TRENDS IN PEDESTRIAN PROTECTION FOR VEHICLES RATED BY AUSTRALASIAN NCAP

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ABSTRACT

Analysis of scores in pedestrian protection tests conducted by ANCAP between 2001 and 2017 indicates that the average score has improved from 7.5 to 25. This has been achieved by steady improvement in the design of relevant vehicle components. Many of these improvements are unlikely to have significant adverse effects on costs or vehicle appearance, provided that good design for pedestrian protection is taken into account early in the design phases for the vehicle.

Based on several real-world crash studies, it is estimated that the improvement of 17.5 points is associated with a 21% reduction in the risk of serious injury for pedestrians.

The improvement was likely driven by NCAP programs in Europe, Australia and Japan, the introduction of GTR9/UN127 in most developed nations (but not Australia) and, more recently, fleet demand for 5-star rated vehicles.

INTRODUCTION

In 2000 the Australasian New Car Assessment Program (ANCAP) commenced rating pedestrian protection using the same protocol as Euro NCAP. This has enabled some Euro NCAP results to be used for ANCAP ratings. Between 2000 and 2017 ANCAP rated more than 600 vehicles, with about half of these ratings based on tests carried out by Euro NCAP. Almost one third of the pedestrian tests were carried out by the Centre for Automotive Safety Research (CASR) in Adelaide, South Australia.

This paper sets out the results of an analysis of the trends with pedestrian protection ratings during the period 2001-2017. An estimate is made of the road trauma savings due to improvements in pedestrian protection.

BACKGROUND

The role of the design of the front of the vehicle in the risk of serious injury to pedestrians has been recognised for many years. Fisher and Hall (1972) looked at the influence of frontal design and speed of impact. Harris (1976) developed early test procedures using the sub-system approach where separate impacts are conducted using headforms and legforms to simulate a collision between pedestrian and vehicle. The European Enhanced Vehicle Safety Committee (EEVC) developed a draft protocol in the late 1980s. This became the basis of the first Euro NCAP protocol for pedestrian protection, which was implemented in 1997 (Lawrence & Hardy 1998).

ANCAP implemented the same pedestrian protection protocol as Euro NCAP in 1999, as part of a package to align with Euro NCAP test and assessment protocols. The first ANCAP results were published in 2000 (Paine & Coxon 2000). Since then CASR has conducted testing for ANCAP and contributed to the development and interpretation of the Euro NCAP protocols.

Test protocol

The test protocol requires three sets of sub-system tests. Impactors used for these tests represent an adult head and a child head striking the bonnet and windscreen areas, an upper legform striking the leading edge of the bonnet and a lower legform striking the bumper fascia. Scores are allocated on the basis of the head injury criterion (HIC) when using the head impactors (maximum 12 points each for the child and adult head impactors respectively), bending moment and forces in the case of the upper legform (maximum 6 points) and for the lower leg impactor shear displacement, knee bend angle and tibia acceleration were measured giving a maximum 6 points.

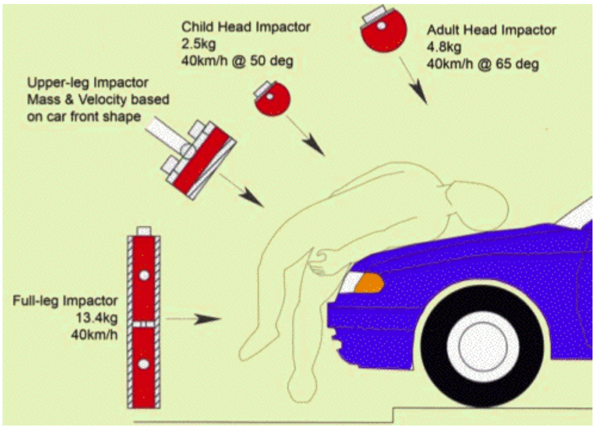

Figure 1. Sub-system tests for pedestrian protection (circa 2008)

An overall score is derived by summing the subsystem scores. Over the period of analysis the maximum available overall score has remained at 36. Between 2000 and 2010 the results were presented as star ratings and as a descriptive rating from 2011:

Table 1 ANCAP Pedestrian Protection Ratings

Score	2000-2010	2011+
27.5 or more	4 stars	Good
18.5 to 27.49	3 stars	Acceptable
9.5 to 18.49	2 stars	Marginal
0.5 to 9.49	1 Star	Poor
Less than 0.5	Zero stars	Poor

There were minor changes to the protocol in 2002 (discussed in Ponte et al., 2004) and significant changes in 2010. The 2010 change generally resulted in lower scores (Ponte et al., 2013).

In 2012 ANCAP introduced the "grid method" where the vehicle manufacturer submits detailed head impact test results for every 100x100 mm grid location and the ANCAP laboratory conducts verification tests on a sample of grid locations. An adjustment is made to the final manufacturer expected score if there is a discrepancy between the submitted and verification test results. These changes also influenced the pedestrian protection scores, but to a lesser extent than the change in 2010.

In 2015 ANCAP replaced the "TRL" lower legform with the "FlexPLI" legform and also made significant changes to the location, energies and performance criteria for the upper leg impactor.

No adjustment for these effects has been made in the following analysis but, generally, the observed improvements will be conservative (vehicles rated to the newer protocols will have slightly better pedestrian protection than the scores suggest).

Other influences on vehicle design

In 2009 Global Technical Regulation 9 (GTR9/UN Regulation 127) "Pedestrian Safety" was published by the United Nations. In 2011 the Australian Department of Infrastructure and Transport issued a Regulation Impact Statement (RIS) recommending that the GTR be implemented as an Australian Design Rule (Department of Infrastructure and Transport, 2011). However, the RIS was withdrawn and the initiative did not go ahead (King, 2011). The latest WHO report on the Global Status of Road Safety notes that "Australia has signed the UN127 for Pedestrian Protection as a Contracting Party but is not enforcing it." (WHO 2018).

Although Australia has not implemented GTR9/R127 it is likely that most cars marketed in Australia have been designed to meet the requirements since they are usually also sold in Europe or Japan. Exceptions are where the extra features such as a pop-up bonnet are standard in Europe/Japan but not in Australia or where additional (e.g. aftermarket bullbars) structures are fitted to the front of the vehicle .

In 2012, under its new Road Map, ANCAP set a minimum pedestrian protection performance threshold as part of an assessed vehicle's overall star rating, (ANCAP 2011). This provided much stronger incentive for manufacturers to do well in the pedestrian impact tests. The Road Map requirements became progressively more stringent between 2012 and 2017. For example, to earn an overall rating of 5 stars in 2012 a vehicle needed at least a "marginal" pedestrian protection rating (minimum of 9.5 points). This increased to a requirement of an "acceptable" rating (minimum 18.5 points) in 2014.

The 2011 ANCAP Road Map set lower pedestrian safety performance requirements for high-seat vehicles (some SUVs, 4WDs, utilities and vans) in recognition of industry claims about the challenges faced in designing these vehicles to perform well in pedestrian protection tests. For example, a pedestrian protection rating of "acceptable" (18.5 or more) was not required for an overall 5 star rating of high-seat vehicles until 2017. However, soon after ANCAP published its 2011 Road Map, Euro NCAP awarded the Australian-designed Ford Ranger pickup the highest score for pedestrian protection of any vehicle tested (at the time), bringing into question the claims about high-seat vehicles.

In 2012 BHP introduced an NCAP 5-star requirement for company light vehicle purchases and for contractors using BHP worksites (Jenkins 2012). Because Euro NCAP and ANCAP included pedestrian protection in the assessment this likely resulted in improved pedestrian protection for vehicles typically purchased by mining companies.

Figure 2. Ford Ranger - a high-seat vehicle that provides good pedestrian protection

SOURCES OF DATA

A database of ANCAP safety ratings from 2000, maintained by one of the authors, was analysed to determine trends in pedestrian protection scores. Only overall scores were analysed.

The trends in pedestrian protection scores were compared with a recent analysis of trends in pedestrian injury in road crashes in Australia and New Zealand (Keall et al., 2018).

RESULTS

Figure 3 illustrates the results of the analysis. A linear trend line for all vehicle types indicates that the average pedestrian protection score improved from 7.5 in 2001/2 to 25 in 2017, a threefold improvement.

Note that the values are based on the number of ANCAP ratings for each vehicle type and the year in which the tested model was released. The method does not account for annual sales. Vehicle types with small sample sizes are not shown in the chart but are included in the overall values ("All"). Appendix B has a table with all data.

RISK OF INJURY

Paine and Coxon (2000) describe Transport Research Laboratory estimates that 8% of all pedestrian fatalities and 21% of all pedestrian serious injuries in the Europe could be prevented through improved vehicle design. The research was associated with Euro NCAP introducing pedestrian protection tests in 1997 (Lawrence 1998).

There have been several studies looking for a correlation between NCAP pedestrian protection scores/ratings and real-world injury to pedestrians. For the purpose of comparison, in the following analysis we translate the estimated injury savings to a percentage reduction for a 10-point improvement in ANCAP/Euro NCAP pedestrian protection score.

Lawrence and others (2006) estimated that introducing the GTR for pedestrian protection in Europe would result in a 4% reduction in fatalities and a 12% reduction in serious injuries. It should be noted that vehicles which score well in NCAP testing are likely to pose a lower risk of pedestrian injury than vehicles which just meet the minimum

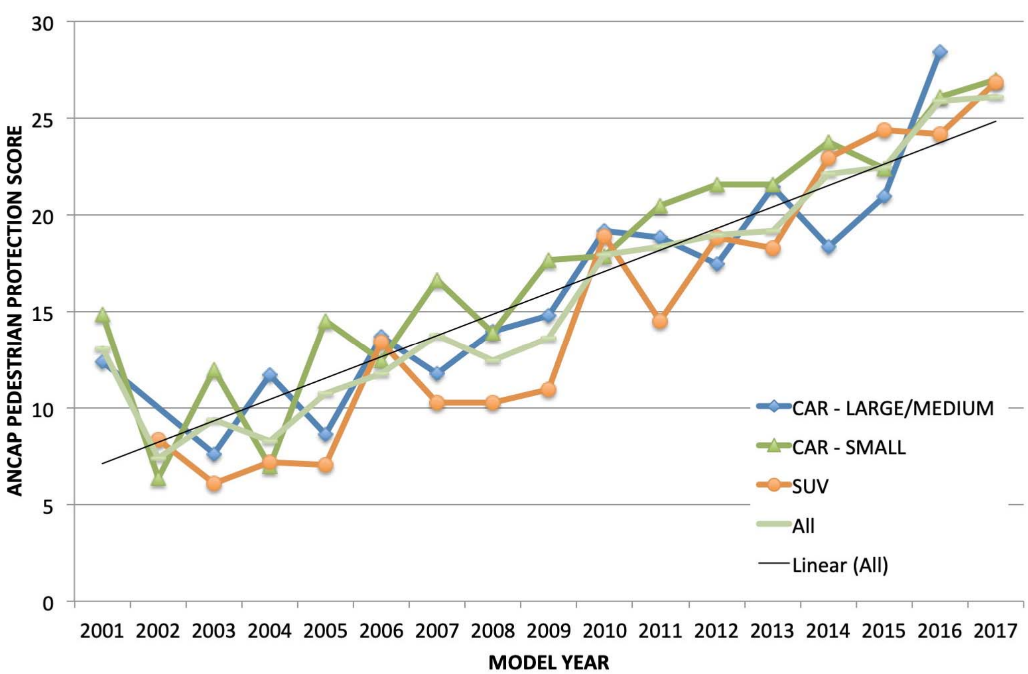

Figure 3. Average ANCAP Pedestrian Protection Scores

requirements of the GTR and so benefits of a high NCAP score will be greater. Based on this, it is estimated that the benefit from a 10-point improvement in NCAP score is at least a 12% reduction in serious injuries.

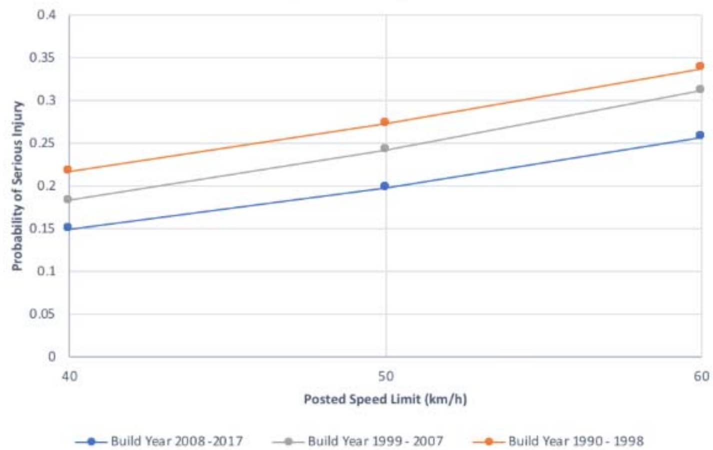

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Figure 4. Probability of serious/fatal injury for pedestrians struck by a car in South Australia (1990-2016)

The Australian RIS that attempted to introduce GTR9 in 2011 used Lawrence's estimates in the benefit-cost analysis (Department of Infrastructure and Transport, 2011).

Strandroth et al., (2011) analysed 609 Swedish crashes where a Euro NCAP-rated vehicle collided with a pedestrian. They grouped the vehicles into 1 and 2 star pedestrian ratings (there were insufficient cases of 3 stars or better). The average score was 6.24 for 1-star vehicles and 13.84 for 2-star vehicles. It was found that injury severity was lower for 2-star cars compared to 1-star cars, with the relative difference in serious injuries (AIS2+) being 17% lower with 2-star cars and severe injuries (AIS3+) were 28% lower, compared to 1-star cars.

This is equivalent to a 22% reduction in serious injury risk for a 10-point improvement in NCAP score.

Pastor (2013) analysed the German National Accident Records and, from 7,576 relevant records, found that the risk of a fatality is reduced by 35% for a vehicle scoring 22 for pedestrian protection, compared with a vehicle scoring 5. The risk of serious injury was reduced by 16%. This is equivalent to a 9.4% reduction in serious injury risk for a 10-point improvement in score.

Keall and others (2018) analysed data on police-reported road crashes in Australia and New Zealand and calculated the risk of serious injury to pedestrians by vehicle type and year of manufacture. Based on that analysis the average risk for vehicles manufactured between 1997 and 2001 was 39.4% compared with 33.6% for vehicles manufactured between 2007 and 2012. This is a 15% reduction in risk.

Over the period 2001 to 2012 the average ANCAP pedestrian protection scores improved from 7.5 to 17. The Keall study did not look specifically at ANCAP pedestrian scores and there are numerous confounding factors but over the period when ANCAP scores improved by 10 point there was an observed 15% reduction in the risk of serious injury to pedestrians.

One of the present authors recently examined South Australian pedestrian crash data from 1990 to 2016. A total of 1,118 serious injury crashes were analysed using a logistic regression model to predict the probability of a fatality or hospital admission. Figure 4 presents the key results of the analysis for posted speed limits of 40, 50 and 60 km/h. The probability of serious injury for vehicles built between 2008 and 2016 was around 19% less than those built between 1999 and 2007. The average ANCAP pedestrian scores for these two build date ranges were 11 and 19 respectively.

Figure 5 shows the derived values for the five studies. Overall it is estimated that a 10 point improvement in NCAP score is associated with a 16% reduction in serious injuries to pedestrians.

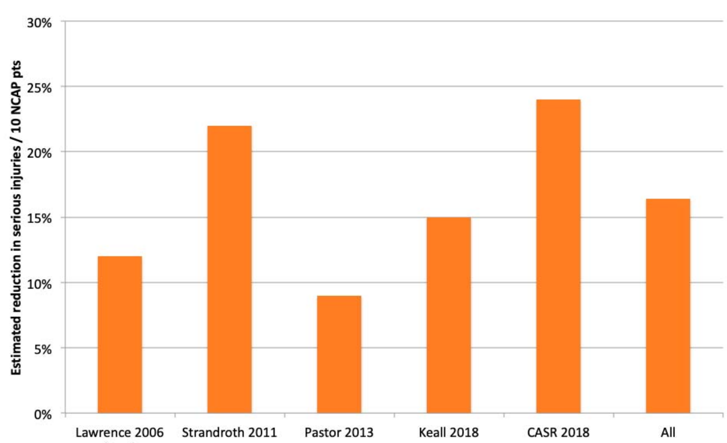

Figure 5. Derived reduction in serious injuries to pedestrians due to a 10 point improvement in NCAP score

Therefore, assuming a linear relationship, the observed 17.5 point improvement in average ANCAP pedestrian scores between 2001 and 2017 equates to a 29% reduction in serious injuries over this period.

IMPROVEMENTS TO VEHICLE DESIGN

Several of the papers referred to above contain observations and information about vehicle design to improve pedestrian protection.

Lawrence (1998) notes that that relatively simple changes to detail in the early design stages of a new model can lead to major improvements in pedestrian protection. Suggested improvements include front bumper fascia re-design (deeper profile, with localised compliance and energy absorption), headlamps (plastic better than glass), bonnet leading edge (locate bonnet latch further rearwards, relocate transverse stiffeners) and bonnet/fender tops (design for crush, increase under-bonnet clearances).

The Australian RIS (Department of Infrastructure and Transport, 2011) quotes the head of a vehicle insurance research organisation that is an ANCAP stakeholder and also conducts evaluations of the cost of repairs in low speed collisions: "...this proves that manufacturers can design vehicles that can perform well in both pedestrian safety and vehicle protection".

The RIS also referred to UK research (Lawrence, 2006) that estimated the cost of design changes to meet the GTR requirements ranged from 27 Euro for a small family car to 47 Euro for a large SUV. However, it was noted that executive cars and sports cars might need relatively expensive active safety such as pop-up bonnets (subsequent Euro NCAP ratings effectively show that this is not essential for meeting the GTR).

Two of our authors have conducted pedestrian protection test for ANCAP over many years. They have observed a change in attitude of vehicle manufacturers towards these tests. In particular, many manufacturers have appointed engineers who specialise in design for pedestrian protection and these engineers have frequently attended the ANCAP testing.

Most of the improvements in head protection are the result of optimising the deformation characteristics of the vehicle's hood, to help 'cushion' the head in a pedestrian head impact. Additionally, allowing adequate space between the under-surface of the optimised vehicle hood and any hard structures underneath it has also been undertaken by most manufacturers to ensure the protective design of the hood is not undone by a rigid structure within the deformations zone (see Hutchinson et al., 2011). This has been observed during testing, as manufacturers are genuinely considering the height and placement of rigid structures such as suspension towers, batteries and engine intakes so deformation space is provided during an impact. Traditionally rigid hood support areas have also been addressed to improve head protection. Examples include moving the top of the firewall lower and rearward and placing a collapsible plastic plenum to create the seal between the rear of the hood and the firewall (a traditionally stiff hood support area). Similarly, the structures of the sidewall supports of the engine bay have been lowered, and collapsible brackets have been used to position wheel guard panels so head impacts in these areas are also less severe.

For vehicles with restrictions on available under bonnet space, active safety systems such as deployable or "pop-up" hoods are being used to create space and give clearance between rigid structures beneath the hood, during a head impact.

Improvements for lower leg protection include the addition of energy absorbers (foam or crush cans) and lower stiffening rails to keep a pedestrian's leg from bending under the front of the vehicle.

Improvements to the upper leg area have involved moving the radiator support and the bonnet latch rearward and creating space between the latch and outer bonnet surface. Headlights with plastic lenses (instead of glass) with breakaway mounting tabs also improve pedestrian protection.

Appendix A contains examples of the changes observed by CASR personnel.

DISCUSSION

The importance of good vehicle design in preventing serious and fatal injuries to pedestrians was recognised in the 1970s at a time when regulations were introducing substantial improvements to vehicle occupant protection (e.g. seat belts). However, the development of suitable test methods for assessing pedestrian protection did not make good progress until the late 1980s, mainly through the work of EEVC.

Euro NCAP introduced pedestrian protection ratings in 1997 as part of its new vehicle safety program. NCAPs in Australia and Japan introduced pedestrian protection ratings a few years later. These consumer programs found that most vehicles of the day had woeful designs for pedestrian protection, although a few vehicles demonstrated that good design was possible without compromising style and functionality.

The first international regulation for pedestrian protection (GTR9/UN127) was published in 2009. Around this time Euro NCAP began to require reasonable performance in pedestrian tests as part of its overall rating. These two developments likely focussed vehicle manufacturer attention on improving vehicle designs for pedestrian protection.

In 2011, the Australian government halted the process to implement GTR9/UN127 but it is likely that the Australian vehicle fleet still improved in terms of pedestrian safety, due to overseas developments (since most vehicles sold in Australia are built overseas). This would have been boosted by ANCAP adding pedestrian protection to its overall rating requirements from 2012.

ANCAP ratings show that there has been a steady improvement in pedestrian protection scores between 2011 (18) and 2017 (25). Noting that just passing the GTR is equivalent to an ANCAP score of 18 (Anderson et al., 2008), it is considered that most of the improvement can be attributed to NCAP programs in Europe, Japan and Australia.

In summary we agree with this statement: "In the absence of any pedestrian regulation in Australia, the incorporation of the pedestrian assessment as part of the ANCAP star rating is by far the most important mechanism for compelling manufacturers to think 'outside the car' and incorporate pedestrian safety in vehicle design." (Ponte et al., 2013)

LIMITATIONS

It took several years for ANCAP to assign ratings to a large proportion of all models for sale in Australia and New Zealand. During the period 2001 to 2004 the ratings were dominated by models tested by Euro NCAP. These tended to be luxury models in Australia and this may have influenced the trends in early years.

Protocol changes described above will have influenced the scores and this has not been taken into account in the analysis of results in this paper.

ANCAP pedestrian protection ratings have not been the sole influence on pedestrian injury during the study period. Europe implemented GTR 9 in 2009 and many cars entering the Australian market since then are likely to have been designed to that regulation.

In 2003, most Australian states reduced residential speed limits from 60k/h to 50km/h. This had a substantial effect on pedestrian fatalities on these roads (Woolley, 2005). Additionally, there was also a reduction in pedestrian casualty crashes (and mean speeds on various roads) as a result of the speed limit changes (Kloeden et al., 2007). The speed limit changes perhaps brought many more car/pedestrian collisions into the 40 km/h impact range, where improved frontal design can be more effective.

Some variation between real-world and laboratory results is understandable because the ANCAP tests simulate a collision at 40km/h and collisions between cars and pedestrians occur over a much wider range of speeds. Design improvements that mitigate a 40km/h collision are unlikely to be as effective at 50km/h or higher speeds (Strandroth et al., 2011). In this regard, the data used for the CASR analysis was confined to posted speed limits from 40 to 60km/h.

The assumption of a linear relationship between NCAP score and risk of serious injury has not be verified but it is considered that over a small range of scores this assumption is reasonable.

CONCLUSIONS

ANCAP pedestrian protection testing between 2001 and 2017 indicates a steady improvement in vehicle design over this period, with the average score improving from 7.5 to 25. Based on several real-world crash studies, it is estimated that this improvement is associated with a 29% reduction in the risk of serious injury for pedestrians.

The improvement was likely driven by NCAP programs in Europe. Japan and Australia, the introduction of GTR9/UN127 in most developed nations (but not Australia) and, more recently, fleet demand for 5-star rated vehicles.

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APPENDIX A - EXAMPLES OF IMPROVEMENTS TO VEHICLE DESIGN (CASR)

Under-bonnet components

Mid-1980s: Stiff firewall and sides of engine bay supporting edge of bonnet. Minimal clearance between suspension tower/air cleaner and bonnet.

Early 2000s: Stiff firewall and sides of engine bay supporting edge of bonnet. Minimal clearance between suspension tower/engine cover and bonnet.

Recent: Firewall and sides of engine bay lowered with bonnet supported by collapsible elements. Suitable clearance is provided between suspension tower/other under bonnet structures and bonnet.

Top edge of fender

Traditional design: Wheel guard supported directly by stiff structure.

Recent design: Wheel guard supported by collapsible element.

Bumper design

Lower support in position to keep leg from bending under car and energy absorbing foam to protect the knee.

Leading edge of bonnet

Bonnet latch moved rearwards and radiator support moved rearward and lowered (recent model)

APPENDIX B - DATA

The following table includes the data presented in Figure 3.

Average ANCAP score for pedestrian protection [number of rated models]

YEAR MODEL RELEASED	CAR LARGE /MEDIUM	CAR SMALL /LIGHT	SUV	ALL
2001	12.4 [7]	14.9 [6]	-	13.1 [15]
2002	-	6.3 [3]	8.4 [9]	7.4 [13]
2003	7.6 [8]	12 [8]	6.1 [7]	9.4 [29]
2004	11.7 [8]	7 [8]	7.2 [4]	8.3 [25]
2005	8.6 [6]	14.5 [13]	7 [4]	10.8 [27]
2006	13.7 [11]	12.5 [6]	13.4 [11]	11.8 [38]
2007	11.8 [7]	16.6 [17]	10.3 [7]	13.8 [39]
2008	13.9 [10]	13.9 [23]	10.2 [7]	12.4 [47]
2009	14.8 [8]	17.7 [18]	10.9 [7]	13.7 [39]
2010	19.2 [5]	17.9 [18]	18.9 [8]	17.9 [33]
2011	18.8 [9]	20.5 [16]	14.5 [9]	18.4 [42]
2012	17.4 [13]	21.5 [10]	18.8 [11]	19 [43]
2013	21.4 [15]	21.6 [12]	18.3 [14]	19.2 [50]
2014	18.4 [3]	23.8 [11]	22.9 [6]	22.1 [30]
2015	20.9 [9]	22.4 [4]	24.4 [18]	22.5 [47]
2016	28.4 [6]	26.1 [13]	24.2 [9]	25.9 [29]
2017	-	27 [3]	26.9 [6]	26.1 [11]

Notes

"ALL" include other types of vehicles with small sample sizes

2001 data were mostly Euro NCAP ratings of "prestige" vehicles, as sold in Australia