PROMOTING VEHICLE CRASHWORTHINESS

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1. A BRIEF STATEMENT OF THE ISSUE

Australia's national road safety strategy assumes that continuing improvements in vehicle crashworthiness will result in a 10 per cent reduction in fatalities per 100,000 population by 2010, provided that current levels of commitment are maintained.[1]

The purpose of this paper is to demonstrate that improved vehicle design standards have led to improved crash performance under both controlled conditions and on the road.

2. AN ASSESSMENT OF THE ROAD SAFETY ISSUE

During the early to mid 1970s in particular, a series of Australian Design Rules (ADRs) was introduced in Australia to improve vehicle occupant protection[2]. Examples during 1969-1972 included:

- ADR 4 (seat belts fitted to front seats)
- ADR 2 ('anti-burst' door latches and hinges)
- ADR 10A (energy-absorbing steering columns)
- ADR 22 (head restraints).

Examples during 1975-1977 included:

- ADR 5B (improved location of seat anchorages)
- ADR 4C (dual-sensing locking retractor inertia reel seat belts)
- ADR 29 (improved side door strength).

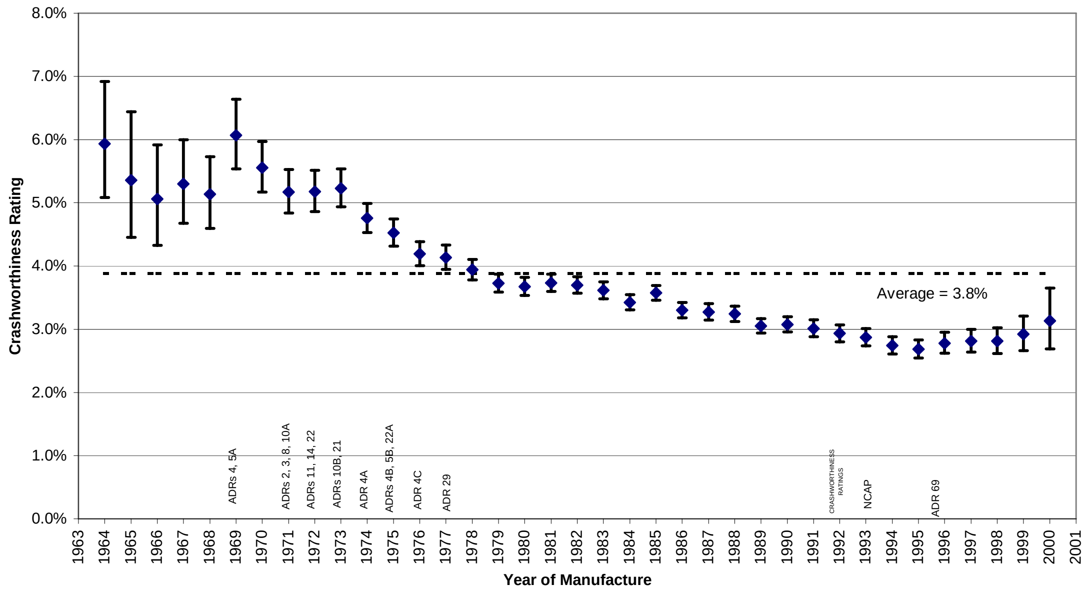
The safety emiles/hourasis in the manufacture of vehicles has continued through two developments in particular[2]:

- The introduction of programs to advise consumers of relative vehicle safety. The Australian New Car Assessment Program (ANCAP) assesses relative vehicle safety through a program of crash barrier testing. A series of studies, based on vehicles' performance in real crashes reported to Police, is conducted by the Monash University Accident Research Centre (MUARC) and marketed as Used Car Safety Ratings (UCSR). Both programs commenced in 1992 and continue to be conducted.
- The development and implementation of ADR 69 in 1995, ADR 72 in 1999 and ADR 73 in 2000 have also been important, in that they have produced major improvements in standards for frontal and side impact occupant protection.

The finding that improved design standards have indeed led to improved crashworthiness, under both controlled conditions and on the road, needs to be vigorously promoted if the maximum road safety returns are to be made from these developments. (Throughout this report, 'crashworthiness' relates to the protection against injury offered by the vehicle to its occupants, most often the driver, in the event of a crash.)

Figure 1 shows the relationship between vehicle crashworthiness (the risk of death or serious injury given involvement in a crash where at least one vehicle was towed away) and year of vehicle manufacture, from 1964 to 2000. It also shows the dates of introduction of major Australian Design Rules concerned with safety for passenger vehicles. Figure 1 shows a clear association between the introduction of key safety-based ADRs and improvements in vehicle crashworthiness, particularly during the 1970s.

Figure 1: Crashworthiness by year of vehicle manufacture (with 95 per cent confidence limits)
(From Newstead, Cameron, Watson & Delaney, 2003)



3. CURRENT POLICIES AND PRACTICES IN AUSTRALASIAN JURISDICTIONS

All new vehicles sold in Australia must comply with all appropriate ADRs.

The implementation and promotion of ANCAP assessment is supported by the following transport authorities and automobile clubs:

- NSW Roads & Traffic Authority
- Transport South Australia
- Land Transport Safety Authority of New Zealand
- Queensland Transport
- Western Australia Department for Planning and Infrastructure
- Tasmanian Department of Infrastructure, Energy and Resources
- Federal Department of Transport and Regional Services

- RACV
- NRMA
- RACWA
- RACQ
- RAA South Australia
- Northern Territory Automobile Association
- RACT
- New Zealand Automobile Association.

Estimation of the Used Car Safety Ratings is carried out as part of a research program undertaken by the Monash University Accident Research Centre. The research program is sponsored by:

- RACV
- VicRoads
- NRMA
- RTA
- RACWA
- ATSB
- TAC
- Land Transport Safety Authority of New Zealand.

4. A REVIEW OF THE RESEARCH

4.1 ANCAP

ANCAP is a program that tests the crashworthiness of most major current car models by conducting barrier crash tests under laboratory-controlled conditions. The primary purpose of the program is to provide consumer information on relative vehicle safety in crashes. In providing consumer information, the ANCAP program also hoped to emulate US experience of similar consumer crash test programs which led to informed consumer pressure on manufacturers to rapidly improve safety in their vehicles. Because a vehicle can be tested as soon as it is released for sale, ANCAP primarily targets consumers of new vehicles, with the program claiming to cover 70-80 per cent of the new vehicle market.

The testing procedures have varied since ANCAP was first implemented in 1992, when performance during a full frontal impact crash only was assessed.[3] Now ANCAP uses the testing procedures and rating system developed for Euro-NCAP, whereby each vehicle model is subjected to at least two crashes[4]:

- An off-set frontal impact test, whereby the car is driven at 64 km/h into a barrier with a crushable aluminium face. The crash forces are concentrated on the driver’s side of the vehicle and the use of a deformable barrier simulates the effect of crashing into another vehicle.[3]
- A side impact crash, whereby the driver’s side of the stationary vehicle is struck by a trolley travelling at 50 km/h.

Where vehicles have side airbags or the equivalent, their manufacturers can elect to have a third test performed to gain extra safety credit.[4] The vehicle is crashed side-on at 29 km/h into the equivalent of a round power pole, at a position in line with the head of the dummy – with any extra safety credit being for low risk of head injury.

Vehicle crashworthiness ratings derived from crash barrier testing depend heavily upon the forces experienced by dummies in the driver and front-passenger positions, restrained by the vehicle's seat belts. The dummies are fitted with sensors to detect dummy kinematics, forces and other data which would be experienced by an average male in the event of a crash, from which head injury outcomes, chest deformation, chest loading and upper and lower leg loadings can be determined.

In addition, infant (18 months) and toddler (three years) dummies are placed in child restraints in the rear seat for both crash tests. Results of these tests are, however, not considered relevant to Australia and are not published as part of ANCAP, nor are they replicated on locally-tested vehicle models. A separate child restraint evaluation program is run in Australia by the New South Wales RTA, NRMA and RACV in association with the Australian Consumers Association, with results published periodically in the form of a brochure titled 'Buyers Guide to Child Restraints'. Tests under this program are based on the Australian Standards but involve higher crash forces and additional test procedures.

Each of four body regions (head, chest and upper and lower legs) is scored up to four points, whereby a severe injury would be scored zero while a minimal injury would earn the maximum four points. Where more than one injury measurement applies for a given body region, the score for the most severe injury is used. In the offset crash test, passenger injuries also contribute to the scoring. The worst four injury outcomes on either the driver or passenger dummy for each test are combined to produce a maximum score of 32 points.

With the offset test the injury scores can be modified: for example, excessive rearward movement of the steering wheel might result in an additional penalty point, reducing a given head score of four to three. Other modifiers include airbag stability, steering column movement, A-pillar movement, structural integrity, hazardous structures in the knee impact area, and brake pedal movement.

If a pole test is conducted and the vehicle shows good head protection, two extra points are added, giving a score out of 34 points.

There is also a star rating system based on the overall score – the greater the number of stars (up to four[1]), the higher the safety rating. In addition to an overall points score and star rating, ANCAP also provides detailed summaries of each model's test performances. A full description of the ANCAP test protocols and scoring procedures can be found at www.euroncap.com.

As well as assessing the safety of vehicle occupants, ANCAP also undertakes pedestrian protection testing, which rates the protection a vehicle model offers to pedestrians in a frontal impact. The pedestrian test procedure has three components assessing different parts of the vehicle structure, using test dummy parts rather than a whole dummy. The tests aim to replicate accidents involving child and adult pedestrians in which impacts occur at 40 km/h. The component tests of the pedestrian protection assessment are:

- a legform to bumper test in which a dummy leg form is impacted into the front bumper of the vehicle

[1] Since the preparation of this paper, and the addition of further points for a seat belt reminder system, it is now possible to achieve a five-star rating.

- an upper legform to bonnet leading-edge test
- headform to bonnet top in which both child and adult head forms are impacted into various areas of the top of the vehicle bonnet.

Force measurements from the dummy components in the tests are translated into injury parameters from which a pedestrian protection star rating out of a possible four is calculated. EuroNCAP has changed the pedestrian protection test to make it more stringent, meaning that results published from January 2002 are not comparable with previous test results.

As ANCAP is fully harmonised with EuroNCAP, many of the ratings published by ANCAP are based on tests carried out in Europe by EuroNCAP. For vehicles tested in Australia, the offset frontal, side impact and pole testing is carried out by Crashlab in Sydney while the pedestrian protection testing is carried out by the Adelaide University Centre for Automotive Safety Research.

There are acknowledged limitations to the ANCAP ratings. Firstly, ANCAP does not – and does not claim to – represent the full range of crash circumstances. It has been estimated that, when the test procedures involved full and off-set frontal crashes, some 60 per cent of real-world crashes were represented[3]. Secondly, in a multi-vehicle collision, occupants of the lighter vehicle are invariably at greater risk of injury, regardless of the crashworthiness of the individual vehicles. ANCAP has therefore categorised vehicles by size and type (small, medium, large, luxury, utilities and four-wheel drives) and has recommended that comparisons are most meaningful only when made within categories. Notwithstanding this, it is generally acceptable to compare vehicles' point scores or star ratings with regard to crashes into fixed objects, regardless of the size or category of the vehicle.

Australia is not the only country to rate relative vehicle crashworthiness using a crash barrier test program. As noted, ANCAP uses the same test protocol and shares results from the Euro-NCAP test program operated in Europe. Similar programs also operate in the USA, Japan and Korea, although the test protocols and scoring procedures used in these programs differ in their detail.

4.2 Assessing crashworthiness from data on real crashes reported to police[5]

Vehicle safety ratings based on police records of real-world crashes and injury outcomes, commenced independently in Victoria and NSW in 1990. These early efforts were soon combined into a single research program, carried out by the Monash University Accident Research Centre (MUARC), which now prepares vehicle safety assessments at regular intervals. These ratings are published as Used Car Safety Ratings (UCSR) by the organisations that sponsor the research. The used car marketing focus is used primarily to differentiate the real crash-based ratings from those derived from the crash barrier tests discussed above which generally focus on new vehicle model releases.

Incomplete reporting of the injury outcomes for vehicle occupants other than the driver in police crash reports means that the ratings only cover injury outcomes for vehicle drivers. In the MUARC reports, the UCSRs, referred to as crashworthiness ratings, are calculated as the product of two factors:

- The injury rate of drivers involved in tow-away crashes (injury risk).
- The serious injury (death or hospital admission) rate of injured drivers (injury severity).

A vehicle's crashworthiness rating is therefore an estimate of a driver's risk of being killed or admitted to hospital once involved in a crash where at least one person is injured and/or requiring at least one vehicle to be towed away. A rating of 3.93 (the current average of all vehicles with 'useable' crashworthiness ratings) means 3.93 drivers killed or admitted to hospital per 100 tow-away crash involvements.

The most recent report[5] has been based on crash data from Victoria and NSW for 1987-2000 and from Queensland and Western Australia for 1991-2000 – in total, involving 1,007,045 drivers in determining injury risk and 199,676 drivers in determining injury severity. After controlling for a number of influences (driver sex and age, speed limit at the crash location, year of occurrence, State of occurrence and number of vehicles in the crash), statistically-reliable crashworthiness ratings have been obtained for 213 vehicle models manufactured between 1982 and 2000. ('Statistically reliable' means that the confidence intervals associated with the ratings fell within specified limits.)

Further, 51 models of passenger cars, four-wheel drive vehicles, passenger vans and light commercial vehicles have been identified as significantly superior, and 44 models as significantly inferior, compared to the average crashworthiness across all vehicles in the analysis. Looking at this spread of results in more detail (and without considering the confidence intervals):

- The safest model had less than half the risk of death or serious injury in a tow-away crash, compared to vehicles with average crashworthiness.
- The least safe model had more than double the risk of death or serious injury in a tow-away crash, compared to vehicles with average crashworthiness.
- The least safe model had more than five times the risk of death or serious injury in a tow-away crash, compared to the safest model.

The same report[5] has looked at changes in vehicle crashworthiness over the years. Taking vehicles manufactured between 1964 and 1969 as the base measure, it was found that the risk of death or serious injury in tow-away crashes had halved for drivers of vehicles manufactured between 1991 and 1998. Put another way, current vehicles are, as a group, twice as safe (as measured by crashworthiness) than vehicles manufactured some thirty years earlier.

This measure of improvement was not, however, evenly spread across all vehicle categories. While large, luxury, medium and 4WD categories have shown general improvement with each year of manufacture, the small, sports and commercial categories have tended towards reduced crashworthiness from 1993 onwards. Two reasons have been suggested for this decline[5]:

- A consumer trend towards purchasing the cheapest but least safe vehicles.
- Polarisation of the Australian vehicle fleet in terms of size, whereby the mid-1990s onwards experienced a sales shift from medium to either small or large car sales. The increased number of larger cars is most likely to impact on the crashworthiness ratings of smaller, lighter vehicles.

4.3 Do the two sets of crashworthiness ratings agree?

Both the Used Car Safety Rating and ANCAP programs purport to measure relative vehicle occupant protection in a crash. In examining the detail of each rating system, however, it is clear that each is measuring a different aspect of vehicle safety. Injury assessment in the ANCAP program is based primarily on the Abbreviated Injury Scale (AIS), which measures the risk of death. As described, ANCAP tests cover a fixed set of crash configurations, impact speeds and occupant characteristics. They do not reflect the role of vehicle mass in crash outcomes. In contrast, the UCSRs measure the risk of death or hospitalisation in a crash severe enough for at least one person to be injured or a vehicle to be towed away. They cover all crash configurations, impact speeds and driver characteristics, albeit with the profile of these standardised across vehicle models compared through use of advanced statistical analysis methods. They also reflect the role of vehicle mass in real crash outcomes. Because of these key differences, it is not necessarily expected that each rating system will lead to the same assessment of relative safety within a group of rated vehicle models.

MUARC investigators have undertaken a number of studies to assess the extent of agreement between the two rating systems. These studies have compared barrier test results with real crash data from Australia, the USA and Europe. A paper summarising the key findings from these studies[6] drew the following conclusions:

- On *average*, there appears to be consistency between the ratings based on real crash outcomes and the barrier test-based ratings.
- This general consistency appears to stem from a strong relationship on average between the barrier test ratings and the injury severity component of the real crash-based ratings (the risk of death or hospitalisation given that some level of injury was sustained). There seems to be little relationship between real crash injury risk (the risk of any injury given involvement in a crash) and the barrier test outcomes.
- The removal of vehicle mass effects from the UCSR crashworthiness measure generally increased the strength of the association with the barrier test measures, as did the consideration of real crash configurations similar to the barrier test configurations (for example frontal impact crashes).
- Although on average overall, barrier test measures appear to be consistent with the real crash measures of vehicle safety, there is not necessarily consistency when comparing ratings for a specific vehicle model. There is a possibility that individual vehicles predicted to have the same safety level by barrier testing will have significantly different estimates of safety based on analysis of real crash outcomes. The converse is also true.

It is encouraging that the conclusions above indicate an overall consistency between the two rating systems (for example, the average real crash safety of vehicles in the ANCAP 4-star category is better than that in the lower-star categories). This is illustrated in Table 1, which is taken from Newstead and Cameron (2002) and which shows average injury risk, severity and UCSR calculated from British crash data for vehicles in each EuroNCAP star category. It shows clearly that, when injury severity and UCSR ratings decrease, the EuroNCAP star rating increases.

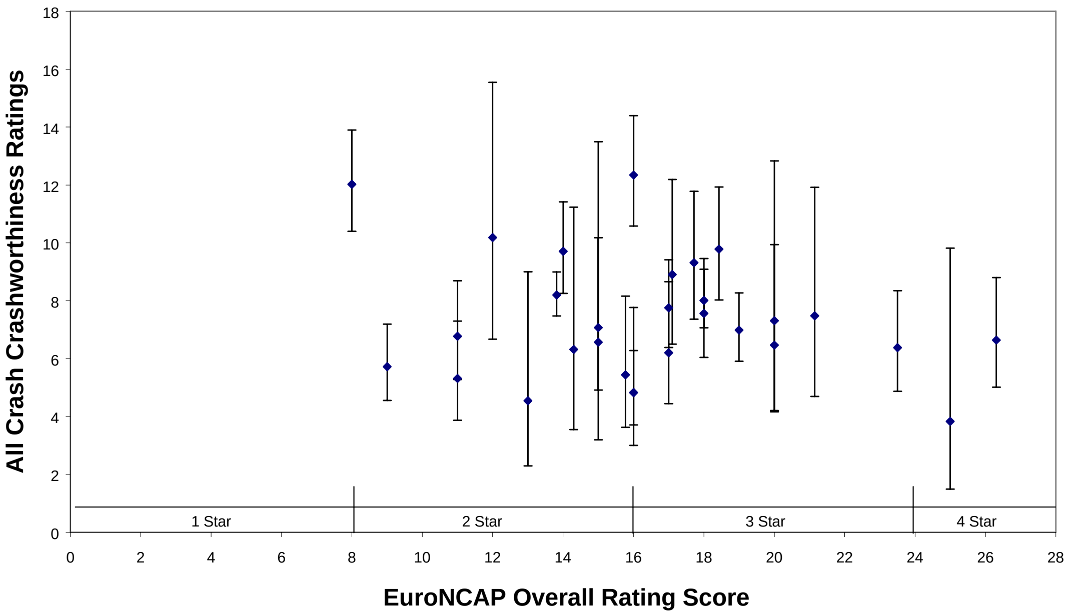
Table 1: Average UCSR estimated from UK data vs. overall EuroNCAP Star Rating

		Crashworthiness estimated from police reported crashes in Great Britain		
		Injury risk	**Injury severity**	**Used car safety rating**
Overall	**1**	75.03	16.02	12.02
EuroNCAP	**2**	65.39	12.23	8.08
Star	**3**	65.40	11.92	7.81
Rating	**4**	66.61	9.39	6.27

N.B.: The lower the UCSR score, the greater the crashworthiness.

However, this consistency frequently did not hold up at the level of individual models, as shown in Figure 2 taken from Newstead and Cameron (2002). For example, Model A with a 4-star ANCAP rating may or may not have better real crash performance than Model B with a lower-star rating.[6]

Figure 2: UCSR estimated from UK data vs. overall EuroNCAP star rating for individual vehicle models.



To some extent, this less-than-complete association can only be expected, given in particular the markedly different approaches used in collecting injury information[7], along with the differences in crash configurations and circumstances represented by the two rating systems. However, it has been demonstrated that it is possible, without changing the current basic measurement procedures for either rating system, to develop weighted rating systems that will potentially provide even more consistency between the two measures of crashworthiness, particularly on a model-by-model comparison basis[7].

5. POLITICAL, SOCIAL AND OTHER FACTORS

There can be no doubt that the new vehicles coming on to the roads in Australasia are safer on average than their predecessors, despite the minor role that safety seems to play in most vehicle promotion campaigns.

The existence of two sets of crashworthiness ratings promoting safety ratings as a key factor in vehicle selection could potentially lead to some consumer confusion when comparing the relative performance of individual vehicle models. For the present, promotional campaigns have minimised the potential for confusion by adopting the following strategy:

- promoting ANCAP ratings for new vehicle purchases
- promoting real crash performance for older (used) vehicles.

This strategy may become difficult to sustain, however, as the number of models with both sets of ratings grows. To some degree, this problem is alleviated by constant changes to the ANCAP test protocol and scoring system, which means that the number of vehicle test results that are directly comparable within that rating system alone are limited. In contrast, ratings for each vehicle model in the Used Car Safety Ratings are re-estimated at each ratings update and are always internally compared. Clearly, the consumer considering the use of both rating systems needs to be fully informed about the content and interpretation of the information presented in each, and to be steered towards the system that offers the best information in the context of their impending vehicle purchase.

An ultimate goal would be to somehow harmonise the information presented by ANCAP and the UCSR into a consistent format. Ongoing research aiming to resolve differences between the ratings, and to develop a single safety system, is to be both welcomed and, where appropriate, supported. This may require willingness amongst barrier-test developers to consider changes to their scoring procedures to make them more consistent with real crash outcomes. Early promise has been offered in this area by research to date.[6] Alternately, or simultaneously, changes to the UCSR system may also be possible to help to achieve this aim.

Differences aside, both rating systems fulfil the role of raising the profile of vehicle safety in the community consciousness. They also both provide a mechanism for monitoring the progress of the vehicle manufacturing industry and vehicle standards regulators in improving vehicle safety standards, through which impetus is provided to make further gains.

As a final consideration, the distinction between vehicle crashworthiness and aggressivity needs to be established. Whereas the former refers to a vehicle’s capacity to protect its occupants in the event of a crash, aggressivity refers to the risk of injury that a given vehicle model represents to other road users – either occupants of other cars or unprotected road users (pedestrians, bicyclists and motorcyclists). Any vehicle safety purchase policy that fails to consider aggressivity could well find itself, for example, promoting the proliferation of large four-wheel-drive vehicles, thereby substantially increasing the overall risk on the roads.[2]

Certainly the early evidence suggests that vehicle aggressivity is a characteristic of vehicle safety performance that is quite independent of crashworthiness.[7] In other words, how well a vehicle protects its own occupants in a crash does not necessarily have a bearing on how it protects other road users with which it collides. This suggests that vehicles can be designed to perform well in relation to both crashworthiness and aggressivity. Indeed, there are examples of vehicles currently available that perform well in both dimensions.

To date, the measures of aggressivity that have been developed by researchers in Australia [2,5] pertain only to 96 individual vehicle models – only 23 of which have ratings either significantly better or significantly worse than average. As this situation improves and the amount of data increases, it will be essential that aggressivity ratings also be considered in future vehicle safety campaigns. In this context, it is also worth noting that the Australian Transport Safety Bureau is undertaking a research program to develop an assessment of vehicle compatibility based on crash testing.

6. CONCLUSIONS

Substantial improvements in vehicle occupant protection mean that modern vehicles are overall twice as safe as those manufactured some three decades ago. However, the level of crashworthiness is not evenly spread across all vehicle makes and models, with the least safe model having more than five times the risk of death or serious injury when involved in a crash, relative to the safest model.

Stronger promotion of vehicle crashworthiness as a key factor in purchasing a vehicle represents a meaningful road safety countermeasure that has been far from fully exploited. However, programs in this area must also consider the issue of aggressivity (i.e. the risk of injury that a given vehicle model represents to other road users) in promoting particular makes and models.

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