Potential for Improving the Relationship between ANCAP Ratings and Real World Data Derived Crashworthiness Ratings

Stuart Newstead & James Scully
Accident Research Centre, Monash Injury Research Institute
Monash University

Tel.: +61 3 9905 4364; Fax: +61 3 9905 4363
Email address: Stuart.Newstead@monash.edu

Abstract

Safer Vehicles is a cornerstone of the Safe Systems approach to road safety. The Australasian New Car Assessment Program is one of the premier programs under the safer vehicles banner. It aims to improve the safety of new vehicles entering the fleet through identifying objective design and performance criteria for manufacturers to improve vehicle safety and publishing information on the relative performance of vehicles in meeting these criteria for consumer information to encourage safer vehicle purchases. Numerous studies have been conducted internationally comparing the ability of the vehicle safety rating summary used by ANCAP to predict vehicle crashworthiness performance in real world crashes. Although many of the studies have been able to show an association between the ANCAP rating and real world vehicle crashworthiness, the correlation between the two measures is far from perfect. In practice, this means that many vehicles that score well under the current ANCAP scoring system will not necessarily exhibit superior crashworthiness in real world crashes thus diluting the effectiveness of ANCAP as a tool for driving the Safe Systems process. This paper presents the results of an analysis which re-weights the ANCAP crash test elements into an overall score to significantly improve the relationship with relative vehicle crashworthiness estimated from real world crash data. Both positive and negative potential implications of adopting the proposed modified scoring system are discussed along with how these relate to vehicle safety policy and strategy.

Keywords

Crash tests, ANCAP, Crashworthiness, Safety ratings, Data Analysis

Background

Safer Vehicles is a cornerstone of the Safe Systems approach to road safety. Improving the safety of new vehicles on the market and encouraging purchase of the safest vehicles available has the potential to contribute significantly to trauma reduction targets set out in road safety strategies across Australasia. The Australasian New Car Assessment Program (ANCAP) is one of the premier programs under the safer vehicles banner. It aims to improve the safety of new vehicles entering the fleet through identifying objective design and performance criteria for manufacturers to improve vehicle safety and publishing information on the relative performance of vehicles in meeting these criteria for consumer information to encourage safer vehicle purchases.

ANCAP rates the relative occupant protection performance of vehicles through a series of controlled laboratory crash tests. The ANCAP offset frontal test involves a crash into a deformable barrier conducted at 64 km/h and 40% offset. Readings from the instrumented dummies within the vehicle are used to provide scores for safety performance in each of four body regions: the head and neck, chest, upper legs and lower legs. The ANCAP side impact test involves a 950kg trolley running into the driver's side of the vehicle at 50km/h. Safety performance is measured in the head, chest, abdomen and pelvis regions. The side impact pole test is conducted at the manufacturers' discretion if the vehicle performs very well in the standard side impact test and is fitted with head protecting side airbags. The test involves the vehicle hitting a steel pole at 29km/h in line with the side of the drivers head. Additional bonus points are awarded if the vehicle contains an advanced seatbelt warning system. Vehicles are awarded an occupant protection star rating on the basis of the vehicle's aggregate point score in the crash tests with 16 points available in each of the offset frontal and side impact tests (4 points for each body region), 2 points are available for the pole test and 3 for the seatbelt reminder system. Allocated star ratings correspond to certain ranges of ANCAP score.

Implicit in the ANCAP testing protocol and its marketing as consumer information to assist in purchasing a safer vehicle is the expectation that the relative crash test score given to each vehicle will predict the relative protection from serious injury vehicles offer in real world crashes. There have been many studies conducted internationally assessing the relationship between NCAP type vehicle safety ratings and real world crash outcomes [1-5]. Although this research uses real world crash data from many jurisdictions and explores the relationship with a range of different crash tests, there are two important common themes that emerge.

Firstly, it is clear that, in general, there is a general relationship between the risk of death or serious injury in a crash and NCAP type ratings with vehicles scoring a higher NCAP star rating having a lower risk of death or serious injury to the driver in a crash. This is encouraging in that it suggests ANCAP is generally reflecting factors that make vehicles safer in real world crashes on average. However, at the individual vehicle level, there is still significant variation in real world crash serious injury risk between vehicles that have the same NCAP rating. This means that a vehicle that is scored well by ANCAP may not perform well in real world crashes. This is illustrated in Figure 1 which presents the risk of death or serious injury to drivers in real world crashes in Australasia estimated from the Used Car Safety Ratings (UCSR) [6] with 95% statistical confidence limits against the overall ANCAP score for 69 models of vehicles rated in both systems. It illustrates the trend to improving ANCAP rating with decreasing real world risk of death or serious injury but also the high degree of dispersion in the real world rating for vehicles with similar ANCAP scores. The R-squared value for the relationship between the overall ANCAP test scores and the UCSR crashworthiness estimates shown in Figure 1 was 0.347. That is, only 35% of the variation in the UCSR crashworthiness estimates for the 69 vehicle models can be explained by the overall ANCAP test scores.

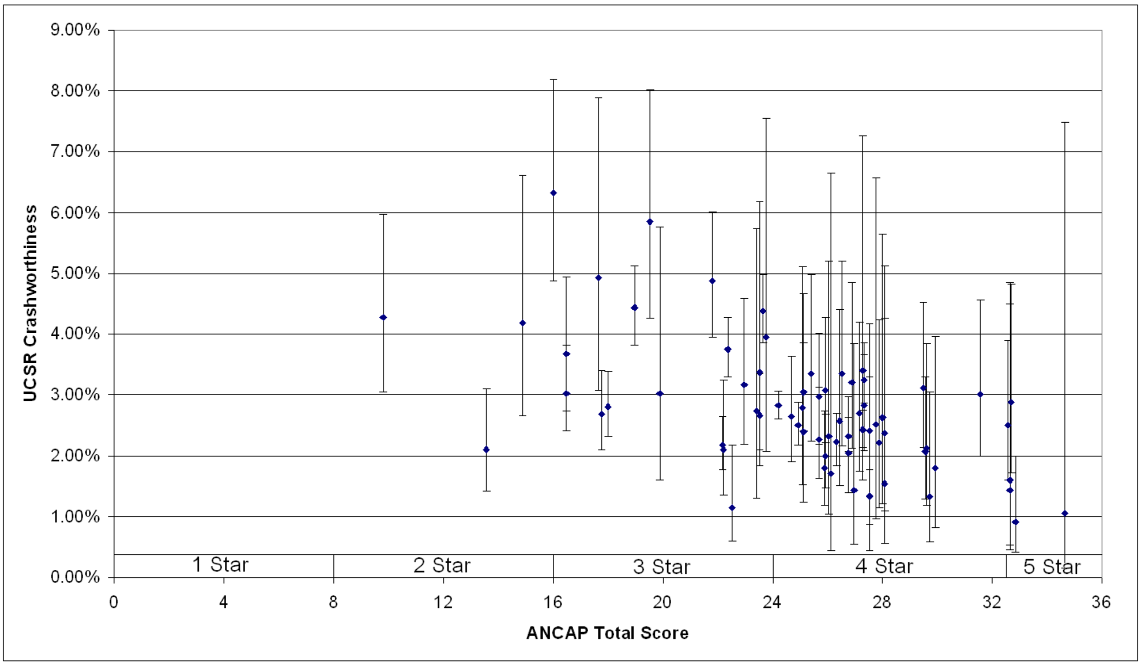

Figure 1: ANCAP test score vs UCSR crashworthiness

One possible reason for the low correlation between UCSR crashworthiness ratings and ANCAP occupant protection scores is the way in which to overall ANCAP score is constructed. The ANCAP score gives equal weighting to the offset frontal and side impact test outcomes implying that each crash configuration is equally represented in real world crashes and hence equally important in the overall assessment of real world performance. It also gives equal weighting to each body region assessed within these major crash tests suggesting each body region is equally vulnerable and equally likely to contribute to overall real world serious injury risk. Assessment of real world data draws this method of scoring into question. For example, analysis of Swedish data shows that 53% of serious injuries are sustained in frontal impacts compared to only 33% in side impacts whilst in offset frontal impacts there is much greater chance of injury to the head and chest than the legs [7]. These results suggest that re-weighting the component measures of the overall ANCAP score could potentially result in improved correlation with overall risk of death or serious injury to drivers in real world crashes.

AIMS

This study aimed to investigate whether the correlation between vehicle secondary safety ratings developed from crash tests and those developed using real world crash data can be improved in the Australasian setting. In particular, it aimed to assess whether the component ANCAP crash test measures could be re-weighted into a new summary measure that had a closer relationship with Used Car Safety Rating crashworthiness scores derived from Australasian crash data under the UCSR program.

DATA AND METHODS

ANCAP crash test results conducted from 1997 to 2007 were collated and covered results for 171 models. Of the 171 models for which ANCAP crash data were available, crashworthiness estimates based on Australasian data were available for 69 vehicle models [6]. Figure 1 shows the UCSR crashworthiness estimates and the aggregated ANCAP score for each of the 69 models used in the analyses plotted against each other.

As described, the side impact component and the frontal offset component of the overall ANCAP score are each comprised of four scores each with a maximum of four points related to four different body regions. For the side impact crash test, each vehicle is assessed in terms of how it protects the head (S_HEAD), chest (S_CHEST), abdomen (S_ABDOMEN) and pelvis (S_PELVIS). In the frontal offset crash test, each vehicle is assessed according to how effectively it protects the head (F_HEAD), chest (F_CHEST), upper legs (from hip to knee, F_UPPER) and lower legs (including the foot, F_LOWER). The optional pole test (POLE) scores a maximum of 2 points whilst the seatbelt (S_BELT) reminder system was scored out of 3 points

Logistic regression models were used to derive the optimum relationship between the ANCAP body region sub-scores from the offset frontal, side impact and pole crash tests and the UCSR crashworthiness ratings. The UCSR crashworthiness ratings were the outcome variable in the model with the offset frontal, side impact and pole crash tests component measure scores and seat belt reminder score included as predictive factors in the model. Vehicle mass was also included in the model acknowledging that the UCSR crashworthiness ratings is not adjusted for the effect of vehicle mass on injury outcome whereas the ANCAP testing processes are reported to be independent of vehicle mass. A stepwise model building process was used to identify only those measures which were significant predictors of UCSR crashworthiness and also helped interpretation of the model by assisting to eliminate ANCAP test measures which were highly correlated.

The UCSR crashworthiness estimates predicted from the logistic regression model were the equivalent of a re-weighted ANCAP scoring protocol. Improvement in the re-weighted ANCAP measure derived from the logistic regression modelling procedure was assessed through comparison of model R-squared values. Graphical representation of the re-weighted ANCAP scoring protocol against the UCSR crashworthiness values was also used to indicate predictive power.

RESULTS

Results of the stepwise selection process for constructing a predictive model of the UCSR crashworthiness score from the ANCAP offset frontal and side impact body region scores plus pole test score, seat belt reminder score and vehicle kerb mass is shown in Table 1. The parameter estimates for each factor included in the model are given in Table 1 along with their standard errors and estimated statistical significance based on an asymptotic chi-squared test indicating the improvement in model fit upon including the factor in the model. A statistical significance of 0.1 was chosen for factor inclusion in the model.

The resulting model did not include covariates associated with the risk of chest injuries in the offset frontal or the side impact crash tests nor did it include the abdomen score from the side impact test or the seatbelt reminder system score. These factors were eliminated from the model in the stepwise selection process employed as they did not statistically significantly improve the model fit. This is a reflection of these factors either not being associated with the outcome measure or being highly correlated with a factor that remained in the model. All other factors were significant predictors of crashworthiness. Each of the parameters also had a sign which was in accordance with that expected with a higher ANCAP component measure score, indicating better safety performance, being associated with a lower risk of real world death or serious injury. The only exception to this was the head injury score with a higher numerical (better) head injury score being associated with worse real world crashworthiness. Possible reasons for this are explored in the discussion.

Table 1: *Parameters of the logistic model of UCSR crashworthiness ratings against ANCAP crash test measures derived by using the stepwise selection approach described.*

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-1.7184	0.4085	17.6954	<.0001
KERBMASS	1	-0.00041	0.000047	75.235	<.0001
F_HEAD	1	0.0511	0.0224	5.2289	0.0222
F_UPPER	1	-0.0946	0.0167	32.0775	<.0001
F_LOWER	1	-0.0881	0.0131	45.1553	<.0001
S_HEAD	1	-0.0941	0.0484	3.7851	0.0517
S_PELVIS	1	-0.1645	0.0889	3.4229	0.0643
POLE	1	-0.1234	0.0604	4.177	0.041

The proportion of variation in the real world crashworthiness ratings explained by the re-weighted ANCAP body region scores derived from the predicted values estimated from the logistic regression model of Table 1 was 66.1%. This is significantly higher than the 35% for the standard ANCAP scoring protocol shown in Figure 1. Figure 2 shows the UCSR crashworthiness scores plotted against the re-weighted ANCAP derived from the logistic regression model. It reflects the much higher concordance between the two measures with significantly less variation in the crashworthiness metric for those vehicles with similar predicted scores from the logistic model.

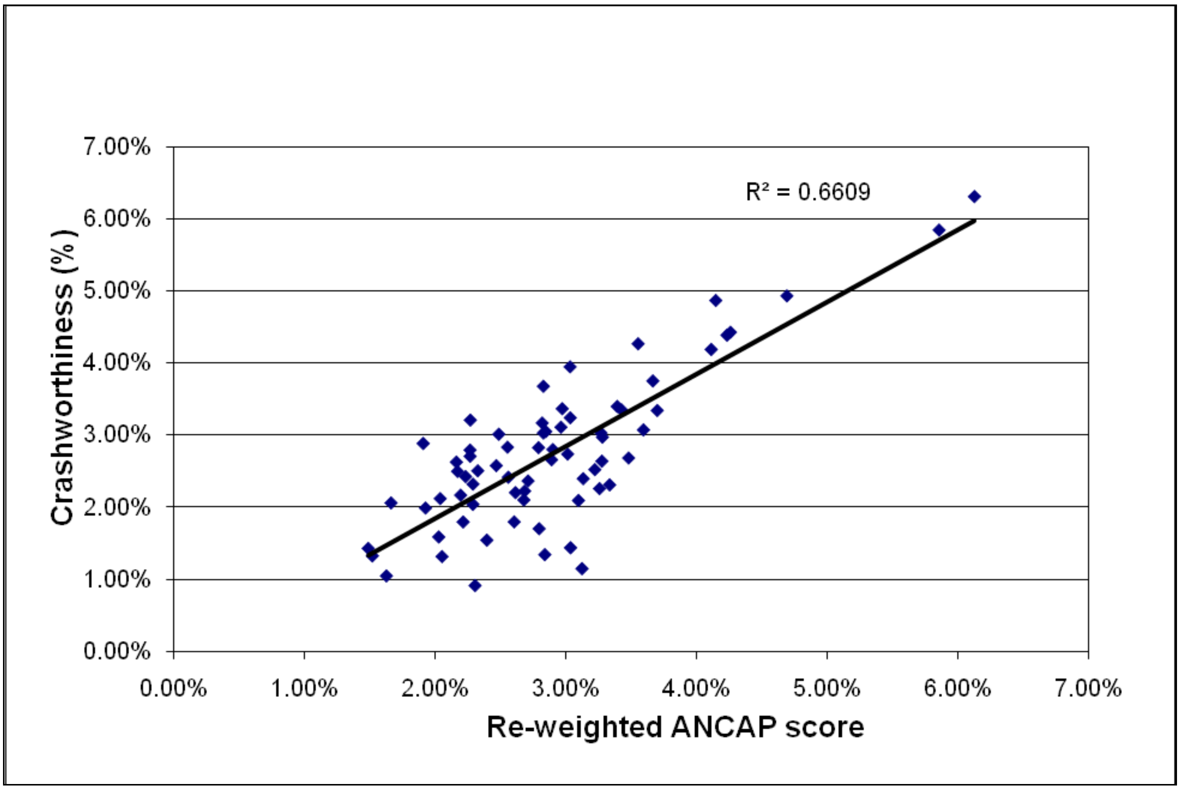

Figure 2: Actual UCSR crashworthiness vs that predicted from the logistic model based on ANCAP component test score measures

DISCUSSION

Analysis presented in this paper has demonstrated that it is possible to dramatically improve the relationship between the ANCAP occupant protection score and the crashworthiness measure of occupant protection derived from real world data under the Used Car Safety Ratings program. Improvement in the relationship has been achieved by re-weighting the individual component measures derived from the crash tests to form a modified overall score. Deriving a new ANCAP scoring system in this way has the primary advantage that it improves the relationship with the real world data based crashworthiness measure through better use of the existing crash test protocols and measurements from the crash test dummies. Consequently it provides the opportunity for all retrospective ANCAP test data to be re-scored instead of forcing a change to test protocols and only being able to apply the new scoring system to future test.

Deriving the re-weighted ANCAP scoring function through regression modelling is potentially problematic as it does not guarantee the resulting function will have intuitively plausible weightings for each of the component measures. In general, the weightings produced through the regression modelling process in this instance have good intuitive plausibility in having the expected direction of relationship. A better score on each component measure was associated with lower real world risk of death or serious injury. The relative magnitude of the coefficients for the 5 body region scores included in the best fitting model is also generally plausible. The frontal test upper and lower leg scores and side impact chest score all had similar weighting in the model with the side impact pelvis score having slightly higher weighting. Elimination of some body region scores assigned by ANCAP from the final model implies that these measures are not required in order to best predict real world injury risk.

The coefficient for the frontal impact head score was the only factor with a sign contrary to that expected. Taken on face value this result suggests that a good offset frontal head injury score is associated with poorer real world injury outcomes. This is particularly surprising since analysis of information in Transport Accident Commission injury compensation claims data indicated that 36% of occupants who were seriously injured received a serious head injury highlighting the importance of this body region. There is some suggestion in the literature that measurements taken during the frontal offset crash test to estimate the level of head protection provided by a vehicle do not accurately reflect the risk of serious head injury. Specifically, there is concern that the Head Injury Criterion (HIC) reading on which the head score is based does not accurately reflect the actual risk of serious injury [8]. This is an issue that requires careful further investigation. It also has some potential implications for the practical use of the re-weighted ANCAP score in that it may divert focus by manufacturers trying to achieve good ANCAP scores for their vehicles from trying to optimise head injury protection in offset frontal impacts. However, if HIC is not a good predictor of real world head injury risk the current scoring system may not be leading to optimised head injury protection anyway.

Adoption of the new re-weighted ANCAP scoring system derived from the analysis in this study offers the potential to provide consumer advice on relative occupant protection performance that is more consistent with that provided in the Used Car Safety Ratings through the crashworthiness index. Using the new summary score would mean there is less likelihood that a vehicle that rated well under ANCAP would rate poorly in the UCSR crashworthiness index and vice versa. Despite the significant improvement in consistency offered by the new score, its correlation with the UCSR crashworthiness index is still not perfect. This is expected given that the ANCAP crash test protocols only cover a limited range of crash configurations. Of significance, ANCAP does not cover occupant protection performance in rear impact or rollover crashes. These two crash types represent around 20% of crashes resulting in serious injury outcomes [7]. The lack of perfect predictive power of the re-weighted score gives some credence to ANCAP expanding the test protocols to consider additional crash types. ANCAP's future road map [9] indicates that tests for whiplash protection and roof strength will be included in future which may improve the potential correlation with real world occupant protection but would also mean the re-weighted scoring system derived in this study would have to be recalibrated.

Discussion so far has identified the potential benefits of adopting a new ANCAP scoring protocol which better predicts real world outcome. However, there are also some potential significant disadvantages in adopting the re-weighted scoring system. A major benefit from ANCAP influencing consumers to purchase vehicles it scores highly is to place pressure on manufacturers to design vehicles which perform well on the criteria set by ANCAP. The leverage ANCAP has with manufacturers to meet each criterion set is strongly related to the point score assigned to each criteria. Adopting a new scoring system such as that proposed here that only reflects real world importance of the criterion might limit the leverage ANCAP has to encourage manufacturers to meet that criterion. As the gains offered by new technology become smaller due to focusing on more specific parts of the vehicle safety problem, the new scoring system could provide less motivation to adopt the new technology even if it is highly effective and more importantly highly cost effective. This is a potential trade-off that must be carefully considered.

A further problem in the re-weighted ANCAP score derived in this study is the strong influence of vehicle mass in predicting of serious injury risk in real world crashes. Excluding vehicle mass from the model significantly reduced its predictive power of real world outcomes. Having vehicle mass in an ANCAP scoring system could present a major problem in giving manufacturers the option to achieve good score simply by increasing mass. From the perspective of the impact of the vehicle on the environment and other road users in a crash this is undesirable. The identified role of mass in real world crash injury outcomes confirms that ANCAP is only useful for comparing the occupant protection performance of vehicles of a similar mass. This point is often lost in the promotion of ANCAP with many consumers and the media seeming to believe a 5 star rated small car will give the same real world occupant protection performance as a 5 star rated large car. Whether ANCAP should more overtly state the inability of its ratings to be compared across mass classes is also a difficult question given it may have the same effect as including mass explicitly as a factor in the ANCAP summary score. Reflection of mass in the UCSRs is less of a problem since the UCSRs, unlike ANCAP in being a post-hoc assessment of vehicle safety, have a limited ability to change the profile of new vehicles entering the fleet and influence how manufacturers focus their designs.

Another factor potentially affecting the usefulness of the re-weighted ANCAP summary score derived in this study is the new direction for ANCAP outlined in the future road map [9]. As well as including whiplash and roof strength tests as noted, the aim is for ANCAP to include assessment of safety assist technologies. Many of these technologies are focused on crash avoidance, or primary safety, rather than injury mitigation in a crash (secondary safety). Primary safety features being considered by ANCAP include lane departure warning systems, alcohol interlocks and blind spot monitoring. Mixing assessment of primary and secondary safety assessment has already occurred with ANCAP limiting of vehicles without electronic stability control to a maximum of 4 stars. Combining the measurement of both primary and secondary vehicle safety performance in the ANCAP score will further distance ANCAP from the UCSR crashworthiness ratings which measure only secondary safety. It positions ANCAP more in the role as a safety scoring system based on the presence or absence of certain features in combination with meeting set performance criteria. This is in contrast to the UCSR ratings which remain firmly focused as a safety rating system measuring performance on a single outcome criterion; the likelihood of death or serious injury in a crash.

The growing separation in focus of ANCAP and the UCSRs in the future limits the potential to reconcile the consistency of the two sources of consumer information since they will be focusing on different aspects of vehicle safety performance. This suggest that instead of trying to adopt a means to ensure the scoring systems from the two programs accord as well as possible, as proposed here, it will perhaps be more important in the future to develop communications strategies that clearly articulate what each program is measuring to avoid consumers making uninformed comparison of the two programs. However, it is still important to use real world data to provide local validation of the performance of features included in the ANCAP scoring system to ensure ANCAP is not promoting the adoption of safety features that are ineffective or have unintended negative safety consequences.

CONCLUSIONS

This study has defined a re-weighted ANCAP scoring system that provides rankings of relative vehicle occupant protection performance that are much more consistent with those derived from analysis of real world crash outcomes in the Used Car Safety Ratings crashworthiness assessment. The new scoring system offers the potential to avoid apparent conflicts in the ratings from the two systems hence increasing the credibility of each to the consumer and media. However, the potential improvement comes at the possible detriment to ANCAP meeting its broader objectives. The re-weighted scoring system would potentially limit the influence ANCAP had on manufacturers to include certain safety features in vehicles or to meet certain performance criteria which might ultimately slow the rate of safety improvement of new vehicle designs particularly for highly cost effective technologies. It also makes explicit the role of vehicle mass in determining real world injury outcomes which may encourage vehicle manufacturers or consumers to trade good design for increased mass which conflicts with environmental imperatives. This is a particular problem for ANCAP which primarily influences new vehicles entering the fleet.

The results of the study considered in the light of future developments outlined for ANCAP highlight the need to develop careful communications strategies around the ANCAP and UCSR ratings. The strategy should inform vehicle purchasers of the difference between the ANCAP and UCSR programs, detail what information each is providing and highlight the most effective way to use the information from each to inform vehicle purchases.

REFERENCES

- 1. Newstead, S., et al., *Study of the relationship between injury outcomes in police reported crash data and crash barrier test results in Europe and Australia,* in *Quality criteria for the safety assessment of cars based on real-world crashes*. 2006, Comite Europeen Des Assurances - SARAC II. p. 241.
- 2. Newstead, S.V., et al., *U.S. consumer crash test results and injury risk in police reported crashes.* Traffic Injury Prevention, 2003. **4**: p. pp. 113-127.
- 3. Lie, A. and C. Tingvall, *How Do Euro NCAP Results Correlate with Real-Life Injury Risks? A Paired Comparison Study of Car-to-Car Crashes.* Traffic Injury Prevention, 2002. **3** p. 288-293.
- 4. Farmer, C.M., *Relationships of Frontal Offset Crash Test Results to Real-World Driver Fatality Rates.* Traffic Injury Prevention, 2005. **6**(1): p. 31 - 37.
- 5. Kullgren, A., A. Lie, and C. Tingvall, *Comparison Between Euro NCAP Test Results and Real-World Crash Data.* Traffic Injury Prevention, 2010. **11**(6): p. 587 - 593.
- 6. Newstead, S.V., L.M. Watson, and M.H. Cameron, *Vehicle safety ratings estimates from Police reported crash data: 2009 update. Australian and New Zealand crashes during 1987-2007*. 2009, Monash University Accident Research Centre: Melboune, Australia.
- 7. Buzeman, D., D. Viano, and P. Lovsund, *Injury probability and risk in frotal crashes: effects of sorting techniques on priorities for offset testing* Accident Analysis and Prevention, 1998. **30**(5): p. 583-595.
- 8. Nirula, R., et al., *The New Car Assessment Program: Does It Predict the Relative Safety of Vehicles in Actual Crashes?* Journal of Trauma Injury, Infection and Critical Care, 2004. **57**: p. 779-786.
- 9. ANCAP, *ANCAP Road Map 2011-2015*. 2011, Australasian New Car Assessment Program: Canberra, Australia.