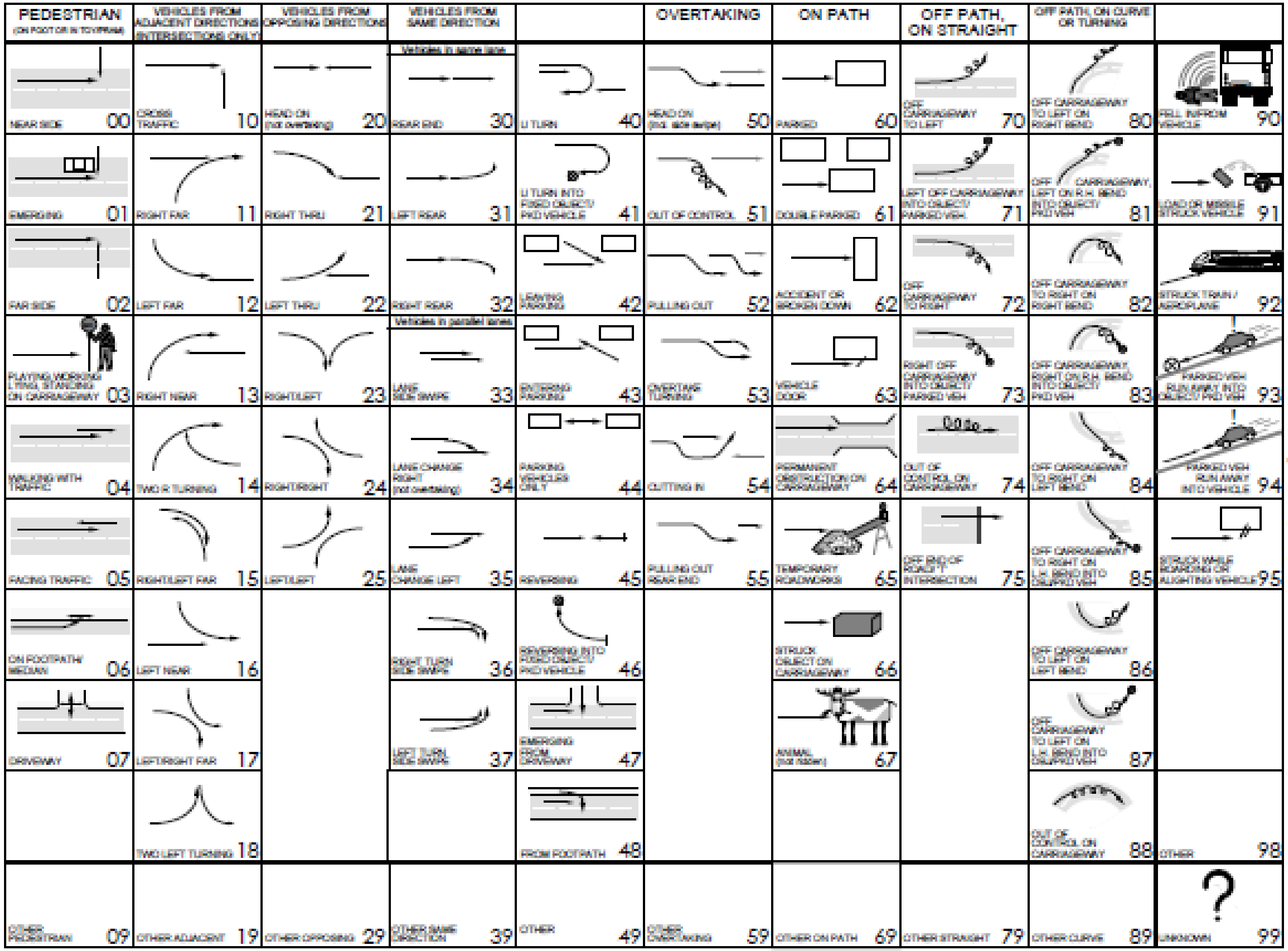
14 APPENDIX

A.1 DCA CHARTS AND RUM CODES ACROSS EACH AUSTRALIAN JURISDICTION

Victoria



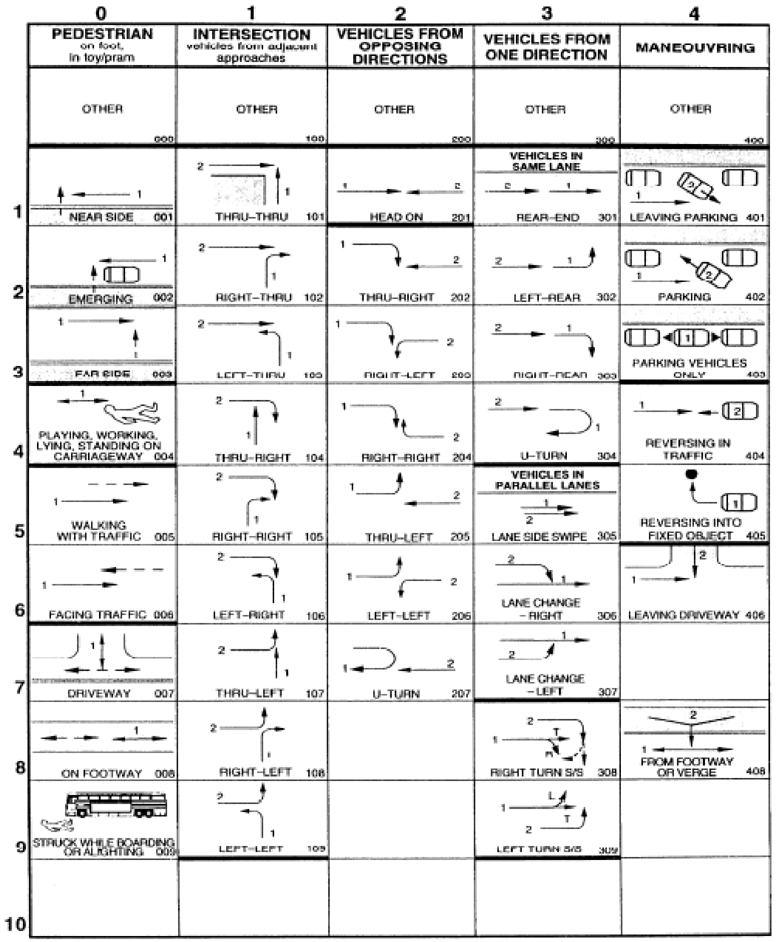
NSW



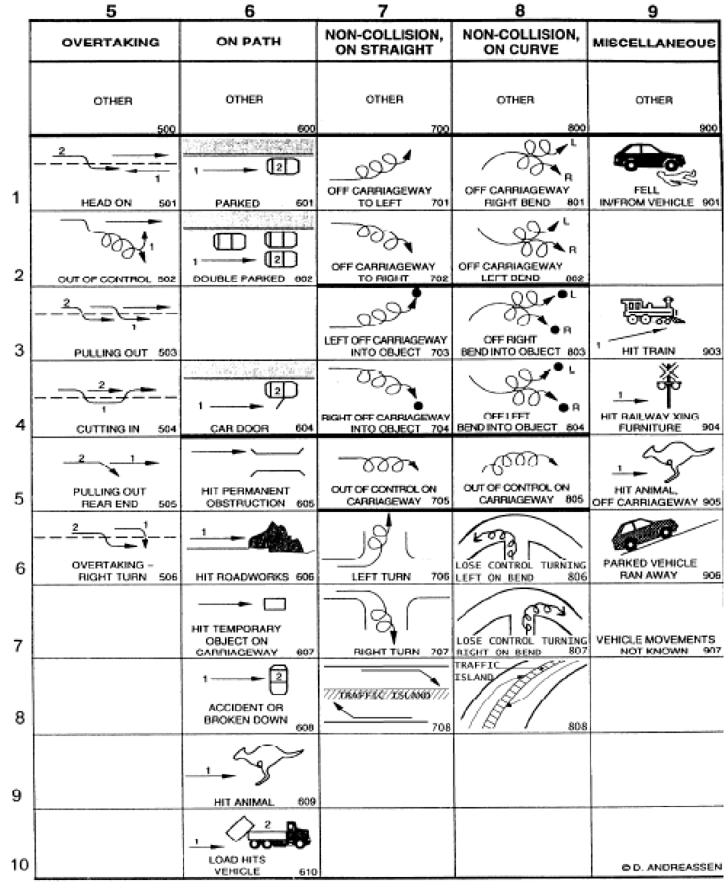
ROAD USER MOVEMENT (R.U.M.) CODE

This is recorded for the first impact according to the table below.
Note: The 'key' vehicle is represented by the dark arrow —— and is the first vehicle listed for each accident in the accident description list (ADL).

Queensland



0
1
2
3
4
PEDESTRIAN
on foot, in toy/pram
INTERSECTION
vehicles from adjacent approaches
VEHICLES FROM OPPOSING DIRECTIONS
VEHICLES FROM ONE DIRECTION
MANEOUVRING
OTHER 000
OTHER 100
OTHER 200
OTHER 300
OTHER 400
NEAR SIDE 001
THRU–THRU 101
HEAD ON 201
VEHICLES IN SAME LANE
REAR–END 301
LEAVING PARKING 401
EMERGING 002
RIGHT–THRU 102
THRU–RIGHT 202
LEFT–REAR 302
PARKING 402
FAR SIDE 003
LEFT–THRU 103
RIGHT–LEFT 203
RIGHT–REAR 303
PARKING VEHICLES ONLY 403
PLAYING, WORKING, LYING, STANDING ON CARRIAGEWAY 004
THRU–RIGHT 104
RIGHT–RIGHT 204
U–TURN 304
REVERSING IN TRAFFIC 404
WALKING WITH TRAFFIC 005
RIGHT–RIGHT 105
THRU–LEFT 205
VEHICLES IN PARALLEL LANES
LANE SIDE SWIPE 305
REVERSING INTO FIXED OBJECT 405
FACING TRAFFIC 006
LEFT–RIGHT 106
LEFT–LEFT 206
LANE CHANGE – RIGHT 306
LEAVING DRIVEWAY 406
DRIVEWAY 007
THRU–LEFT 107
U–TURN 207
LANE CHANGE – LEFT 307
ON FOOTWAY 008
RIGHT–LEFT 108
RIGHT TURN S/S 308
FROM FOOTWAY OR VERGE 408
STRUCK WHILE BOARDING OR ALIGHTING 009
LEFT–LEFT 109
LEFT TURN S/S 309
10



5
6
7
8
9
OVERTAKING
ON PATH
NON-COLLISION, ON STRAIGHT
NON-COLLISION, ON CURVE
MISCELLANEOUS
OTHER 500
OTHER 600
OTHER 700
OTHER 800
OTHER 900
HEAD ON 501
PARKED 601
OFF CARRIAGEWAY TO LEFT 701
OFF CARRIAGEWAY RIGHT BEND 801
FELL IN/FROM VEHICLE 901
OUT OF CONTROL 502
DOUBLE PARKED 602
OFF CARRIAGEWAY TO RIGHT 702
OFF CARRIAGEWAY LEFT BEND 802
PULLING OUT 503
LEFT OFF CARRIAGEWAY INTO OBJECT 703
OFF RIGHT BEND INTO OBJECT 803
HIT TRAIN 903
CUTTING IN 504
CAR DOOR 604
RIGHT OFF CARRIAGEWAY INTO OBJECT 704
OFF LEFT BEND INTO OBJECT 804
HIT RAILWAY XING FURNITURE 904
PULLING OUT REAR END 505
HIT PERMANENT OBSTRUCTION 605
OUT OF CONTROL ON CARRIAGEWAY 705
OUT OF CONTROL ON CARRIAGEWAY 805
HIT ANIMAL, OFF CARRIAGEWAY 905
OVERTAKING – RIGHT TURN 506
HIT ROADWORKS 606
LEFT TURN 706
LOSE CONTROL TURNING LEFT ON BEND 806
PARKED VEHICLE RAN AWAY 906
HIT TEMPORARY OBJECT ON CARRIAGEWAY 607
RIGHT TURN 707
LOSE CONTROL TURNING RIGHT ON BEND 807
VEHICLE MOVEMENTS NOT KNOWN 907
ACCIDENT OR BROKEN DOWN 608
TRAFFIC ISLAND 708
TRAFFIC ISLAND 808
HIT ANIMAL 609
LOAD HITS VEHICLE 610
10
© D. ANDREASSEN

Western Australia

98	Pedest: Other	33	Same Dirn: Same Lane Right Rear
1	Pedest: Near Side	34	Same Dirn: Same Lane U - Turn
2	Pedest: Emerging From Near Side	35	Same Dirn: Parallel Lanes - S/swipe
3	Pedest: Far Side	36	Same Dirn: Change Lanes - Right
4	Pedest: Play / Work / Stand On Cway	37	Same Dirn: Change Lanes - Left
5	Pedest: Walking With Traffic	38	Same Dirn: Parallel Lanes - Turn Right S/swipe
6	Pedest: Walking Against Traffic	39	Same Dirn: Parallel Lanes - Turn Left S/swipe
7	Pedest: In Driveway	40	Manoeuv: Other
8	Pedest: On Footway	42	Manoeuv: Leaving Parking
9	Pedest: Struck Boarding / Alighting	43	Manoeuv: Parking
10	Intx: Other	44	Manoeuv: Parking Veh Only
11	Intx: Thru - Thru	45	Manoeuv: Reversing In Traffic
12	Intx: Right - Thru	46	Manoeuv: Reverse Into Fixed Obj
13	Intx: Left - Thru	47	Manoeuv: Leaving Driveway
14	Intx: Thru - Right	48	Manoeuv: Loading Bay
15	Intx: Right - Right	49	Manoeuv: From Footway
16	Intx: Left - Right	50	Overtaking: Other
17	Intx: Thru - Left	51	Overtaking: Head On
18	Intx: Right - Left	52	Overtaking: Out Of Control:
19	Intx: Left - Left	53	Overtaking: Pulling Out
20	Opposite Dirn: Other	54	Overtaking: Cutting In
21	Opposite Dirn: Head On	55	Overtaking: Pull Out - Rear End
22	Opposite Dirn: Thru - Right	56	Overtaking: Into Right Turn
23	Opposite Dirn: Right - Left	60	On Path: Other
24	Opposite Dirn: Right - Right	61	On Path: Parked
25	Opposite Dirn: Thru - Left	62	On Path: Double Parked
26	Opposite Dirn: Left - Left	63	On Path: Accident Or Breakdown
27	Opposite Dirn: U - Turn	64	On Path: Open Car Door
30	Same Dirn: Other	65	On Path: Permanent Obstruction
31	Same Dirn: Same Lane Rear End	66	On Path: Temp Roadworks
32	Same Dirn: Same Lane Left Rear	67	On Path: Temp Obj On Cway

Western Australia continued

69	On Path: Hit Animal
70	Off Path On Straight: Other
71	Off Path On Straight: Off Left Cway
72	Off Path On Straight: Off Left Cway Obj
73	Off Path On Straight: Off Rigth Cway
74	Off Path On Straight: Off Right Cway Obj
75	Off Path On Straight: Lost Control On Cway
76	Loss Of Control: Left Turn - Intx

77	Loss Of Control: Right Turn - Intx
80	Off Path On Curve: Other
81	Off Path On Curve: Off Cway Right Bend
82	Off Path On Curve: Off Right Bend In Obj
83	Off Path On Curve: Off Cway Left Bend
84	Off Path On Curve: Off Left Bend In Obj
85	Off Path On Curve: Lost Control On Cway
90	Misc: Passenger Other
91	Misc: Passenger Fell In / From Veh
92	Misc: Load Struck Veh
93	Misc: Struck Train
94	Misc: Struck Rail Xing Furniture
95	Misc: Hit Animal Off Cway
96	Misc: Parked Car Ran Away
97	Misc: Veh Movement Unknown

A.2 LIGHT VEHICLE AGE DISTRIBUTION ACROSS VEHICLE SENSITIVITY AND CRASH SEVERITY

TABLE 26: LIGHT VEHICLE AGE AT TIME OF CRASH DISTRIBUTION ACROSS ALL CRASH SEVERITY

	Light vehicle					
Vehicle age at time of crash	**Non-Sensitive**	**Narrow Sensitivity**	**Pedestrian Sensitivity**	**Hit Bicycle**	**Broad Sensitivity-multivehicle**	**Broad Sensitivity-single vehicle**
0	0.02	0.01	0.02	0.03	0.02	0.02
1	0.07	0.04	0.06	0.05	0.05	0.05
2	0.07	0.05	0.07	0.04	0.05	0.05
3	0.07	0.05	0.07	0.06	0.05	0.05
4	0.07	0.05	0.06	0.06	0.05	0.04
5	0.07	0.05	0.07	0.05	0.06	0.05
6	0.07	0.06	0.06	0.06	0.06	0.04
7	0.07	0.06	0.05	0.05	0.06	0.05
8	0.06	0.06	0.06	0.05	0.06	0.05
9	0.06	0.06	0.06	0.06	0.06	0.05
10	0.05	0.06	0.05	0.04	0.06	0.06
11	0.05	0.06	0.05	0.06	0.05	0.05
12	0.04	0.05	0.05	0.06	0.05	0.05
13	0.04	0.05	0.04	0.05	0.05	0.05
14	0.03	0.05	0.04	0.04	0.04	0.05
15	0.03	0.04	0.04	0.04	0.04	0.04
16	0.03	0.04	0.03	0.04	0.04	0.04
17	0.02	0.03	0.02	0.04	0.03	0.04
18	0.02	0.03	0.02	0.02	0.02	0.03
19	0.01	0.02	0.01	0.03	0.02	0.03
20	0.01	0.02	0.01	0.01	0.02	0.02
21	0.01	0.02	0.01	0.03	0.01	0.02
22	0.01	0.01	0.01	0.01	0.01	0.01
23	0.01	0.01	0.01	0.01	0.01	0.01
24	0.00	0.01	0.01	0.00	0.01	0.01
25	0.00	0.01	0.00	0.00	0.00	0.01
26	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 27: LIGHT VEHICLE AGE AT TIME OF CRASH DISTRIBUTION ACROSS FATAL CRASHES

	Light vehicle					
Vehicle age at time of crash	**Non-Sensitive**	**Narrow Sensitivity**	**Pedestrian Sensitivity**	**Hit Bicycle**	**Broad Sensitivity-multivehicle**	**Broad Sensitivity-single vehicle**
0	0.01	0.00	0.02	0.00	0.02	0.02
1	0.07	0.01	0.05	0.00	0.06	0.04
2	0.08	0.04	0.08	0.00	0.06	0.02
3	0.05	0.03	0.03	0.00	0.04	0.04
4	0.02	0.10	0.07	0.15	0.05	0.03
5	0.04	0.04	0.06	0.23	0.05	0.05
6	0.10	0.01	0.04	0.08	0.05	0.02
7	0.04	0.10	0.05	0.08	0.05	0.05
8	0.05	0.04	0.07	0.00	0.05	0.04
9	0.06	0.09	0.04	0.23	0.06	0.04
10	0.05	0.04	0.04	0.08	0.06	0.03
11	0.06	0.09	0.09	0.08	0.04	0.03
12	0.05	0.03	0.04	0.08	0.05	0.02
13	0.01	0.01	0.05	0.00	0.04	0.09
14	0.04	0.06	0.04	0.00	0.05	0.02
15	0.08	0.03	0.04	0.00	0.04	0.09
16	0.00	0.06	0.06	0.00	0.03	0.05
17	0.02	0.01	0.02	0.00	0.04	0.02
18	0.02	0.07	0.01	0.00	0.03	0.04
19	0.05	0.03	0.01	0.00	0.03	0.07
20	0.04	0.01	0.02	0.00	0.03	0.03
21	0.02	0.03	0.01	0.00	0.02	0.03
22	0.00	0.01	0.01	0.00	0.02	0.02
23	0.01	0.01	0.01	0.00	0.01	0.00
24	0.00	0.00	0.01	0.00	0.01	0.04
25	0.00	0.01	0.01	0.00	0.01	0.03
26	0.00	0.00	0.01	0.00	0.00	0.01
27	0.00	0.01	0.00	0.00	0.00	0.03
28	0.00	0.00	0.01	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00
30	0.01	0.00	0.00	0.00	0.00	0.01
31	0.00	0.00	0.00	0.00	0.00	0.01
32	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00
38	0.01	0.00	0.00	0.00	0.00	0.00

TABLE 28: LIGHT VEHICLE AGE AT TIME OF CRASH DISTRIBUTION ACROSS SERIOUS INJURY CRASHES

Vehicle age at time of crash	Light vehicle					
	Non-Sensitive	Narrow Sensitivity	Pedestrian Sensitivity	Hit Bicycle	Broad Sensitivity-multivehicle	Broad Sensitivity-single vehicle
0	0.03	0.02	0.02	0.02	0.02	0.01
1	0.08	0.05	0.06	0.03	0.05	0.04
2	0.07	0.05	0.06	0.04	0.06	0.04
3	0.07	0.05	0.07	0.07	0.05	0.05
4	0.06	0.04	0.06	0.03	0.06	0.04
5	0.06	0.05	0.06	0.06	0.05	0.05
6	0.06	0.05	0.06	0.05	0.05	0.05
7	0.06	0.05	0.05	0.05	0.05	0.05
8	0.06	0.05	0.06	0.04	0.06	0.04
9	0.05	0.06	0.05	0.05	0.06	0.05
10	0.05	0.06	0.05	0.04	0.05	0.05
11	0.05	0.06	0.05	0.08	0.05	0.05
12	0.04	0.05	0.05	0.06	0.05	0.05
13	0.04	0.05	0.04	0.07	0.05	0.04
14	0.04	0.05	0.04	0.04	0.04	0.05
15	0.03	0.05	0.04	0.06	0.04	0.05
16	0.03	0.04	0.03	0.02	0.04	0.04
17	0.02	0.03	0.02	0.06	0.03	0.04
18	0.02	0.03	0.02	0.04	0.03	0.03
19	0.01	0.02	0.02	0.01	0.02	0.03
20	0.01	0.02	0.01	0.03	0.02	0.03
21	0.01	0.02	0.01	0.00	0.01	0.02
22	0.01	0.01	0.01	0.01	0.01	0.02
23	0.01	0.01	0.01	0.00	0.01	0.02
24	0.01	0.01	0.01	0.01	0.01	0.01
25	0.00	0.00	0.00	0.01	0.00	0.01
26	0.00	0.00	0.00	0.00	0.00	0.01
27	0.00	0.00	0.00	0.00	0.00	0.01
28	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 29: LIGHT VEHICLE AGE AT TIME OF CRASH DISTRIBUTION ACROSS MINOR INJURY CRASHES

Vehicle age at time of crash	Light vehicle					
	Non-Sensitive	Narrow Sensitivity	Pedestrian Sensitivity	Hit Bicycle	Broad Sensitivity-multivehicle	Broad Sensitivity-single vehicle
0	0.03	0.02	0.02	0.05	0.02	0.01
1	0.07	0.05	0.07	0.06	0.06	0.04
2	0.07	0.05	0.07	0.04	0.06	0.05
3	0.07	0.05	0.07	0.07	0.06	0.05
4	0.06	0.05	0.06	0.09	0.06	0.04
5	0.06	0.05	0.08	0.04	0.06	0.04
6	0.06	0.06	0.07	0.08	0.06	0.04
7	0.06	0.06	0.06	0.05	0.06	0.05
8	0.06	0.06	0.05	0.05	0.06	0.05
9	0.06	0.06	0.06	0.06	0.05	0.05
10	0.06	0.06	0.05	0.05	0.06	0.05
11	0.05	0.05	0.04	0.03	0.05	0.05
12	0.04	0.05	0.04	0.06	0.05	0.05
13	0.04	0.05	0.04	0.03	0.05	0.05
14	0.04	0.04	0.04	0.03	0.04	0.05
15	0.03	0.04	0.03	0.04	0.04	0.05
16	0.03	0.04	0.03	0.04	0.04	0.05
17	0.02	0.03	0.03	0.04	0.03	0.05
18	0.02	0.03	0.02	0.01	0.02	0.03
19	0.01	0.02	0.01	0.04	0.02	0.03
20	0.01	0.02	0.01	0.01	0.02	0.03
21	0.01	0.01	0.01	0.03	0.01	0.02
22	0.01	0.01	0.01	0.01	0.01	0.02
23	0.01	0.01	0.01	0.01	0.01	0.01
24	0.00	0.01	0.00	0.01	0.01	0.01
25	0.00	0.01	0.00	0.01	0.00	0.01
26	0.00	0.00	0.00	0.01	0.00	0.00

TABLE 30: LIGHT VEHICLE AGE AT TIME OF CRASH DISTRIBUTION ACROSS NO INJURY CRASHES

	Light vehicle					
Vehicle age at time of crash	**Non-Sensitive**	**Narrow Sensitivity**	**Pedestrian Sensitivity**	**Hit Bicycle**	**Broad Sensitivity-multivehicle**	**Broad Sensitivity-single vehicle**
0	0.02	0.01	0.02	0.01	0.02	0.02
1	0.07	0.04	0.04	0.04	0.05	0.06
2	0.07	0.05	0.05	0.03	0.05	0.05
3	0.06	0.04	0.05	0.04	0.05	0.05
4	0.07	0.05	0.07	0.04	0.05	0.05
5	0.07	0.05	0.09	0.03	0.06	0.05
6	0.07	0.06	0.08	0.06	0.06	0.04
7	0.07	0.06	0.07	0.06	0.06	0.05
8	0.07	0.06	0.07	0.06	0.06	0.05
9	0.06	0.06	0.07	0.06	0.06	0.06
10	0.06	0.06	0.05	0.03	0.06	0.06
11	0.05	0.06	0.05	0.09	0.05	0.05
12	0.04	0.05	0.06	0.07	0.05	0.05
13	0.04	0.05	0.03	0.04	0.05	0.05
14	0.03	0.05	0.04	0.04	0.04	0.04
15	0.03	0.04	0.02	0.03	0.04	0.04
16	0.03	0.04	0.02	0.04	0.04	0.04
17	0.02	0.03	0.03	0.03	0.03	0.04
18	0.02	0.03	0.02	0.01	0.02	0.03
19	0.01	0.02	0.01	0.06	0.02	0.03
20	0.01	0.02	0.01	0.00	0.02	0.02
21	0.01	0.02	0.00	0.06	0.01	0.02
22	0.01	0.01	0.02	0.00	0.01	0.01
23	0.01	0.01	0.01	0.03	0.01	0.01
24	0.00	0.01	0.00	0.00	0.01	0.01
25	0.00	0.01	0.00	0.00	0.00	0.01
26	0.00	0.00	0.00	0.00	0.00	0.00

A.3 LIGHT VEHICLE RELATIVE INJURY RISK RESULTS WHICH CONSIDER AEB DESIGN WITH RESPECT TO SPEED

TABLE 31: OVERALL RELATIVE INJURY RISK ASSOCIATED WITH AEB IN VEHICLES MANUFACTURED FROM 2013, OVER 2013 TO 2016

	All Injuries	Fatal and Serious Injuries	Minor Injuries
Fitment	**Narrowly sensitive**		
ALL	0.79 (0.50 1.26) p=0.32	0.27 (0.03 2.14) p=0.21	0.86 (0.53 1.38) p=0.52
SOME	0.77 (0.68 0.86) p=<.0001	0.59 (0.42 0.82) p=0.002	0.80 (0.70 0.91) p=0.0007
	Pedestrian sensitive vehicle		
ALL	1.50 (0.80 2.81) p=0.20	1.80 (0.64 5.05) p=0.26	1.26 (0.50 3.20) p=0.62
SOME	0.88 (0.71 1.08) p=0.21	0.97 (0.72 1.32) p=0.86	0.69 (0.50 0.94) p=0.02
	Broadly sensitive vehicle		
ALL	1.08 (0.78 1.49) p=0.64	1.57 (0.73 3.37) p=0.25	0.93 (0.63 1.35) p=0.69
SOME	0.89 (0.82 0.97) p=0.01	0.86 (0.71 1.04) p=0.11	0.88 (0.80 0.97) p=0.01

TABLE 32: RELATIVE INJURY RISK ASSOCIATED WITH VEHICLES WITH SOME VARIANTS OF THE MODEL WITH AEB, BY SPEED ZONE

	All Injuries	Fatal and Serious Injuries†	Minor Injuries
	Narrowly sensitive		
≤60 km/hr zone	0.78 (0.68 0.89) p=0.0002	0.66 (0.44 0.97) p=0.04	0.80 (0.69 0.92) p=0.002
>60 km/hr zone	0.70 (0.52 0.94) p=0.02	0.42 (0.20 0.86) p=0.01	0.81 (0.58 1.12) p=0.20
	Pedestrian sensitive vehicle		
≤60 km/hr zone	0.87 (0.71 1.08) p=0.21	1.04 (0.75 1.44) p=0.81	0.66 (0.48 0.92) p=0.01
>60 km/hr zone	0.83 (0.30 2.30) p=0.72	0.47 (0.11 1.98) p=0.30	1.52 (0.36 6.51) p=0.57
	Broadly sensitive vehicle		
≤60 km/hr zone	0.89 (0.81 0.98) p=0.01	0.90 (0.71 1.13) p=0.34	0.87 (0.78 0.97) p=0.01
>60 km/hr zone	0.92 (0.75 1.13) p=0.43	0.77 (0.54 1.10) p=0.15	0.94 (0.72 1.23) p=0.65

†Analysis performed without commercial vehicles.

A.4 HEAVY VEHICLE AGE DISTRIBUTION ACROSS VEHICLE SENSITIVITY AND CRASH SEVERITY

TABLE 33: HEAVY VEHICLE AGE AT TIME OF CRASH DISTRIBUTION ACROSS ALL SEVERITY CRASHES

	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
Vehicle age at time of crash	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
0	0.05	0.00	0.02	0.04	0.01	0.02	0.01	0.00	0.03	0.05	0.02	0.02
1	0.07	0.22	0.05	0.07	0.05	0.04	0.03	0.00	0.08	0.10	0.06	0.07
2	0.04	0.22	0.03	0.07	0.05	0.04	0.08	0.06	0.06	0.10	0.08	0.05
3	0.12	0.11	0.04	0.08	0.06	0.03	0.06	0.06	0.06	0.10	0.05	0.06
4	0.08	0.00	0.05	0.07	0.05	0.04	0.09	0.22	0.07	0.08	0.05	0.07
5	0.01	0.00	0.08	0.07	0.06	0.05	0.10	0.00	0.06	0.07	0.07	0.04
6	0.05	0.11	0.06	0.06	0.07	0.09	0.08	0.00	0.08	0.06	0.09	0.07
7	0.09	0.00	0.08	0.05	0.07	0.07	0.08	0.17	0.05	0.05	0.07	0.05
8	0.07	0.00	0.05	0.06	0.07	0.07	0.03	0.17	0.05	0.04	0.06	0.05
9	0.05	0.00	0.03	0.05	0.06	0.08	0.03	0.00	0.05	0.04	0.07	0.09
10	0.02	0.00	0.03	0.05	0.06	0.05	0.02	0.11	0.02	0.03	0.06	0.07
11	0.04	0.00	0.02	0.05	0.05	0.04	0.05	0.00	0.04	0.03	0.04	0.06
12	0.06	0.00	0.04	0.04	0.04	0.05	0.05	0.00	0.04	0.03	0.04	0.04
13	0.01	0.11	0.03	0.03	0.03	0.04	0.02	0.06	0.07	0.03	0.03	0.02

Vehicle age at time of crash	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
14	0.03	0.00	0.05	0.04	0.04	0.04	0.03	0.00	0.05	0.02	0.03	0.03
15	0.01	0.00	0.03	0.03	0.03	0.03	0.00	0.00	0.02	0.02	0.03	0.03
16	0.04	0.00	0.01	0.02	0.04	0.04	0.03	0.00	0.01	0.02	0.02	0.02
17	0.02	0.00	0.04	0.02	0.03	0.02	0.02	0.06	0.02	0.02	0.02	0.02
18	0.02	0.11	0.02	0.01	0.02	0.01	0.03	0.06	0.01	0.01	0.02	0.01
19	0.03	0.00	0.02	0.02	0.02	0.03	0.03	0.06	0.00	0.02	0.01	0.01
20	0.03	0.00	0.02	0.01	0.02	0.02	0.03	0.00	0.02	0.02	0.01	0.03
21	0.04	0.00	0.00	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.01	0.01
22	0.00	0.00	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
23	0.01	0.00	0.01	0.01	0.01	0.02	0.03	0.00	0.01	0.01	0.01	0.01
24	0.00	0.00	0.02	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01
25	0.00	0.00	0.03	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.02
26	0.01	0.00	0.03	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01
27	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
28	0.01	0.00	0.03	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01
29	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00

Vehicle age at time of crash	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
31	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 34: HEAVY VEHICLE AGE AT TIME OF CRASH DISTRIBUTION ACROSS FATALITY CRASHES

	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
Vehicle age at time of crash	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
0				0.14	0.00	0.00	0.00		0.00	0.00	0.00	0.14
1				0.00	0.05	0.00	0.00		0.00	0.38	0.07	0.00
2				0.14	0.09	0.25	0.00		0.00	0.00	0.07	0.00
3				0.00	0.09	0.00	0.00		0.00	0.00	0.00	0.00
4				0.00	0.18	0.00	0.00		0.00	0.00	0.07	0.29
5				0.00	0.00	0.25	0.00		0.00	0.00	0.03	0.00
6				0.14	0.00	0.00	0.00		0.00	0.00	0.10	0.43
7				0.00	0.09	0.25	0.00		0.00	0.13	0.07	0.00
8				0.00	0.09	0.00	0.00		0.00	0.13	0.07	0.00
9				0.00	0.05	0.00	0.00		0.25	0.13	0.10	0.00
10				0.00	0.05	0.00	0.00		0.00	0.00	0.07	0.14
11				0.29	0.05	0.00	0.00		0.00	0.00	0.03	0.00
12				0.00	0.00	0.00	0.00		0.00	0.00	0.07	0.00
13				0.14	0.05	0.25	0.00		0.00	0.00	0.03	0.00
14				0.00	0.05	0.00	0.00		0.00	0.00	0.03	0.00

Vehicle age at time of crash	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
	Bus >=9 seats and < 4.5tonn e	Bus >=9 seats and <4.5 tonne or <25 seats	Unknow n weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknow n weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknow n weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknow n weight heavy
15				0.00	0.00	0.00	0.00		0.00	0.00	0.03	0.00
16				0.00	0.05	0.00	0.00		0.00	0.13	0.03	0.00
17				0.00	0.05	0.00	0.00		0.00	0.00	0.00	0.00
18				0.00	0.00	0.00	0.50		0.00	0.00	0.00	0.00
19				0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
20				0.00	0.00	0.00	0.00		0.00	0.13	0.00	0.00
21				0.14	0.00	0.00	0.00		0.00	0.00	0.00	0.00
22				0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
23				0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
24				0.00	0.00	0.00	0.00		0.00	0.00	0.03	0.00
25				0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
26				0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
27				0.00	0.05	0.00	0.00		0.25	0.00	0.07	0.00
28				0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
29				0.00	0.05	0.00	0.00		0.00	0.00	0.00	0.00

TABLE 35: HEAVY VEHICLE AGE AT TIME OF CRASH DISTRIBUTION ACROSS SERIOUS INJURY CRASHES

	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
Vehicle age at time of crash	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
0	0.00		0.04	0.06	0.03	0.01	0.00	0.00	0.04	0.04	0.02	0.02
1	0.23		0.00	0.08	0.07	0.04	0.03	0.00	0.07	0.09	0.05	0.06
2	0.15		0.04	0.08	0.08	0.05	0.03	0.00	0.07	0.08	0.07	0.08
3	0.00		0.15	0.07	0.08	0.06	0.03	0.20	0.09	0.08	0.06	0.02
4	0.08		0.04	0.07	0.06	0.03	0.12	0.00	0.00	0.07	0.05	0.06
5	0.08		0.08	0.03	0.08	0.05	0.12	0.00	0.05	0.06	0.07	0.02
6	0.00		0.04	0.06	0.07	0.08	0.09	0.00	0.07	0.08	0.08	0.09
7	0.00		0.00	0.04	0.06	0.08	0.09	0.00	0.09	0.04	0.06	0.05
8	0.15		0.00	0.06	0.06	0.04	0.00	0.60	0.09	0.05	0.08	0.06
9	0.15		0.04	0.07	0.04	0.06	0.09	0.00	0.07	0.05	0.08	0.11
10	0.00		0.00	0.03	0.06	0.06	0.03	0.00	0.04	0.04	0.07	0.02
11	0.00		0.12	0.04	0.05	0.07	0.09	0.00	0.09	0.03	0.06	0.07
12	0.00		0.04	0.04	0.02	0.08	0.03	0.00	0.02	0.03	0.03	0.02
13	0.00		0.04	0.02	0.01	0.04	0.03	0.00	0.02	0.03	0.05	0.03
14	0.08		0.08	0.04	0.02	0.01	0.00	0.00	0.04	0.03	0.01	0.04

	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
Vehicle age at time of crash	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
15	0.00		0.00	0.03	0.04	0.01	0.03	0.00	0.00	0.02	0.04	0.02
16	0.00		0.08	0.02	0.03	0.05	0.03	0.00	0.02	0.01	0.02	0.01
17	0.00		0.00	0.02	0.01	0.05	0.06	0.00	0.02	0.01	0.01	0.03
18	0.08		0.08	0.01	0.01	0.04	0.03	0.00	0.00	0.01	0.03	0.01
19	0.00		0.00	0.02	0.02	0.02	0.03	0.20	0.02	0.03	0.00	0.01
20	0.00		0.00	0.01	0.02	0.02	0.00	0.00	0.02	0.03	0.01	0.01
21	0.00		0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.02	0.01	0.01
22	0.00		0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.01
23	0.00		0.00	0.01	0.00	0.02	0.06	0.00	0.02	0.01	0.00	0.01
24	0.00		0.04	0.01	0.01	0.04	0.00	0.00	0.02	0.03	0.00	0.01
25	0.00		0.08	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00
26	0.00		0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.01	0.01	0.00
27	0.00		0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00
28	0.00		0.04	0.01	0.01	0.01	0.00	0.00	0.02	0.00	0.01	0.01
29	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03
30	0.00		0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
31	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00

Vehicle age at time of crash	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
32	0.00		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00		0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
35	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
36	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00		0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00

TABLE 36: HEAVY VEHICLE AGE AT TIME OF CRASH DISTRIBUTION ACROSS MINOR INJURY CRASHES

	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
Vehicle age at time of crash	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
0	0.03	0.00	0.02	0.04	0.01	0.02	0.00	0.00	0.03	0.05	0.02	0.02
1	0.09	0.00	0.02	0.07	0.05	0.06	0.02	0.00	0.06	0.10	0.08	0.06
2	0.06	0.00	0.02	0.08	0.04	0.04	0.08	0.20	0.06	0.10	0.09	0.09
3	0.09	0.20	0.05	0.07	0.06	0.05	0.10	0.00	0.07	0.10	0.05	0.06
4	0.04	0.00	0.07	0.07	0.05	0.04	0.06	0.00	0.13	0.09	0.05	0.08
5	0.01	0.00	0.07	0.07	0.06	0.05	0.10	0.00	0.06	0.07	0.09	0.05
6	0.04	0.20	0.05	0.06	0.07	0.06	0.05	0.00	0.11	0.06	0.09	0.08
7	0.10	0.00	0.11	0.05	0.06	0.08	0.11	0.20	0.05	0.05	0.06	0.02
8	0.04	0.00	0.04	0.05	0.07	0.06	0.05	0.00	0.03	0.05	0.06	0.08
9	0.07	0.00	0.05	0.06	0.07	0.08	0.02	0.00	0.05	0.04	0.06	0.07
10	0.01	0.00	0.03	0.06	0.06	0.05	0.03	0.00	0.07	0.02	0.05	0.05
11	0.03	0.00	0.02	0.05	0.06	0.05	0.03	0.00	0.05	0.03	0.04	0.08
12	0.04	0.00	0.02	0.04	0.04	0.05	0.06	0.00	0.06	0.03	0.05	0.03

Vehicle age at time of crash	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
13	0.01	0.20	0.02	0.03	0.03	0.04	0.05	0.20	0.07	0.03	0.03	0.01
14	0.03	0.00	0.04	0.04	0.03	0.05	0.03	0.00	0.02	0.01	0.02	0.04
15	0.01	0.00	0.01	0.03	0.02	0.03	0.00	0.00	0.01	0.03	0.02	0.04
16	0.03	0.00	0.01	0.02	0.03	0.03	0.02	0.00	0.00	0.02	0.01	0.01
17	0.04	0.00	0.05	0.01	0.02	0.02	0.05	0.20	0.00	0.02	0.01	0.02
18	0.03	0.20	0.04	0.02	0.02	0.02	0.06	0.20	0.01	0.02	0.01	0.01
19	0.03	0.00	0.04	0.01	0.02	0.02	0.02	0.00	0.00	0.01	0.02	0.01
20	0.01	0.00	0.02	0.01	0.01	0.02	0.02	0.00	0.00	0.01	0.00	0.01
21	0.06	0.00	0.02	0.01	0.01	0.01	0.00	0.00	0.02	0.01	0.01	0.00
22	0.00	0.00	0.02	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.01
23	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01
24	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
25	0.00	0.00	0.03	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.00
26	0.01	0.00	0.02	0.01	0.01	0.01	0.02	0.00	0.01	0.00	0.01	0.02
27	0.00	0.00	0.03	0.00	0.01	0.01	0.02	0.00	0.00	0.01	0.01	0.00

Vehicle age at time of crash	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
28	0.03	0.00	0.02	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.01	0.00
29	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
36	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
38	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 37: HEAVY VEHICLE AGE AT TIME OF CRASH DISTRIBUTION ACROSS NO INJURY CRASHES

	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
Vehicle age at time of crash	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
0	0.08	0.00	0.02	0.04	0.01	0.02	0.01	0.00	0.03	0.05	0.02	0.02
1	0.03	0.50	0.06	0.07	0.04	0.04	0.03	0.00	0.08	0.11	0.06	0.07
2	0.00	0.50	0.03	0.06	0.04	0.04	0.09	0.00	0.06	0.10	0.08	0.04
3	0.17	0.00	0.03	0.08	0.06	0.02	0.06	0.00	0.05	0.10	0.05	0.07
4	0.11	0.00	0.05	0.08	0.05	0.05	0.10	0.50	0.07	0.07	0.05	0.06
5	0.00	0.00	0.08	0.07	0.05	0.05	0.10	0.00	0.07	0.07	0.06	0.05
6	0.06	0.00	0.07	0.06	0.07	0.11	0.09	0.00	0.07	0.05	0.09	0.06
7	0.08	0.00	0.07	0.05	0.08	0.05	0.07	0.25	0.04	0.05	0.08	0.06
8	0.08	0.00	0.06	0.06	0.07	0.08	0.03	0.00	0.04	0.03	0.06	0.04
9	0.00	0.00	0.02	0.05	0.06	0.07	0.03	0.00	0.05	0.04	0.07	0.09
10	0.03	0.00	0.03	0.05	0.06	0.04	0.01	0.25	0.01	0.04	0.06	0.08
11	0.06	0.00	0.02	0.04	0.05	0.03	0.04	0.00	0.03	0.03	0.04	0.05
12	0.08	0.00	0.05	0.04	0.04	0.05	0.04	0.00	0.04	0.03	0.04	0.04
13	0.00	0.00	0.04	0.02	0.03	0.04	0.00	0.00	0.08	0.02	0.03	0.03

Vehicle age at time of crash	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
14	0.03	0.00	0.06	0.04	0.04	0.03	0.04	0.00	0.06	0.02	0.03	0.03
15	0.00	0.00	0.03	0.03	0.03	0.03	0.00	0.00	0.03	0.02	0.03	0.03
16	0.06	0.00	0.01	0.02	0.04	0.05	0.04	0.00	0.01	0.02	0.02	0.02
17	0.00	0.00	0.03	0.02	0.03	0.01	0.00	0.00	0.03	0.02	0.03	0.02
18	0.00	0.00	0.01	0.01	0.02	0.01	0.00	0.00	0.01	0.02	0.02	0.01
19	0.03	0.00	0.02	0.03	0.02	0.03	0.03	0.00	0.00	0.02	0.01	0.02
20	0.06	0.00	0.02	0.01	0.02	0.01	0.04	0.00	0.02	0.02	0.01	0.03
21	0.03	0.00	0.00	0.02	0.01	0.01	0.03	0.00	0.00	0.01	0.01	0.01
22	0.00	0.00	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00
23	0.03	0.00	0.02	0.01	0.01	0.02	0.03	0.00	0.01	0.00	0.01	0.01
24	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01
25	0.00	0.00	0.02	0.00	0.01	0.03	0.01	0.00	0.01	0.00	0.01	0.02
26	0.00	0.00	0.03	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01
27	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.03	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01

Vehicle age at time of crash	Narrowly sensitive vehicles						Non- sensitive vehicles					
	Bus, plant or agricultural use			Goods or <9 seat heavy vehicle			Bus, plant or agricultural use			Goods or <9 seat heavy vehicle		
	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy	Bus >=9 seats and < 4.5tonne	Bus >=9 seats and <4.5 tonne or <25 seats	Unknown weight category	Goods: >3.5 tonne to <=12 tonne	Prime mover, semi and road trains >12 tonne (where weight is known)	Unknown weight heavy
29	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
33	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00

A.5 ADDITIONAL TABLE FOR HEAVY VEHICLE INJURY SEVERITY ACROSS CRASHES

TABLE 38: AVERAGE ANNUAL INFLATED COUNTS OF FATAL, SERIOUS AND MINOR INJURY CRASHED HEAVY VEHICLES (2013-2016) OVERALL AND BY VEHICLE GROUPS

Crashed vehicles		All crashed vehicles	Narrowly sensitive	% of all
Fatal crashes	Large bus	7	0	0
	Small bus	0	0	
	Unknown bus	8	0	0
	All Bus	16	0	0
	Rigid ≤ 12t	72	2	3
	Articulated and >12t	135	7	5
	Unknown weight	38	1	3
	All truck	245	10	4
	All heavy vehicle	261	10	4
Crashed vehicles		All crashed vehicles	Narrowly sensitive	% of all
Serious injury crashes	Large bus	84	4	5
	Small bus	5	0	0
	Unknown bus	147	8	5
	All Bus	235	12	5
	Rigid ≤ 12t	840	84	10
	Articulated and >12t	826	90	11
	Unknown weight	271	34	13
	All truck	1937	208	11
	All heavy vehicle	2173	219	10
Crashed vehicles		**All crashed Vehicles**	**Narrowly sensitive**	**% of all**
Minor injury crashes	Large bus	179	21	12
	Small bus	7	1	19
	Unknown bus	244	38	16
	All Bus	430	60	14
	Rigid ≤ 12t	1712	347	20
	Articulated and >12t	1215	269	22

	Unknown weight	578	138	24
	All truck	3504	753	21
	All heavy vehicle	3934	814	21

A.6 AN EXPLANATION NOTE FOR INFLATION FACTORS

This analysis used injury crash data from five jurisdictions and 'property damage only' crash data from three, so in order to quantify the potential benefits of AEB nationwide, the data needed to be inflated. New vehicle sales, motor vehicle registrations and national fatality data were used to construct an estimate of the order of magnitude that statistics from the available crash data differs from nationwide estimates.

The 2018 Australian Road Deaths database published by BITRE (Bureau of Infrastructure Transport and Regional Economics [BITRE] 2018) shows that the fatalities for all of Australia over 2013 to 2015 were 1.08 times greater than those over the same period for only the five jurisdictions.

The Australian New Vehicle Sales (spreadsheet 931402.xls formerly at http://www.abs.gov.au/ausstats/abs@.nsf/mf/9314.0 now at https://www.fcai.com.au/sales) showed that new passenger vehicles for all of Australia were 2.06 times greater than the sum of new passenger vehicles over 2013-2015 for the three jurisdictions; and 1.04 times higher than those for all five jurisdictions. For heavy vehicles the factors were 2.12 and 1.05 respectively.

Finally, the Australian Bureau of Statistics Motor Vehicle Census (Australian Bureau of Statistics 2018) light vehicle registrations of 2013 to 2015 were 1.05 times greater for all of Australia than for the sum of the five jurisdictions. The same was true for heavy vehicles. Light vehicle registrations for just WA, NSW and SA required a 2.06 inflation to match those of Australia for the same period. By vehicle type, the three jurisdictional sum of registrations required a 2.24 inflation for campervans, a 2.17 inflation for light commercials, a 2.03 inflation for light rigid trucks, a 2.01 inflation for heavy rigid trucks, a 2.16 inflation for articulated trucks and a 2.07 inflation for buses.

Thus the exposure (as measured by registrations) was 1.05 times higher for both light and heavy vehicles when inflating for the five jurisdictions with non-fatal injuries and non-fatal injury crashes. Fatalities and fatal crashes were inflated by 1.08; a value derived by using road deaths as the exposure. The exposures of both registrations and new vehicle sales led to an inflation of 2.06 for light vehicle property damage only crashes, as these were derived from only three jurisdictions. For heavy vehicles, the New Vehicle Sales derived 2.12 was used, which seemed not only to average the factors for the heavy vehicle types of the registration derived inflation factors, but also reflect that AEB will likely be in new vehicles only.

A.7 CONFOUNDER ANALYSIS FOR LIGHT PASSENGER VEHICLES

The distributions of the following variables amongst sensitive and non-sensitive vehicles were explored for the potential to bias the overall estimates of relative injury risk through confounding: driver age, driver sex, vehicle group, road conditions, weather, ESC fitment, Brake Assist fitment, jurisdiction, crash year, intersection location, and road curvature. Very small, but significant[5] differences in class proportions for the narrowly sensitive and the sensitive vehicle sets were common, however the differences for a handful of these were larger and significant.

This following section of this report examines the confounding potential for driver age and sex, vehicle market group and intersection location. These variables showed the largest significant differences.

The confounding potential within the broad/pedestrian sensitive crashed vehicle analysis was not a priority for this analysis. The types of crashes used in broadly (and pedestrian) sensitive crashes are quite different in nature to the narrowly sensitive set, so their analyses have been accepted as likely to have sources of bias not present in the narrowly sensitive analysis. The non-sensitive set cannot match both narrowly and broadly sensitive crashed vehicle sets well. The charts in this section illustrate the differences for drivers' age, drivers' sex, vehicles' type or size and intersection location.

A.7.1 Market group/ Vehicle size

Utilities and vans are present in the narrowly sensitive vehicle set in greater proportions and cars represent lesser proportions than in the non-sensitive vehicle set. This has led to an examination of the distribution of broad vehicle groups within AEB fitment and sensitivity groups (see FIGURE 8. As is shown in FIGURE 9, commercial vehicles are very poorly represented in the AEB fitment groups and if AEB fitment had a different level of effectiveness in this group, regression analysis without stratification would definitely lead to bias. However, it may also be true that commercial vehicles are too poorly represented in the AEB fitted group to be included in the analysis. There is only a small proportion of commercial vehicles in the narrowly sensitive "some" fitment group.

[5] Comparison of column proportions using a significance level of 0.05 with Bonferroni adjustments.

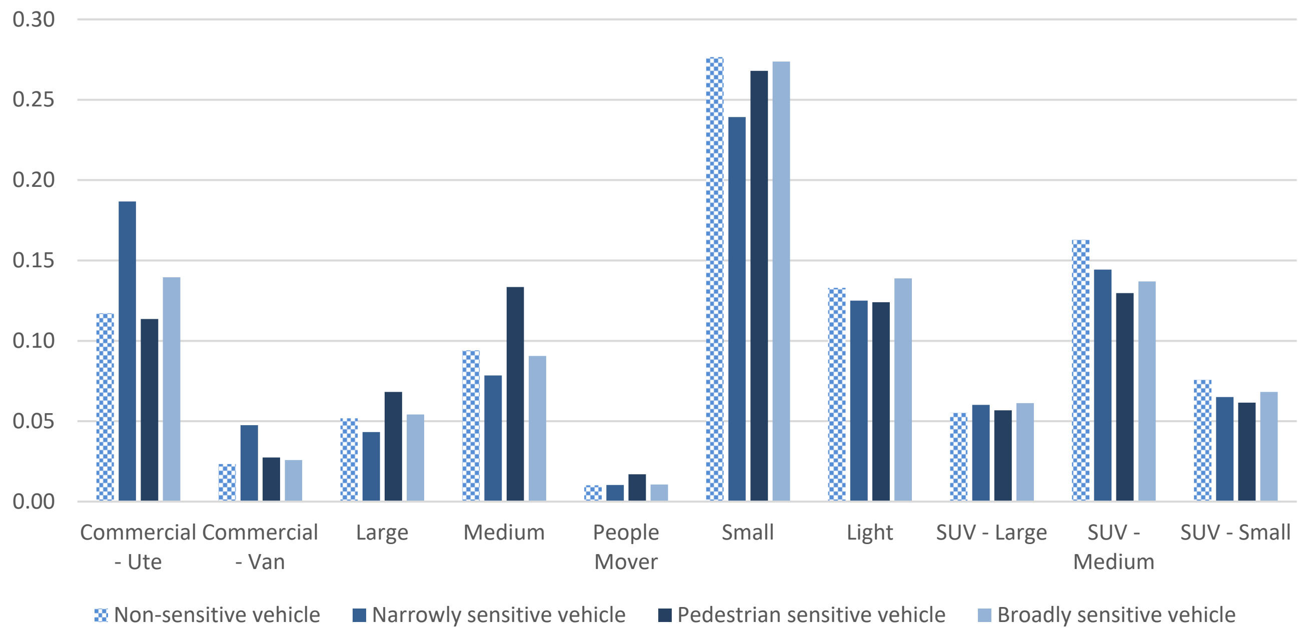


FIGURE 8: PROPORTION OF VEHICLE TYPE WITHIN VEHICLE SENSITIVITY CLASSES OF THE LIGHT VEHICLE RELATIVE RISK ANALYSIS SET

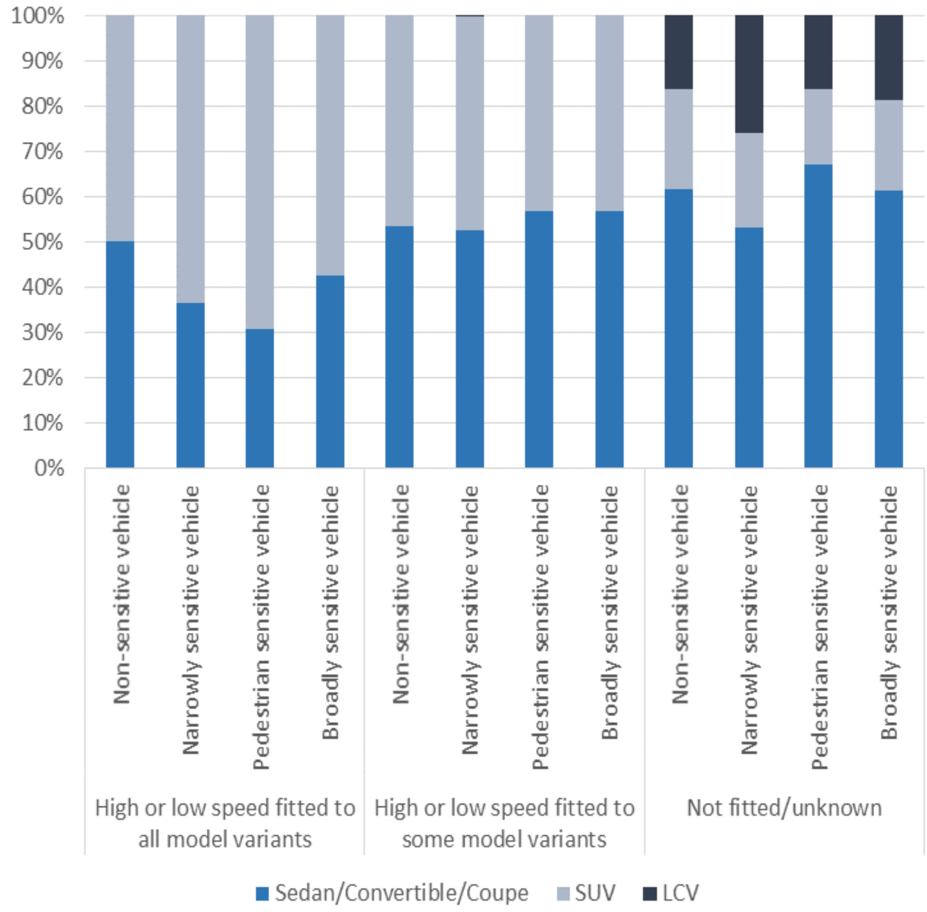


FIGURE 9: PROPORTION OF BROAD VEHICLE TYPE WITHIN VEHICLE SENSITIVITY AND AEB FITMENT SUB-SETS

A sensitivity analysis was carried out without this vehicle group using different alternative stratification variables (with speed zone). The distribution of vehicle groups without commercial utilities and vans is uniform amongst the sensitivity groups within the *not fitted* and the *some fitted* classes (FIGURE 10). Although there are some differences in proportions between the narrowly sensitive and non-sensitive groups of the *all fitted* classes, the quantified differences are very small and unlikely to induce any bias in overall estimates. Given the uniformity, a sensitivity analysis was attempted using intersection, road surface, driver age and driver sex, rather than vehicle group to explore other confounding effects.

The relative injury risk was found to be robust to different stratification methods which suggested that bias from these potential confounders is insignificant relative to the confidence intervals of the estimates (FIGURE 11). Speed zone and one other confounding variable were used to stratify the datasets prior to analysis. When variables other than vehicle size were chosen, commercial utilities were not included, so that the potential bias from commercial vehicles could be avoided. The quantities of commercial vehicles with AEB created more of a nuisance than a measurable level, so their removal from the data was considered acceptable for this sensitivity analysis. When stratified by vehicle size and speed zone, removal of commercial vehicles had the effect of widening the confidence interval without effecting the estimate. When stratified by speed zone and sex, road surface or intersection location, the relative injury risk for models with some variants fitted with AEB differed only by 0.02, which was one eighth of the 95% confidence interval associated with the estimates. The conclusion is that there is poor evidence of significant confounding bias from these variables to the overall estimate of the benefits of AEB fitted to some variants.

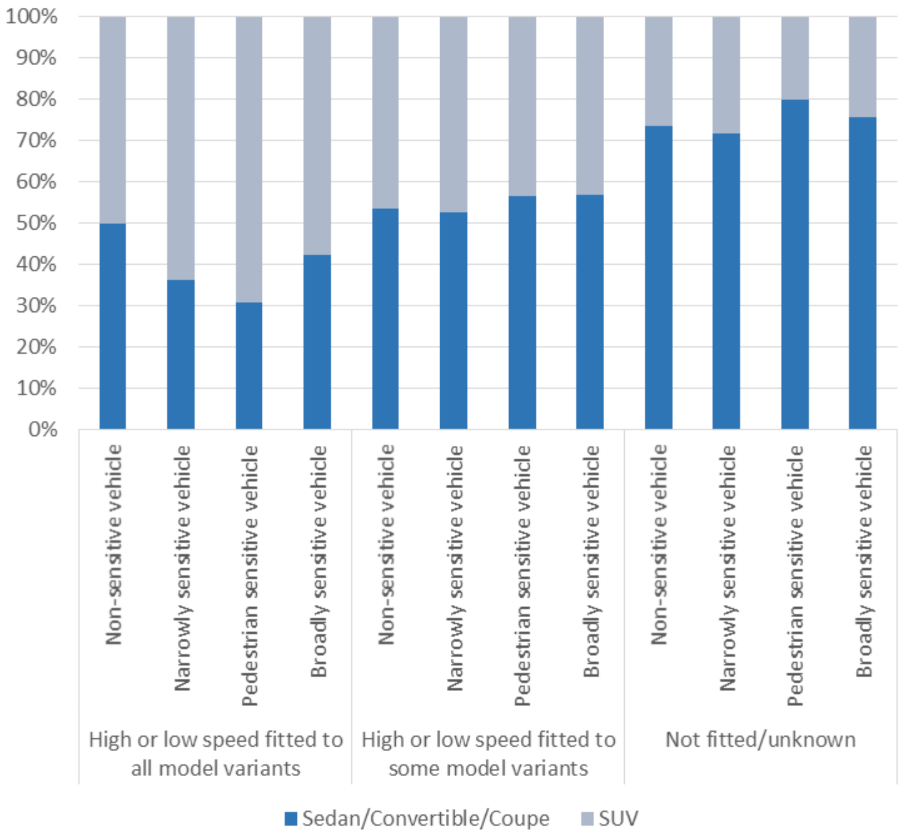


FIGURE 10: PROPORTION OF BROAD VEHICLE TYPE WITHIN VEHICLE SENSITIVITY AND AEB FITMENT CLASSES (NO COMMERCIALS)

FIGURE 11: RELATIVE INJURY RISK FOR NARROWLY SENSITIVE VEHICLE MODELS WITH SOME VARIANTS FITTED WITH AEB USING DATA STRATIFIED IN DIFFERENT WAYS

A.7.2 Driver Age

Driver age is significantly lower in the narrowly sensitive group than in the non-sensitive group (FIGURE 12), and the distribution is similar within the *some fitment* and the *no fitment* classes (FIGURE 13). The differences, although not large, appear to be predominately between the under 25 and over 25 groups, with greater similarity in the distribution of older drivers. This means that the non-sensitive crashes have greater representation both in the younger and older age groups.

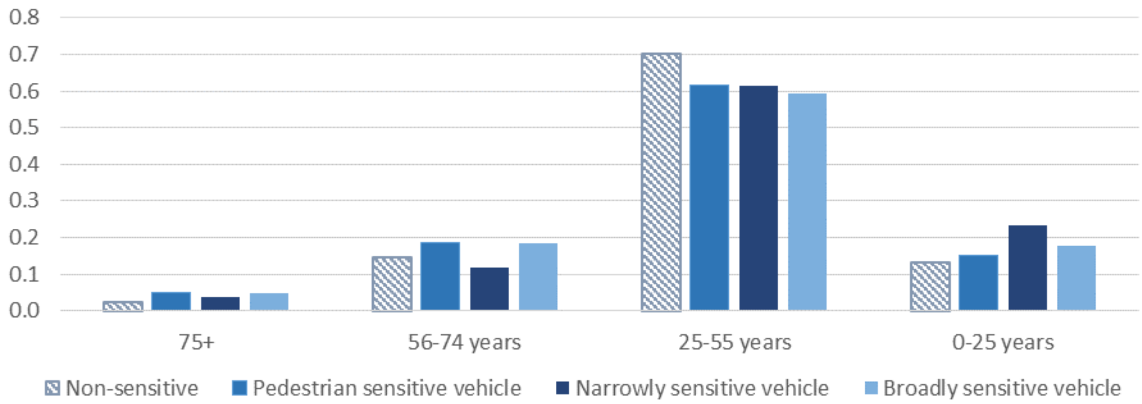


FIGURE 12: PROPORTION OF DRIVER AGE WITHIN VEHICLE SENSITIVITY CLASSES OF THE LIGHT VEHICLE RELATIVE RISK ANALYSIS SET

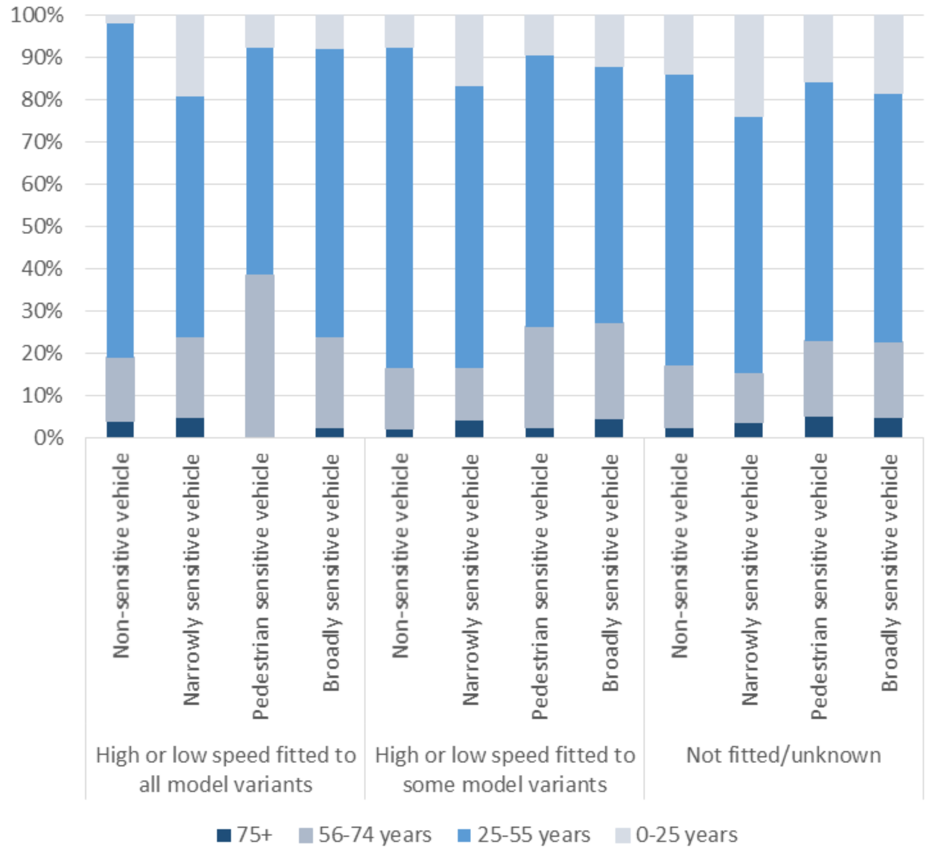


FIGURE 13: PROPORTION OF DRIVER AGE WITHIN VEHICLE SENSITIVITY AND AEB FITMENT CLASSES

Analysis stratified by age and speed zone found that although not significantly different from one (no AEB effect), drivers aged 25 and under, of models with some variant fitment were associated with a relative risk of injury significantly different from 0.78, the overall point estimate. This relative risk was estimated at 1.07 (95% CI 01.79 to 1.43, p=0.7). It may be seen in FIGURE 14, that the risk associated with drivers aged greater than 25 years is similar and likely to be different from that for drivers aged 25 and under. The 95% confidence intervals are smaller for the age groups with more occupants, and all confidence interval bands overlap with 0.80, however, the three older age groups appear representative of a similar but different associated risk. The common underlying risk appears to be greater than the risk estimated using vehicle size stratification shown in blue (0.78).

The overall estimator therefore is pulled in both directions by opposing confounding influences from the distributional differences of the narrowly sensitive and non-sensitive vehicle groups, which are likely to cancel each other out to some degree. The somewhat larger risk estimates of the drivers aged under 55 is representing a proportionally large age group, so its influence will likely overpower the lower risk estimates of the older drivers and may result in a small over-estimation of AEB effectiveness.

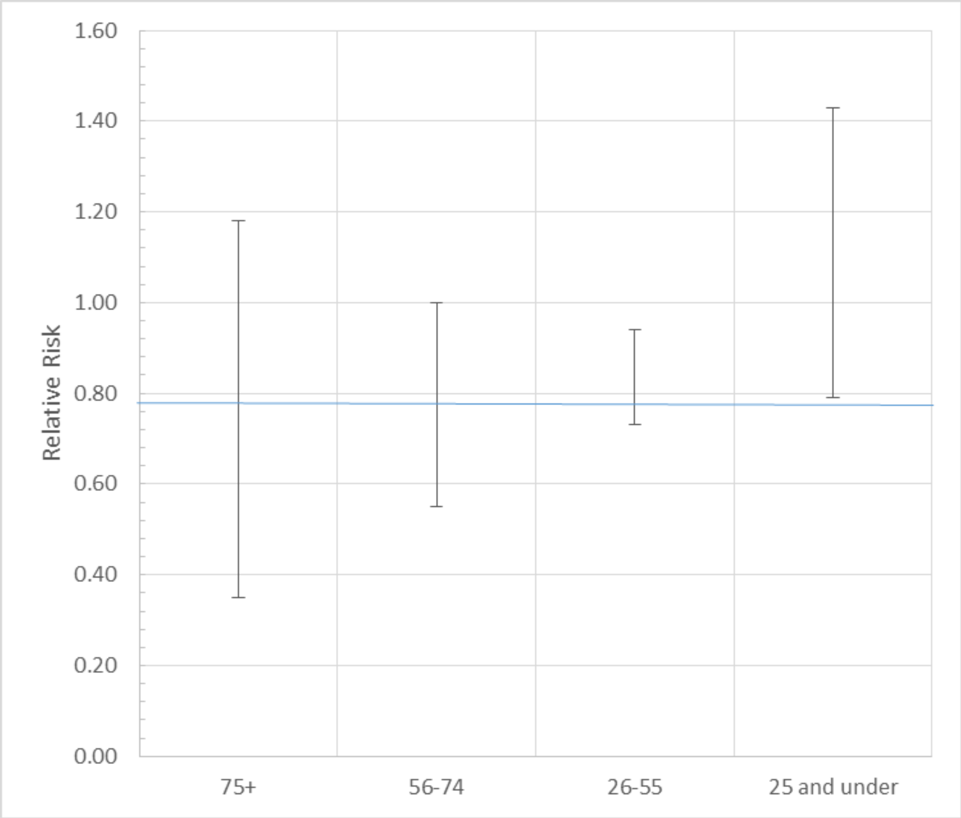


FIGURE 14: RELATIVE INJURY RISK BY DRIVER AGE GROUP FOR NARROWLY SENSITIVE VEHICLE MODELS WITH SOME VARIANTS FITTED WITH AEB USING DATA STRATIFIED BY SPEED ZONE AND DRIVER AGE

A.7.3 Driver Sex

Male drivers were significantly over-represented in the narrowly sensitive vehicle set (FIGURE 15), and the distribution was similar within the *some fitment* and the *no fitment* classes (FIGURE 16).

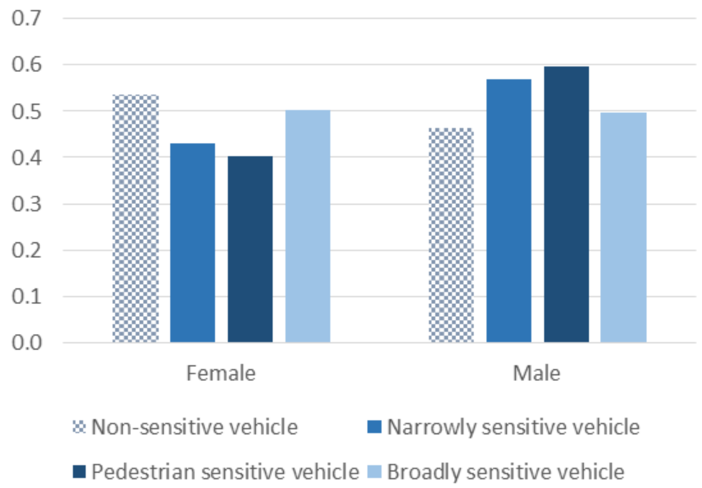


FIGURE 15: PROPORTION OF DRIVER SEX WITHIN VEHICLE SENSITIVITY CLASSES OF THE LIGHT VEHICLE RELATIVE RISK ANALYSIS SET

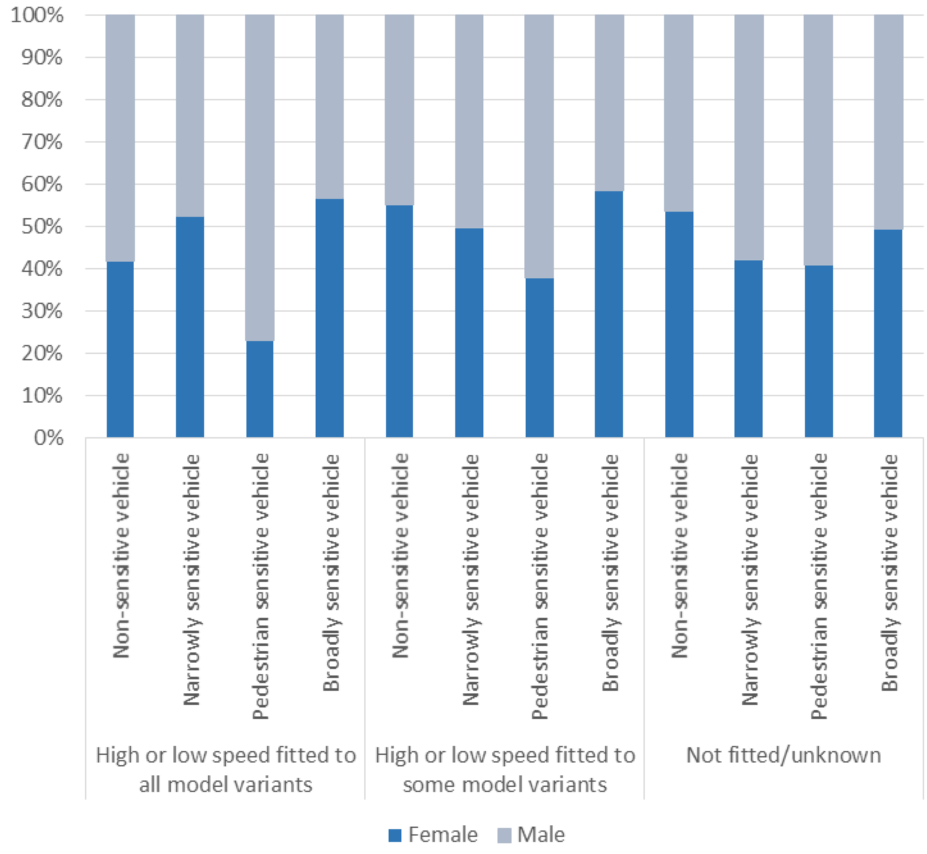


FIGURE 16: PROPORTION OF DRIVER SEX WITHIN VEHICLE SENSITIVITY AND AEB FITMENT CLASSES

When the analysis was performed using speed zone and driver sex as strata, the associated injury risk by sex, for some model fitment was not significantly different from 0.78 for both males and females; there were heavily overlapping confidence intervals for the two estimates: Female was 0.82 (95% CI: 0.70 to 0.95, p=0.008) and Male was 0.75 (95% CI: 0.65 to 0.87, p=0.0002). No significant difference for the risk of injury within narrowly sensitive crashes was observed for males and females and there was no significant evidence of confounding bias from sex.

A.7.4. Intersection Location

Narrowly sensitive vehicles have crashed significantly more frequently at intersections than have the non-sensitive vehicles (FIGURE 18) and the distribution was similar within the *some fitment* and the *no fitment* classes (FIGURE 17).

When the analysis was performed using speed zone and crash location as strata, the associated injury risk by location, for some model fitment was not significantly different from 0.78 for both intersection and non-intersection locations, and there were heavily overlapping confidence intervals for the two estimates: Intersection was 0.78 (95% CI: 0.68 to 0.90, p=0.0004) and non-intersection was 0.84 (95% CI: 0.71 to 0.99, p=0.0036). No significant difference for the risk of injury within narrowly sensitive crashes was observed by location and there was no significant evidence of confounding bias from location.

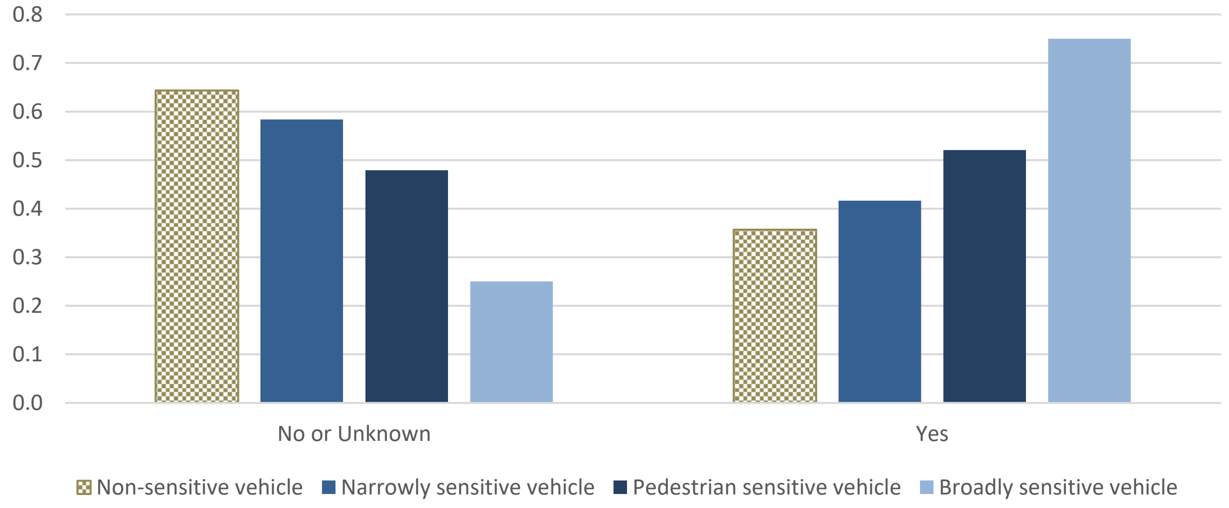


FIGURE 17: PROPORTION OF CRASH LOCATIONS WITHIN VEHICLE SENSITIVITY CLASSES OF THE LIGHT VEHICLE RELATIVE RISK ANALYSIS SET

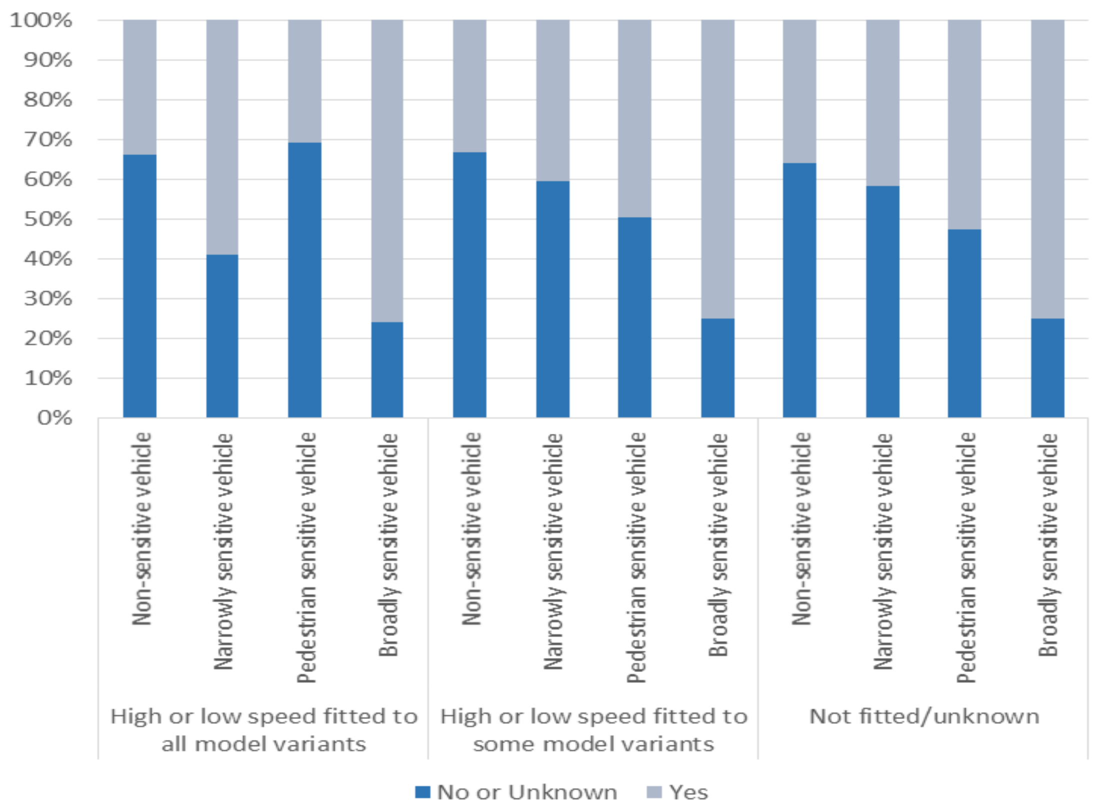


FIGURE 18: PROPORTION OF CRASH LOCATIONS WITHIN VEHICLE SENSITIVITY AND AEB FITMENT CLASSES

A.8 CONFOUNDER ANALYSIS FOR THE HEAVY VEHICLES

The heavy vehicle confounder analysis is based on the crash years 2013 to 2015. Table 39 and Table 40 present the distribution of some possible confounder crash attributes amongst the sensitive and non-sensitive heavy vehicle sets of 2013 to 2015. In particular, Table 40 presents the column proportions which were statistically tested, for each vehicle type and overall, for significant differences between the sensitive and non-sensitive sets.

The age of drivers significantly differed across the types of trucks driven. There were larger proportions of drivers aged 75 years and older and 25 years and younger and smaller proportions of drivers aged in between, in the sensitive vehicle set. The same was found to be true of light vehicles (FIGURE 12). For light vehicles, younger drivers were associated with a greater risk of an injury crash when fitted with AEB. This might reflect on opposing biases cancelling each other out to some degree so that it is difficult to predict the net resultant bias.

For both heavy and light vehicle analyses, male drivers were significantly over-represented in the narrowly sensitive vehicle set (FIGURE 14, Table 40), however the effects of AEB were not found to be significantly different by sex in the light vehicle fleet. Thus, driver sex is not likely to be a confounding variable for heavy vehicles. In addition, the proportion of females was only 0.04, so the actual variation between the sensitive and non-sensitive sets is too small to induce a measurable bias for all but the unlikely case of there being very large differences between the effects of AEB by driver sex.

The crash weather, and by inference, the road surface, were not found to differ between sensitive and non-sensitive groups so this variable is also not a confounder in the heavy vehicle analysis.

There were proportionally fewer of the newest vehicles in the sensitive vehicle set for the rigid trucks under 12 tonnes, and proportionally more aged 11 to 15. Furthermore, there were proportionally more unknown size buses aged 16 years and over in the sensitive group. Generally, older vehicles are less safe so these significant distributional differences may bias towards an under-estimation in the effects of AEB.

TABLE 39: CRASH ATTRIBUTES AMONGST THE 2013-2015 SENSITIVE AND NON-SENSITIVE CRASHED HEAVY VEHICLES

		Heavy Vehicle Non-sensitive							Heavy Vehicle Narrowly sensitive						
		Total	Rigid: <=12 t	Articulated & large rigid	Unknown weight truck	Large bus	Small bus	Unknown bus	Total	Rigid: <=12 t	Articulated & large rigid	Unknown weight truck	Large bus	Small bus	Unknown bus
Driver Age Grouping-AEB	75 years and older	197	41	108	11	2	0	35	858	156	569	45	4	1	83
	56-74 years	341	109	97	40	9	0	86	626	187	219	108	33	2	77
	25-55 years	1,257	550	378	160	38	0	131	2,688	1,075	899	534	61	2	117
	25 years and younger	177	118	34	19	0	0	6	624	427	108	86	2	0	1
	Unknown	33	8	24	1	0	0	0	4	1	2	1	0	0	0
Driver Sex	Female	122	67	14	3	5	0	33	179	102	37	8	3	0	29
	Male	1,776	745	560	217	40	0	214	4,243	1,696	1,558	674	87	5	223
Precipitation	Wet/Snow/fog	176	79	56	17	4	0	20	415	179	123	77	14	2	20
	Dry	1,721	732	524	212	44	0	209	4,101	1,608	1,475	695	81	3	239
	Unknown	108	15	61	2	1	0	29	284	59	199	2	5	0	19
Vehicle Age	Unknown	202	0	109	42	5	0	46	529	8	363	103	15	0	40
	Less than 3 years	337	196	76	26	5	0	34	608	329	172	61	17	2	27
	3 to 5 years	393	205	93	37	14	0	44	808	386	268	90	18	0	46
	6 to 10 years	470	175	182	65	8	0	40	1,225	468	453	233	23	1	47
	11 to 15 years	282	100	88	34	7	0	53	775	338	243	141	11	1	41
	16 years and over	321	150	93	27	10	0	41	855	317	298	146	16	1	77

TABLE 40: CRASH ATTRIBUTES DISTRIBUTION AMONGST THE 2013-2015 SENSITIVE AND NON-SENSITIVE CRASHED HEAVY VEHICLES

		Heavy Vehicle Non-sensitive						Heavy Vehicle Narrowly sensitive					
		Total	Rigid: <=12 t	Articulated & large rigid	Unknown weight truck	Large bus	Unknown bus	Total	Rigid: <=12 t	Articulated & large rigid	Unknown weight truck	Large bus	Unknown bus
Driver Age Grouping-AEB	75 years or older	0.10	0.05	0.17	0.05	0.04	0.14	**0.18**	**0.08**	**0.32**	0.06	0.04	0.30
	56-74 years	0.17	0.13	0.15	0.17	0.18	0.33	**0.13**	0.10	0.12	0.14	0.33	0.28
	25-55 years	0.63	0.67	0.59	0.69	0.78	0.51	**0.56**	**0.58**	**0.50**	0.69	0.61	0.42
	25 years or younger	0.09	0.14	0.05	0.08	0.00	0.02	**0.13**	**0.23**	0.06	0.11	0.02	0.00
	Unknown	0.02	0.01	0.04	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.00	0.00	0.00
Driver Sex	Female	0.06	0.08	0.02	0.01	0.11	0.13	**0.04**	**0.06**	0.02	0.01	0.03	0.12
	Male	0.94	0.92	0.98	0.99	0.89	0.87	**0.96**	**0.94**	0.98	0.99	0.97	0.88
Precipitation	Wet/Snow/fog	0.09	0.10	0.09	0.07	0.08	0.08	0.09	0.10	0.07	0.10	0.14	0.07
	Dry	0.86	0.89	0.82	0.92	0.90	0.81	0.85	0.87	0.82	0.90	0.81	0.86
	Unknown	0.05	0.02	0.10	0.01	0.02	0.11	0.06	0.03	0.11	0.00	0.05	0.07
Vehicle Age	Unknown	0.10	0.00	0.17	0.18	0.10	0.18	0.11	0.00	0.20	0.13	0.15	0.14
	Less than 3 years	0.17	0.24	0.12	0.11	0.10	0.13	**0.13**	**0.18**	0.10	0.08	0.17	0.10
	3 to 5 years	0.20	0.25	0.15	0.16	0.29	0.17	0.17	0.21	0.15	0.12	0.18	0.17
	6 to 10 years	0.23	0.21	0.28	0.28	0.16	0.16	0.26	0.25	0.25	0.30	0.23	0.17
	11 to 15 years	0.14	0.12	0.14	0.15	0.14	0.21	0.16	**0.18**	0.14	0.18	0.11	0.15
	16 years and over	0.16	0.18	0.15	0.12	0.20	0.16	0.18	0.17	0.17	0.19	0.16	**0.28**

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