DEVELOPMENT OF A METHOD OF ESTIMATING THE COSTS OF INJURIES PREDICTED BY ANCAP TESTING IN AUSTRALIA

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ABSTRACT

A database of comprehensive injury costs was developed using data from finalised personal injury claims where a single injury was sustained. A method of combining costs for cases with multiple injuries was developed. Injury Assessment Functions were used to predict the probability of head, chest and lower limb injury from measurements taken from Hybrid III dummies in Australian New Car Assessment Program full frontal and offset tests. Costs for injury to each body region were obtained by summing the product of the probability of injury and the cost of injury for each level of injury and body region. These costs were then combined for each of driver and passenger position and for each vehicle. Results showed a wide range of costs in the initial ANCAP tests in 1992 and 1993, with a considerable reduction in subsequent testing, in both full frontal and offset tests. Injury costs in offset tests were lower than in frontal tests and were higher for passengers than drivers.

INTRODUCTION

Testing for the Australian New Car Assessment Program (ANCAP) has been carried out in Australia since 1992. Griffiths (1996) demonstrated that there was a reduction in the probability of head injury in large and medium vehicles between 1992 and 1994, and that the performance of Australian vehicles was inferior to US vehicles of similar mass. Another method of comparing the occupant protection performance of different vehicles, and of the same vehicle over time, is to use estimates of the costs of injuries predicted from crash testing, in this case, from the Australian ANCAP program.

AIM

The aims of this project were to:

1. Develop a database of comprehensive injury costs by body region and injury severity;
2. Estimate the costs of injuries predicted by measurements obtained from anthropometric test devices in different models of vehicles in full frontal and offset crash tests;
3. Analyse changes in the costs of injuries for the same vehicle model in different tests, and for groups of vehicles.

METHOD

A series of steps were involved in the process of estimating injury costs for ANCAP tests.

1. Comprehensive costs of injury by level of severity for each body region were established.
2. The probability of injury for a given body region at various impact levels was established using appropriate Injury Assessment Functions.
3. For a particular vehicle in a particular test, the cost of injury was determined from the product of the probability of injury of a particular severity and the cost of that injury, summed over all injury severities.
4. A method of combining the costs of injuries to several body regions into a single sum was developed for cases with multiple injuries.
5. Cost estimates were developed separately for driver and front seat passenger in each of frontal and offset frontal impact tests.
6. Comparisons were made between successive tests of the same vehicle, and between classes of vehicles.

INJURY COSTS

Comprehensive costs for road injury by injury severity level for each body region were developed using data from 49,755 personal injury insurance claims from New South Wales and from other sources. The claims data included the Abbreviated Injury Scale (AIS) (1985 revision) coding for up to five injuries per person. The components of these costs included hospital and medical, rehabilitation, modifications to home etc, aids and appliances, economic loss, general damages, legal and investigations, long term and home care, insurance administration, property damage, travel delay, accident investigation, motor vehicle insurance, unpaid earnings, non-victim costs, and other costs. These costs were estimated for cases with finalised claims for single injuries.

Table 1
Injury costs by component, body region and severity (A$ 000s)

Severity	Costs A$ 000					
	Head			**Chest**		
	Additive	Non-additive	Total	Additive	Non-additive	Total
AIS 1	1.9	16.5	18.4	1.2	6.8	8.0
2	4.6	25.4	30.0	3.9	14.1	18.0
3	14.8	56.8	71.6	5.4	18.7	24.1
4	75.2	648.0	723.2	15.6	18.7	34.3
5	75.2	648.0	723.2	15.6	18.7	34.3

Severity	Costs A$ 000					
	Upper leg			**Lower leg**		
	Additive	Non-additive	Total	Additive	Non-additive	Total
AIS 1	2.1	17.2	19.3	1.7	11.2	12.9
2	8.7	34.2	42.9	8.5	33.5	42.0
3	16.3	47.8	64.1	18.9	53.8	72.8
4	16.3	47.8	64.1	-	-	-
5	16.3	47.8	64.1	-	-	-

A method of combining costs was developed for cases with multiple injuries. It was assumed that some costs could be attributed to each individual injury; these were termed additive costs, while other costs could only be attributed to either the crash event or would apply equally to all injuries, and could only be counted once. These were termed non-additive costs. Additive costs included hospital and medical, rehabilitation, modifications to home etc, and aids and appliances, while non-additive costs included the remainder. In cases where there were injuries to more than one body region, the additive costs for each region were summed, and added to the largest non-additive cost from any body region. Costs for fatal injuries were not included. Average total costs for the four body regions used in evaluating vehicle design changes and their additive and non-additive components are set out in Table 1.

PROBABILITY OF INJURY

For each body region the probability of injury was estimated using an appropriate Injury Assessment Function (IAF). The Australian ANCAP test program provided measurements from the Hybrid III dummies used, for the head (Head Injury Criterion (HIC)), the chest (deflection in millimetres and acceleration in g), upper leg (knee impact force, kN), and for the lower leg (Tibial Index).

Head Injury

A search for an appropriate IAF revealed that Newman, Tylko and Miller (1992) had proposed an IAF for head impacts which used Gmax, a measure which combined linear and angular accelerations. As these values were not available from the ANCAP test results, the family of curves proposed by Newman et al (1992), were transferred to a base of HIC values, by extrapolation from a curve for AIS 4 head injury proposed by Mertz (1994). These curves were then compared with those proposed by NHTSA (1995), which were based on work by Prasad and Mertz (1985). The curves developed from Newman were steeper and provided greater discrimination between impacts of similar magnitude. Although the assumptions made in developing both sets of curves were equally tenuous, the NHTSA curves have been used in estimating the probability of head injury as they have been widely used and have become accepted as the industry standard (Figure 1).

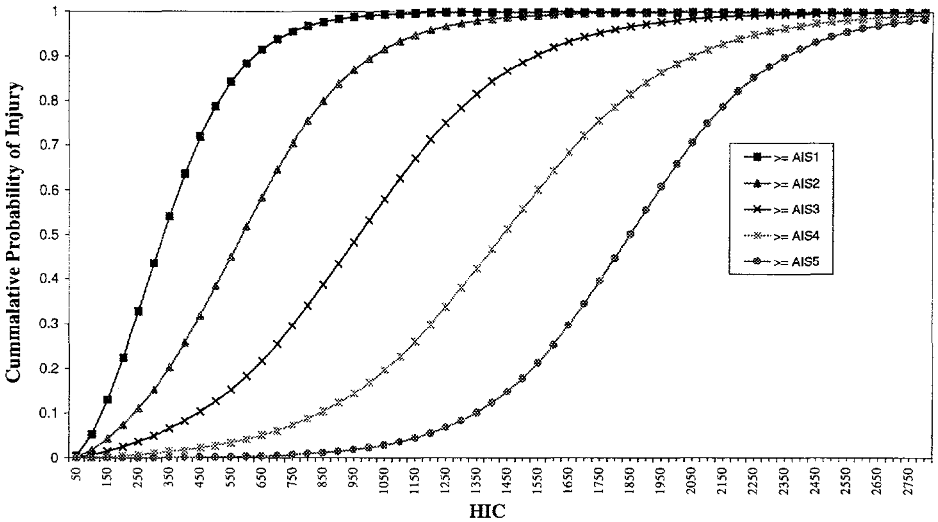

Figure 1 Probability of head injury severity as a function of HIC.

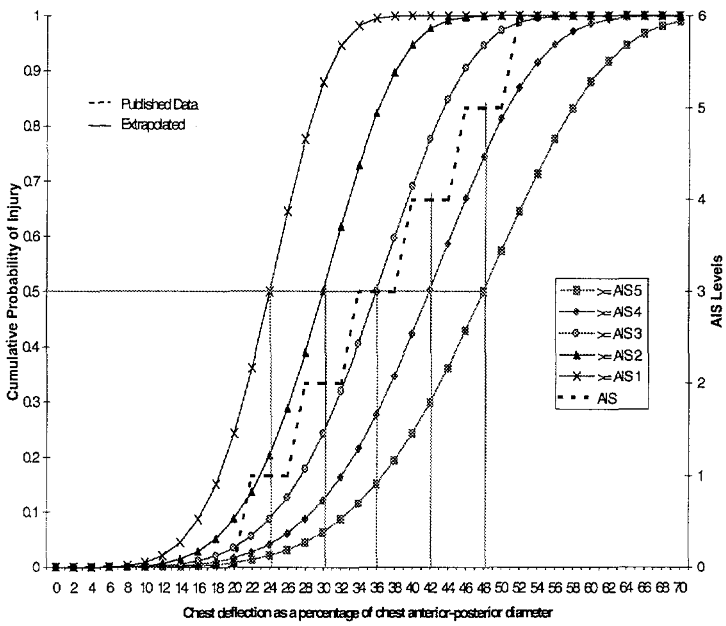

Figure 2 Probability of chest injury as a function of chest deflection

Chest Injury

The probability curves for chest injury of Newman et al (1992), based on chest deflection as a percentage of chest anterior-posterior diameter were adopted (Figure 2). The anterior-posterior diameter of the Hybrid III chest was assumed to be 223mm.

Upper Leg

The knee impact force criterion of Mertz (1994) was adopted, where a knee impact force of 7.5kN indicated AIS3 upper leg injury, equivalent to a fracture of the femur or pelvis.

Lower Leg

The Tibial Index of Mertz (1994) was used for lower leg injury. Peak bending moment for the upper and lower tibia (M) and peak axial compression force for the lower tibia (P) were used in the equation:

$$\text{Tibial index} = M/225\text{Nm} + P/35.9\text{kN}$$

A Tibial Index greater than 1.0 indicates an injury of AIS2, which is equivalent to a fracture of the tibia.

COST OF INJURY

For each body region, the cost of the injury was obtained by summing the product of the probability of occurrence of each level of severity of injury (as predicted by the injury assessment functions) by the cost of the injury of that severity, divided into its additive and non-additive components. That is, for each body region:

$$\text{Additive Injury Cost} = \Sigma\,(P_i\,.Ca_i)$$

Where $i = AIS1, AIS2, AIS3, AIS4, AIS5$
P = probability of injury
Ca = additive cost

and

$$\text{Non-additive Cost} = \Sigma\,(P_i.\,Cna_i)$$

Where $i = AIS1, AIS2, AIS3, AIS4, AIS5$
P = probability of injury
Cna = non-additive cost

Cost For Each Seated Position

Having determined the appropriate cost for all four body regions, a cost was calculated for each driver and front passenger position. Additive costs were summed across all body regions and added to the maximum of the non-additive costs for any region. That is, for each driver and front passenger:

$$\text{Occupant Cost} = \Sigma(\text{Additive Injury. Cost})j + \text{MAX}(\text{Non-additive Injury. Costs})j$$

j = *Head, Chest, Upper Leg and Lower Leg*

Cost Per Vehicle

A total cost per vehicle was obtained, by adding the driver cost and passenger cost. The full-frontal and offset tests were treated independently. That is, for each full-frontal and offset test;

$$\text{Vehicle Cost} = \Sigma(\text{Occupant costs})k$$

Where k = Driver, Passenger

NEW CAR ASSESSMENT PROGRAM (ANCAP)

The first ANCAP tests of Australian cars were carried out in 1992 and 1993 as full frontal tests at 56km/h. Offset tests with 40% overlap, using a deformable barrier, at 60km/h were introduced in 1994. The impact speed for the offset tests was subsequently raised to 64km/h. Additional tests on the same model were carried out when there was thought to have been a substantial change in occupant protection performance. Therefore, while the majority of vehicles had been tested at least twice in the five years 1992 - 1997, there were a number for which only one test had been performed. Only the first and the latest test have been included when discussing changes in individual vehicles, regardless of how many tests were performed. If only one test was performed, then it was considered in the first set of tests. Results for full frontal and offset tests are presented separately. Large and medium cars were grouped together, being vehicles with a mass of 1200kg and over.

RESULTS

For the 80 vehicle tests published by the ANCAP program, injury costs were calculated for driver and passenger for frontal and offset tests. Due to the large volume of data, results are only presented for large and medium cars, ie, those with a mass of 1200kg and over. Frontal and offset tests are presented separately.

Figure 3 presents the estimated costs of the predicted injuries to driver and passenger for frontal tests for large/medium cars.

The total injury cost for the initial test ranged widely, from over A$1.2 million to under A$100,000. For all except one of the six models where at least one or more test was performed, there were substantial differences. All the latest models tested were equipped with driver airbags.

These results are summarised in Figure 4, which shows the large spread of costs in the initial tests, with four models having costs over A$600,000. This compares with the latest tests where all but one were under A$400,000.

The mean cost for the six models which were tested at least twice was A$757,080 for the first test and A$257,520 for the latest, a difference of A$499,560. For all full frontal tests of large and medium vehicles the mean total cost was A$488,190.

Figure 5 shows the results for the offset frontal tests. In general these costs were lower than for the full frontal tests. The mean total cost was A$153,000 per test. It is notable that the improvement in costs in successive tests seen in the full frontal tests is not seen in the offset tests where costs in some models were higher in later tests.

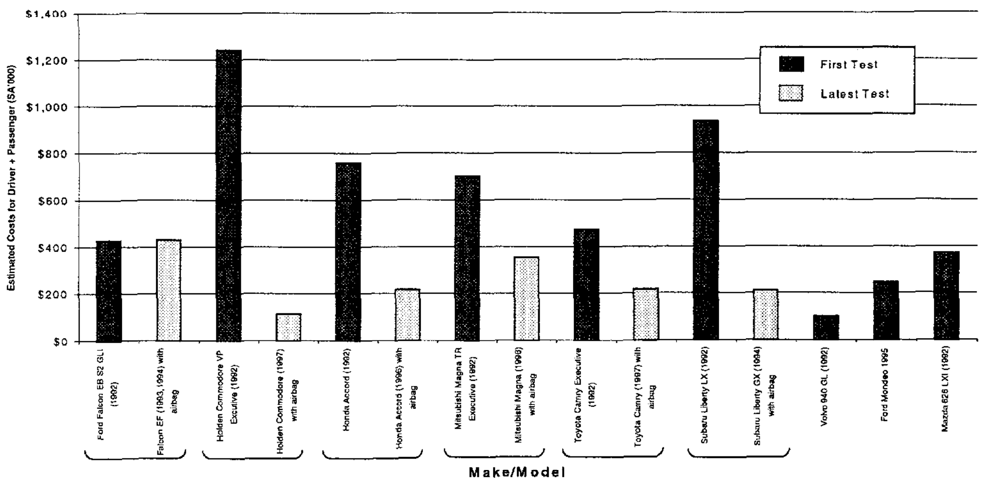

Figure 3 Estimated total cost of injuries for large/medium cars in full frontal tests (A$ 000s)

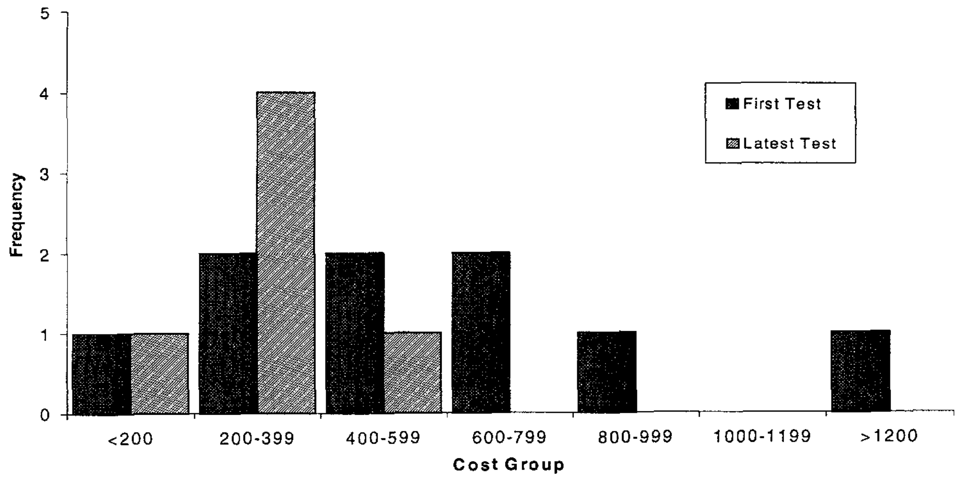

Figure 4 Comparison of costs between the first and latest tests, large/medium cars, full frontal tests(A$ 000s)

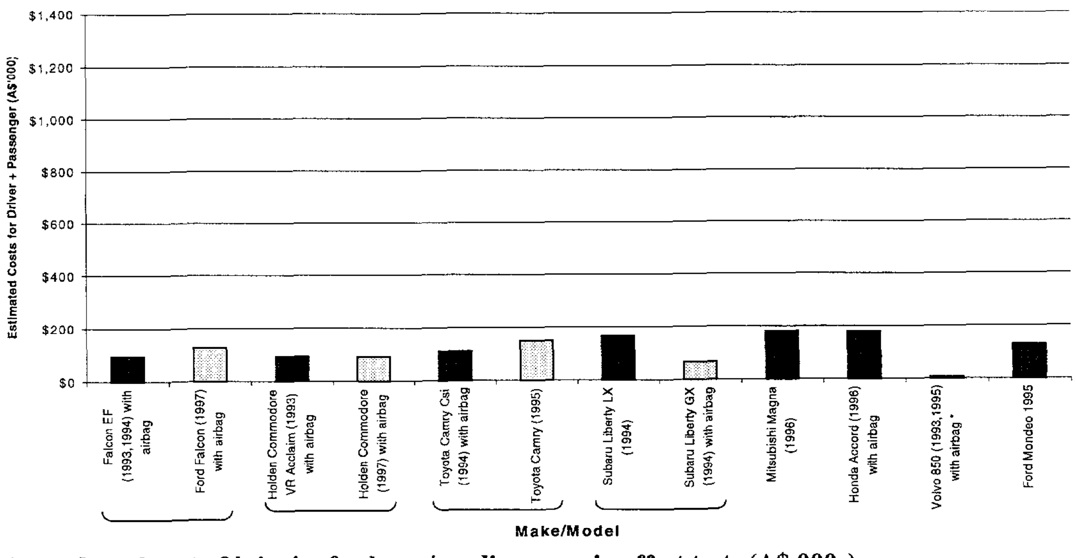

Figure 5 Estimated total cost of injuries for large/ medium cars in offset tests (A$ 000s)

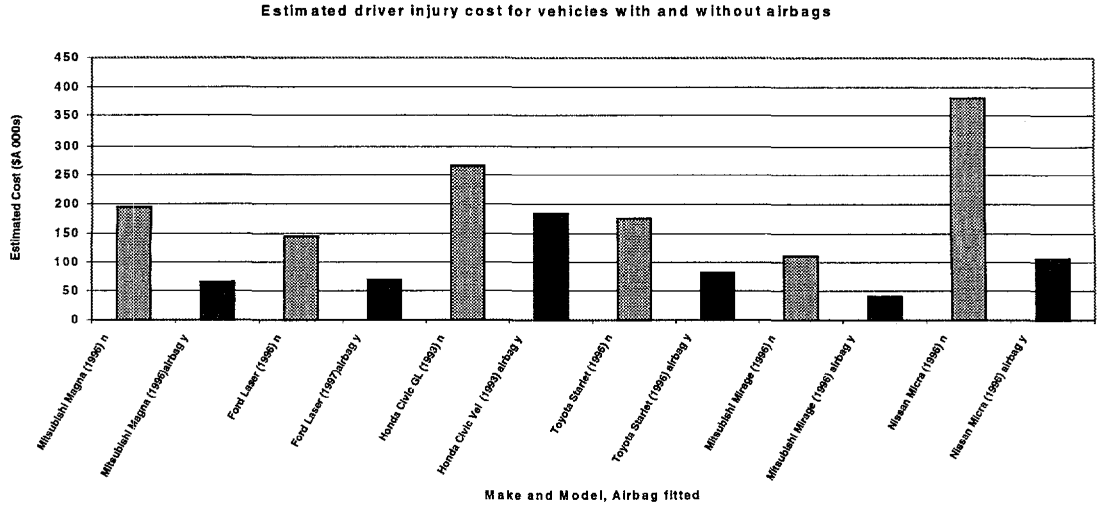

Figure 6 The effect of a driver airbag on estimated cost of injury (A$ 000s)

Mean Driver, Passenger and Total Costs

In 14 (63.6%) of the 22 frontal tests where data were available, passenger injury costs were higher than driver costs. This is reflected in the respective mean costs for all tests, where the driver mean cost was A$210,360 and for the passenger, A$277,830. For offset tests, the mean cost for drivers was A$114,000 and for passengers, A$39,400.

The Effect of Airbags

Six models were tested with and without driver side airbags. The results are shown in Figure 6. In each case there was a considerable decrease in costs of driver injury, although the magnitude of the change depended to some extent on the initial cost in the no airbag state. The mean difference was A$121,000 with a range from A$69,000 to A$276,000. In percentage terms, the difference ranged from 27.7% to 69.2% of the initial cost.

DISCUSSION

A number of assumptions were made in the course of this project, all of which may affect the magnitude of the costs estimates. With regard to the Road Injury Cost Database, the cost estimates were largely based on finalised personal injury claims over a seven year period. The estimates for the more severe head injuries will be considerably lower than they should be, because these claims can take up to five years to be settled. The IAFs used were the best estimates available but they are dependent on a number of assumptions that may later be shown to be inaccurate. Notwithstanding these problems, the method has been applied consistently for all vehicles and provides an indication of the relative performance of vehicles with each other and over time. The results also show that it is possible to greatly reduce the costs of injuries, as demonstrated in standardised crash tests, through appropriate changes in vehicle construction.

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