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BENEFITS OF A 64KM/H OFFSET CRASH TEST IN AUSTRALIA

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Benefits of a 64km/h offset crash test in Australia

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Abstract:

A previous study was undertaken to estimate the benefits of Australia adopting the EEVC proposed frontal offset standard which specifies a dynamic crash test with a 40deg overlap into a deformable barrier at 56km/h using Harm figures derived in 1995. Consumer groups routinely carry out offset crash tests of new passenger cars using the European offset test procedure, but at a higher 64km/h, crash test speed. These independent test are aimed at providing information to the general public on the safety performance of new vehicles to help consumers choose safer cars. This study set out to assess the benefit in reduced societal Harm if manufacturers met the regulation requirements at the higher 64km/h crash test speed. Using the same method as in the earlier study, a set of assumptions was developed to estimate likely injury reductions from compliance with the 64km/h test. These were then converted into likely annual Harm savings and Harm saved per vehicle. On the basis of the evidence presented here, the 64km/h crash test seems to provide considerable benefit to Australia in addition to that expected from ADR 73/00. The total benefit likely to accrue if all cars were to comply with the 64km/h crash test would be somewhere between A$404 million and A$520 million annually with 100% fleet compliance. The break-even cost per car across its lifetime would be on average somewhere between A$404 and A$651. The additional benefit above ADR 73/00 would be of the order of 24% to 36% in reduced Harm in frontal crashes. No data were available on any likely disbenefit resulting from designing for the higher crash test and further research is warranted to confirm this. These savings are conservative, based on more recent injury costs published by the Bureau of Transport Economics, Canberra, Australia.

Key Words:
Safety, Accident, Vehicle Occupant, Injury,
Countermeasure, Cost-Benefit, Economic, Harm, Evaluation

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Contents

Figures

Tables

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EXECUTIVE SUMMARY

INTRODUCTION

An earlier report by the Monash University Accident Research Centre demonstrated that the introduction of a new dynamic offset frontal standard incorporating the recently introduced European standard was likely to provide significant Harm reductions to passenger car occupants in frontal crashes (Fildes, Digges, Dyte, Gantzer & Seyer, 1996). These benefits were calculated for two crash test speeds, namely 56km/h and 60km/h.

The Land Transport Division of the Commonwealth Department of Transport ultimately implemented a new Australian Design Rule ADR 73/00, which harmonised with the European test configuration and injury criteria at a 56km/h crash speed.

In recent years, the New Car Assessment Program in Australia (ANCAP) introduced a dynamic offset crash test in their program of assessing the relative performance of new makes and models of passenger cars sold in Australia. This crash test essentially adopts the same crash and injury criteria in ADR 73/00 but at an increased crash speed of 64km/h.

This study estimated the likely benefits to Australian consumers of a vehicle meeting this more stringent crash test requirement and whether there are likely to be any disbenefits in increased Harm to a vehicle from complying with this requirement.

EUROPEAN & CONSUMER OFFSET TESTS

ADR 73/00 specifies a range of head, neck, chest, femur and lower leg criteria for two Hybrid III test dummies situated in the front seat of a passenger car impacting a deformable face fixed barrier offset 40% on the driver's side.

The injury criteria specified for the dummies are more comprehensive than those that currently apply in ADR 69 or FMVSS 208. In addition, there are also criteria specified for maximum steering wheel intrusion in an upward direction and in rotation. This is seen as a real benefit for improved occupant protection by providing a more comprehensive test of the likelihood of injury in a relatively severe and common collision.

ADR 73/00 calls for a crash test impact speed of 56km/h. Tests conducted by ANCAP, EuroNCAP, and those conducted by the Insurance Institute for Highway Safety (IIHS) raised this crash severity figure by around 15% to 64km/h. The rationale for this is based on the philosophy that consumer tests should be more stringent tests of crashworthiness than those required by regulation, and that the higher test speed more clearly discriminates occupant protection performance between the vehicles.

The previous study (Fildes et al, 1996) showed a likely Harm reduction of somewhere between A$297 and A$418 per annum if all passenger cars were to comply with the proposed European standard (a 17% to 23% reduction in Harm in frontal crashes). The final saving would depend upon the percent of frontal airbag sales at the time of implementation. There was an expectation that a higher crash test speed would lead to higher benefits (eg; the benefits in this report for 60 km/h were between 10% and 15% higher) with little or no apparent disbenefits.

LIKELY INJURY REDUCTIONS

Some limited test and dummy (injury) data were available from consumer crash tests previously undertaken in Europe, the USA and Australia on which to base the likely injury reduction figures. These data were examined, along with previous estimates in Fildes et al (1996), to arrive at the expected savings. From this examination, nine assumptions were developed and fed into the Harm analysis. These assumptions are outlined in Table 1 below:

Table 1 The nine critical assumptions used in the 64km/h benefit analysis

No.	Assumption
1	A universal benefit would accrue from a general crashworthiness design improvement (15% reduction for 69% of the frontal Harm).
2	There would be an added benefit from 100% fitment of a driver airbag, which would be accelerated by mandating the offset test.
3	There would be fewer chest injuries from more stringent criteria, mainly for small to medium sized car occupants.
4	Fewer pelvic and thigh injuries from more stringent femur load and time dependent injury criteria.
5	New knee criteria would lead to fewer knee injuries for all crashes up to the test speed.
6	Fewer tibia and fibula fractures from inclusion of Tibia Index.
7	Fewer ankle-foot injuries from structural improvement to the floor and toe-pan areas.
8	A reduction in neck injuries by including a neck injury criterion.
9	Equal effectiveness would apply to occupants in all front-seating positions.

INJURY DISBENEFITS

Test data collected by ANCAP and IIHS were addressed to test for any likely disbenefits. Evidence from the ANCAP program failed to demonstrate that Australian vehicles were particularly stiff, although it was noted that most of these vehicles pre-dated the introduction of this requirement and may not be representative of current models.

Furthermore, Adrian Lund and colleagues at the IIHS conducted a series of comparative crash tests looking at the relative effects of geometry, mass and vehicle structure (Lund 1999). Their results showed that increased mass and increased ride height of the striking vehicle increased both the deformation of the struck vehicle and the struck vehicle drivers' injury risk. However, increased stiffness produced inconsistent results, increasing extent of struck vehicle deformation but not always increasing dummy injury measures. Even large changes in striking vehicle stiffness were apparently mitigated by minor changes in vehicle geometry. IIHS concluded that the geometric location of stiff elements in the fronts of vehicles, and how that affected the intrusion profile in the struck vehicle was more important than overall vehicle stiffness in side impact compatibility.

On the basis of this analysis, it was not possible to estimate any disbenefit from the higher test speed and, therefore, no disbenefits were included in the calculations. This does not mean that there are no disbenefits from the 64km/h frontal offset test, but rather no data exists currently to confirm the presence of these. More research is warranted here when it is possible to assess how vehicle designs might be influenced by this higher crash speed.

THE HARM REDUCTION METHOD

An analysis was then performed using these assumptions as a basis for calculating the likely Harm saved by the 64km/h offset requirement. The Harm Reduction method developed by the Monash University Accident Research Centre in conjunction with Professor Kennerly Digges of the George Washington University in Virginia that had been used in the earlier offset benefit study was again used here.

The national Harm database developed previously (eg; Monash University Accident Research Centre, 1992; Fildes, Digges, Carr, Dyte & Vulcan 1995; Fildes et al, 1996) was the basis for calculating the benefits of the 64km/h requirement. Allowances were made for subsequent vehicle safety improvements such as ADR 69 in arriving at these benefits.

Analysis by body region was undertaken using a 3-step cascading model. Harm saved from the universal benefit was first deducted, followed by increase in airbag usage (up to 100%) and finally specific countermeasure benefits. Given that the 1996 and current rates of sales of passenger cars with driver airbags was not known, these benefits were calculated for a range of possible airbag sales rates from 70% to 100% for new passenger cars.

OFFSET BENEFITS

The benefits of the 64km/h crash test requirement were calculated for both the annual Harm saved assuming all vehicles in the fleet were compliant as well as the unit Harm benefits per car across its lifetime. In computing unit Harm benefits, 5% and 7% discount rates were employed for either a 15 or a 25-year fleet life.

Annual Harm Benefits

The annual Harm reduction amount that would accrue from the 64km/h offset requirement was estimated to be between A$297 million and A$520 million (in $1996 values). This represents an additional annual Harm saving of between 24% and 36% over that estimated at 56km/h. This equates to an annual Harm saving of A$305 million to A$534 million in 1999 dollar values. Naturally, the full benefits would only apply when all vehicles in the fleet comply with this requirement.

As noted earlier, this assumes no disbenefit would occur that would negate some of these savings. It is important to stress that while there was no evidence found to suggest that the higher test speed would influence design such to induce more injuries at other test speeds, this needs to be tested more rigorously when suitable data become available.

Unit Harm Benefits

The unit Harm benefit (the average savings per car across its lifetime) was calculated using 5% and 7% discount rate and 15 and 25 year fleet life. These estimates showed that unit Harm savings for the 64km/h requirement would be somewhere between $304 and $668 per car in A$1999 values.

It should be noted that the most conservative estimate was for a 20% reduction in frontal Harm attributed directly to this requirement, which assumes no benefit from increased frontal airbag use. Again, these figures are between 24% and 36% higher than that estimated previously for a 56km/h crash test speed.

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

New Australian Design Rule ADR 73/00 came into force in Australia in 2000 and requires vehicle manufacturers and importers of passenger cars to comply with a dynamic frontal offset crash test procedure. This standard is based on a new European offset test procedure ECE Reg 94/01 which calls on manufacturers not to exceed a set of Hybrid III dummy injury criteria for a 40% frontal offset crash test into a deformable barrier at 56km/h. Figure 1.1 shows the crash test set up and Table 1.1 the test and dummy injury criteria.

Table 1.1 Test criteria for Hybrid III & intrusion specified in ADR 73

Body Region	Hybrid III Criteria
Head	1000 HIC + 80g max for 3 seconds
Neck	Axial tension plus shear force plus extension
Chest	50mm max deflection plus V*C less than 1.0
Femur	9.0 kN for first 10msecs then maximum 7.56 kN
Tibia	Tibia Index (TI) less than 1.3 plus 8 kN max. compression plus 15mm max. slide knee joint
Intrusion	100mm rearward plus 80mm upwards plus 25deg max. rotation

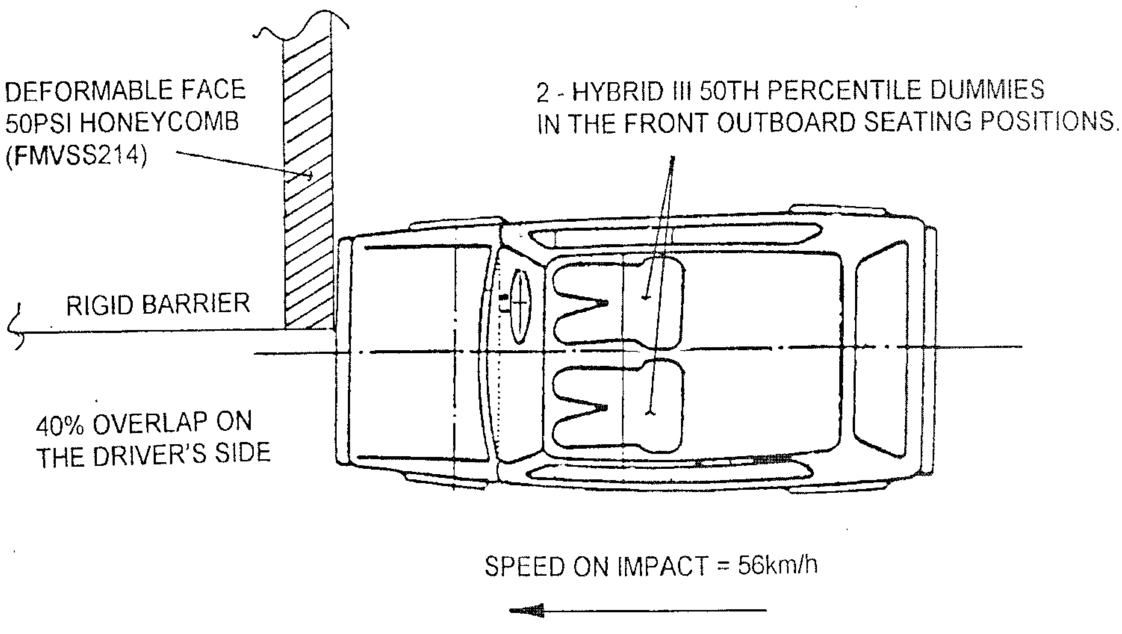

Figure 1.1 Crash test layout for the ECE Reg. 94/01 deformable offset crash test

1.1.1 Consumer Testing

The New Car Assessment Programs in Australia and Europe, as well as those carried out by the Insurance Institute for Highway Safety (IIHS) in the USA, routinely carry out offset crash tests of new passenger cars using the European offset test procedure, but at a higher

64km/h test speed. These independent tests are carried out to provide information to the general public on the safety performance of new vehicles to help consumers choose safe cars. A 15% higher test speed than is regulated by governments has been adopted by these organisations to provide a more severe test of vehicle crash performance and because the higher test speed more clearly discriminates occupant protection performance between the vehicles.

1.1.2 Offset Crash Test Benefits

In 1996, the Monash University Accident Research Centre conducted an analysis for the Federal Office of Road Safety of the likely Harm benefits associated with the introduction of ADR 73 (Report CR165, Fildes, Digges, Dyte, Gantzer and Seyer, 1996). It was reported that compliance with the European test at 56 km/h would yield additional annual Harm benefits for Australia of between $297 million and $418 million, depending on the level of airbag sales of new passenger cars when the standard was introduced. This equates to a unit Harm benefit per car, assuming a 15-year vehicle life and a 5% discount rate, of between $334 and $471. These benefits also assume that vehicles also have to comply with the current dynamic full frontal standard ADR 69.

In addition to calculating the benefits at the 56km/h test speed, this report also estimated the likely benefits of the offset test procedure if the test speed was raised to 60 km/h. However, this higher test speed option was not considered suitable for adoption in Australia to ensure harmonisation with European regulations. The question arises, what would be the annual Harm benefits if manufacturers were expected to meet these higher severity crash speeds?

This report for the New Car Assessment Program in Australia set out to address this question by providing estimates of annual and unit Harm savings for a 64km/h offset crash test using a similar procedure to that calculated in CR 165.

1.2 PROJECT OBJECTIVES

The main aim of the study was to estimate the annual and unit Harm benefits likely to accrue in Australia if all vehicles complied with an offset frontal impact standard that is similar to that currently specified by ADR 73, but at a higher crash severity speed of 64km/h. Several objectives (constraints) were specified for the analysis to ensure consistency with the previous benefit calculations, namely:

- that the benefits would be calculated in the same way as in CR 165;
- that the benefits would be based on the same Harm distribution that existed in June 1996;
- that the set of assumptions that were derived in CR 165 would apply where appropriate other than when necessary to revise these to suit the higher test speed;
- that the airbag benefit allowed for this analysis would assume airbag sales figures ranging from 70% to 100%; and
- that fleet life periods of 15 and 25 years and discount future earning rates of 5% and 7% be used in determining the unit benefits per car.

Benefits would be expressed in both 1996 dollars (to enable comparison with the original benefits) as well as in current 1999 dollars. For completeness, the earlier 56km/h benefit would also be inflated to 1999 costs.

1.3 OVERVIEW OF THE APPROACH

The study utilised the Harm reduction method to compute the potential benefits of the proposed dynamic offset frontal impact requirement. Harm refers to the cost of trauma and is the product of the frequency of injury and cost to the community.

Initial research using the Harm Reduction method was conducted by Malliaris in the US during the 1980s. MUARC subsequently adopted and developed this method for use in Australia during the 1990s (refer FORS report CR100, (Monash University Accident Research Centre, 1992) for a full outline of this development and its application in describing the potential benefits of a range of frontal crash countermeasures). Since then, it has also been used for assessing the relative merits of Australia adopting either the US or European side impact regulations (Fildes, Digges, Carr, Dyte & Vulcan, 1995) and the European frontal offset test procedure (Fildes et al, 1996).

Originally, the method was used to specify the total injury savings by the introduction of a particular safety measure. However, in conjunction with Professor Kennerly Digges of George Washington University, MUARC subsequently expanded the method to permit a more detailed and systematic assessment of injury reduction by body region and seating position, which could then be summed to total Harm reduction and unit Harm benefits.

CHAPTER 2 THE HARM REDUCTION APPROACH

The study utilised the ***Harm Reduction*** method developed at the Monash University Accident Research Centre to compute the potential benefits of the proposed offset frontal impact requirement. Harm is a measure of the societal cost of casualties where each injury is weighted according to its cost to the community. It is arguably a more useful metric for setting injury priorities as it embraces not only high frequency events but also those that result in significant treatment, rehabilitation and long-term consequences. Thus, Harm has become broadly accepted as a relevant metric for road safety improvement in Australia.

2.1 HARM DATABASE

As noted in section 1.1, the annual Harm benefit was calculated using the same Harm method and database used previously in CR165 (Fildes et al, 1996). This was justified on the grounds of consistency with the previous benefit calculation. As ADR73/00 was only mandated in 2000, it is argued that these benefits would still be quite relevant for the existing vehicle fleet.

The existing Harm database at MUARC comprised a series of Harm matrices for frontal, side and rollover crashes by body region, restraint condition, side of impact for side collisions, and contact sources. These matrices provided many of the baseline data required to ascertain these benefits. In undertaking the analysis, though, it was necessary to separate full from offset frontal Harm distributions to ensure that the analysis did not overstate the benefits.

2.2 INJURY MITIGATIONS

One of the most difficult and critical tasks in assessing the benefit of an offset test procedure is in determining the likely injury mitigations. The accuracy of the estimates is necessarily a function of the amount of test and real world data available. Where no test data are available, it is necessary to use expert judgement in assessing the likely injury reductions associated with the introduction of a new countermeasure. Those with considerable experience in the area of interest are best able to make reasonable estimates of injury mitigation, based on their knowledge of how manufacturers are likely to respond to new regulations and requirements.

Estimating injury reductions is the one area most vulnerable to error and criticism. A number of steps were undertaken here to ensure that the final benefit calculations would be the most rigorous available and likely to be accepted by the industry, namely to:

- review the earlier expert panel assumptions;
- review new test data results available for 64km/h offset crash tests; and
- assess the likelihood of any disbenefit from a higher test speed.

Professor Kennerly Digges was again commissioned as a sub-consultant to MUARC in this project to help determine the likely injury reductions associated with meeting a 64km/h requirement. As Professor Digges had also participated in the original study, his prior experience proved to be most valuable in estimating injury mitigation for an offset frontal standard, given the lack of data generally available on the likely real-world effectiveness.

2.3 HARM REDUCTION METHOD

The Harm Reduction method has been described in detail previously in earlier reports. An overview of the method is provided here for those not familiar with the approach, including some slight recent changes to the discounting procedure. The concept of "Harm" was first developed in the US and applied to National Crash Severity Study (NCSS) database by the National Highway Traffic Safety Administration as a means of determining countermeasure benefits for road safety programs (Malliaris, Hitchcock & Hedlund 1982; Malliaris, Hitchcock & Hansen 1985; Malliaris & Digges 1987). In its original form, it was not suitable for immediate application to these data as it lacked an Australian cost basis. Moreover, it had never quite been used previously for itemising injury reductions by body regions as was envisaged here. Thus, the development and use of Harm in the previous study (Monash University Accident Research Centre 1992) and the current study represent a significant international advancement in the ability to assess injury mitigation of vehicle countermeasures.

2.3.1 Harm & Injury Mitigation

Harm is a metric for quantifying injury costs from road trauma. It is a function of the number of injuries sustained, expressed in terms of community costs. The Harm method adopted here comprised the systematic approach outlined in detail in Monash University Accident Research Centre (1992). This approach is more suited for use in computing likely benefits of countermeasures where there are no global estimates of the likely improvements but where there are results reported on the expected specific body region injury reductions (many publications on the likely effectiveness of new regulations, for instance, show specific test results for particular body region and contact source benefits). The method allows a picture of the expected overall benefit to be pieced together from a series of individual body region and seating position estimates. A computer spreadsheet was developed for making the detailed Harm calculations by body region, similar to that used previously in CR100.

2.3.2 National Statistics & Harm Estimates

The first step in the process was to develop National Harm patterns for Australia. These estimates form the basis of the potential savings of injury costs from new occupant protection countermeasures aimed at reducing or preventing injury. This process was described fully in CR 100 (Monash University Accident Research Centre 1992) and will not be repeated here. However, a summary is provided to outline how this was achieved (those requiring more detail are referred to the original publication). It draws heavily on the excellent work undertaken by Max Cameron and his co-workers at MUARC in the original study.

2.3.3 Occupant casualties and injuries

Unfortunately, no comprehensive Australia-wide database of injuries and their causes was available for this analysis, thus it was necessary to construct one. This involved a complex process of merging several data sources of fatalities, hospitalised occupants and those needing medical treatment, with the necessary checks and balances to ensure that the numbers, use of restraints, seating position, impact direction and speed zone were representative of Australia, generally.

Three data sources were available for constructing the Australia-wide casualty database. First, details of those killed in Australia are collected by the Federal Office of Road Safety's "*Fatal File*" of which the 1988 database was most relevant. Second, MUARC's "*Crashed Vehicle File*" described in the previous Chapter contained a random sample of 500 crashes where at least one occupant was either hospitalised or killed in Victoria between 1989 and 1992, containing comprehensive details on crash characteristics, injuries and cause of injury. Third, the Transport Accident Commission in Victoria maintain a detailed injury and crash database on all casualties in Victoria which involve injury costs of A$317 (1987) or more.

Annual Australia-wide estimates were produced by merging these three databases and adjusting the numbers to suit national averages between 1988 and 1990. In total, the database comprised 1,612 killed, 17,134 hospitalised and 58,448 medically treated (not admitted to hospital) occupants or 77,194 total casualties involving an estimated 284,540 injuries at a rate of 3.7 injuries per occupant casualty. This was taken to represent a single year of occupant casualties in Australia.

Source of injury was not available in either the FORS Fatal File or the TAC database, but was in the Crashed Vehicle File (CVF). To correct for this deficiency, the most severe hospitalised and killed cases in the CVF were taken to represent all fatalities and the minor CVF cases (hospitalised for 3 or less days) were taken to represent non-hospitalised injury sources. Thus, injuries within the Fatal File and TAC database were assumed to have been caused by the same sources as their relevant proxies in the CVF. Following this adjustment, the Australia-wide all injury database was then complete.

Subsequently, these data were broken down by the key factors likely to be relevant for this offset crash analysis (eg. seating position, restraint use, and type of frontal impact) and the frequencies of injuries to these occupants, categorised by the body region and Abbreviated Injury Scale (AIS) severity level disaggregated by the same factors as above as well as by the contact source of the injury. These tables formed the basic pattern of injuries and injury sources used in this analysis.

2.3.4 Casualty costs

The next step was to derive comprehensive cost data, categorised and disaggregated by the same factors as for the injury frequency estimates noted above. This was necessary so that individual units of Harm (eg; restrained Head injuries of AIS severity 2) could be established to permit detailed cost savings to be arrived at for incremental changes in trauma patterns. Estimates of the cost of injury by AIS in Australia were published by the Bureau of Transport Economics for 1985 $A (Steadman & Bryan, 1988). However, these figures do not breakdown injury costs by body region that is essential for estimating the Harm reductions associated with side impact improvements. To estimate this, it was necessary to use the average cost of each specific injury based on a matrix of average injury costs in the USA developed by Miller, Pindus, Leon & Douglass (1990) and explained in detail in Monash University Accident Research Centre (1992).

These figures were then converted into Australian average injury costs in A$(1991). The estimated total injury cost to car occupants during 1988-90 was calculated to be $3142.6 million per annum in 1991 prices. The re-scaled average injury costs per level of injury severity are given in Table 2.1.

Table 2.1 Total injury cost ("Harm") to occupants of cars and car derivatives in all types of impact (1991 $A millions, average per annum during 1988-90)

BODY REGION	INJURY SEVERITY							TOTAL
	Minor (AIS = 1)	Moderate (AIS = 2)	Serious (AIS =3)	Severe (AIS = 4)	Critical (AIS = 5)	Maximum (AIS = 6)	Unknown	
External	0.0	4.3	0.2	0.0	0.5	6.2	0.0	11.2
Head	12.8	116.6	217.2	290.4	524.9	49.4	0.0	1211.2
Face	99.4	80.3	29.9	2.8	0.0	0.0	0.7	213.1
Neck	20.1	14.1	25.7	0.6	16.3	2.6	0.0	79.5
Chest	33.6	63.7	139.3	99.4	47.5	68.0	0.0	451.4
Abdomen-Pelvis	36.4	64.8	89.7	21.2	23.3	2.0	0.0	237.4
Spine	3.8	23.4	30.9	3.5	42.8	18.3	0.0	122.7
Upper Extremity	64.4	147.4	85.0	0.0	0.0	0.0	0.0	296.7
Lower Extremity	64.4	188.6	265.4	0.6	0.2	0.0	0.0	519.3
TOTAL	334.9	703.2	883.3	418.4	655.6	146.4	0.7	3142.6
No. Occupants Sustaining Injury								77194

2.3.5 Relevance of 1991 Figures

It would have been preferable to have recent injury patterns and costs available for this analysis, given the sizeable reductions that have occurred in the road toll between 1991 and now, along with recent inflationary effects. However, it was not possible to re-do these estimates within the time frame and budgetary constraints of the project. It should be noted, though, that these two influences would tend to offset each other (the effects of a reducing road toll would be somewhat ameliorated by the increase in cost of injury through inflation). Thus, it was felt that the total Harm figures were still appropriate for this analysis.

2.3.6 Baseline Harm Matrices

The total harm in Table 2.1 was then broken down by seating position, restraint use and impact direction by using the same procedures for subsets of the injury and occupant casualty data. These figures provided the baseline injury-cost data for establishing the potential cost savings of an offset impact regulation to reduce occupant injuries in near-side offset frontal crashes. Each injury in the CVF was associated with a contact source of the injury. For the hospitalised occupants included in this file it was possible to disaggregate the injury frequencies and total harm by the contact source. However, neither the Fatal File nor the TAC claims records contained injury contact sources to allow similar categorisation of the injuries of the killed and medically treated occupants.

To achieve this, data were selected from the CVF to act as proxies for the killed (the proxy was those hospitalised for more than 20 days, plus the 23 actual fatalities) and the medically treated but not admitted to hospital (the proxies were those hospitalised for less than 3 days). The injury frequencies from these proxies were adjusted within each AIS severity level by body region category to match the principal estimates.

Where the proxy occupants did not sustain any injuries in an injury category for which Harm was estimated by the principal method, the distribution of harm by contact source was estimated from the contact source distribution of the next lowest injury severity level within the same body region.

The total Harm within each body region of the front seat occupants involved in offset frontal impacts, broken down by contact source of the injury, for both restrained and unrestrained occupants respectively, was ultimately produced and used as the baseline Harm figures to calculate the potential savings if an offset impact regulation was to be introduced. This process is explained further in the next section.

CHAPTER 3 INJURY REDUCTION ASSUMPTIONS

As noted earlier, estimating new safety countermeasure benefits is inherently difficult as, for the most part, there are no real-world data available to estimate the likely injury reductions of a new design feature or countermeasure. A number of steps were undertaken therefore to ensure that the final benefit calculations would be the most rigorous available and likely to be accepted by the industry. These included a review of the earlier expert panel assumptions for their relevance tody, a further review of new test data results available for 64km/h offset crash tests, and an assessment of the likelihood of any disbenefit from a higher test speed. These are discussed in more detail below.

3.1 ORIGINAL INJURY MITIGATION ASSUMPTIONS

In estimating the benefits of CR165 (Fildes et al, 1996), an expert group was formed to estimate the likely body region injury reductions based on their specialist knowledge and various unpublished test results. This group comprised a number of internationally acclaimed biomechanical and crash test researchers from government and industry as well as senior government administrators with particular knowledge in vehicle standards. In arriving at these mitigation assumptions, these people were provided with limited test data findings from the literature, available at that time. The group met originally in Washington DC in conjunction with NHTSA's Pelvic and Lower Extremity Injury conference in December 1995 from which a number of assumptions regarding the likely impact of the standard and the resultant expected injury reductions were agreed to and these are shown in Table 3.1.

Table 3.1 The nine critical assumptions agreed to in CR 165 (Fildes et al, 1996)

No.	Assumption
1	A universal benefit would accrue from a general crashworthiness design improvement (10% reduction @56 km/h and a 15% reduction at 60 km/h).
2	There would be an added benefit from 100% fitment of a driver airbag that would be accelerated by mandating the offset test.
3	There would be fewer chest injuries from more stringent criteria, mainly for small to medium sized car occupants.
4	Fewer pelvic and thigh injuries from more stringent femur load and time dependent injury criteria.
5	New knee criteria would lead to fewer knee injuries for all crashes up to the test speed.
6	Fewer tibia and fibula fractures from inclusion of Tibia Index.
7	Fewer ankle-foot injuries from structural improvement to the floor and toepan areas.
8	A 25% reduction in neck injuries by including a neck injury criterion.
9	Equal effectiveness would apply to occupants in all front seating positions.

It was necessary to re-visit these injury criteria in the light of more recent evidence of the likely effectiveness of the standard. In addition, the original expert panel was again consulted seeking their views on the new assumptions made for the 64km/h standard.

3.2 MORE RECENT EVIDENCE

For the original calculations, there were government test data from 56 km/h and 60 km/h crash tests, carried out in Europe and Canada during the mid-1990s. No data were available, however, for the higher 64km/h offset crash test speed. However, since then, a number of institutions performing consumer tests of new vehicles such as the Insurance Institute for Highway Safety (IIHS) in the USA, EuroNCAP in Europe and ANCAP in Australia have commenced offset testing at 64km/h. In the course of conducting this analysis, it was possible to obtain test results from Europe (McDonough, 1999) as well as to hold discussions with IIHS in Virginia to determine the likely added benefit of increasing the test speed to 64km/h.

3.3 DISBENEFITS OF A HIGHER TEST SPEED

There has been some concern raised by the industry around the world that adopting the higher crash test speed of 64km/h for the offset test was likely to cause an injury disbenefit to vehicle occupants. This argument is based on two assumptions. First, that stiffer frontal structures to all vehicles would result from manufacturers attempts to ensure their passenger vehicles met this “community standard” and secondly, that the extra stiffness would be more injurious to partner vehicles, especially in a side impact crash.

3.3.1 Increased Stiffness

The increase in stiffness values across the fleet in Australia was assessed by comparing stiffness values of Australian vehicles that performed well and badly on the ANCAP offset crash tests conducted at 64km/h in Australia. Test data were available on approximately 20 vehicles sold in Australia that had been tested against ANCAP test criteria. These vehicle results are summarised in Table 3.2 below.

Table 3.2 Summary of 64km/h offset crash test vehicles conducted by ANCAP

Test Vehicle	Results		Test Vehicle	Results	
	Overall	Structure		Overall	Structure
1997 - Toyota RAV4	Marginal	Accept	1996 - Daihatsu Charade	Marginal	Poor
1997 - KIA Sportage	Poor	Marginal	1995 - Daewoo Cielo	Marginal	Poor
1996 - Honda Accord	Accept	Accept	1996 - Honda Civic	Accept	Marginal
1995 - Toyota Camry	Marginal	Marginal	1996 - Hyundai Lantra	Poor	Poor
1997 - Toyota Camry	Marginal	Accept	1996 - Ford Laser	Poor	Poor
1997 - Holden Commodore	Accept	Marginal	1996 - Nissan Micra	Marginal	Poor
1997 - Ford Falcon	Marginal	Accept	1996 - Mitsubishi Mirage	Accept	Accept
1996 - Mitsubishi Magda	Marginal	Marginal	1996 - Nissan Pulsar	Marginal	Poor
1995 - Ford Mondeo			1996 - Toyota Starlet	Marginal	Accept
1996 - Holden Barina	Poor	Poor	1997 - Toyota Prado		

Ratings based on ANCAP interpretation of crash test results (see Buyer’s Guide to Crash Tests, published by New Car Assessment Program, March 1996 onwards, for details of these results).

A stiffness analysis was conducted of these ANCAP cars, which is shown in Table 3.3 below. Stiffness values were derived from a series of offset frontal crash tests conducted at Crashlab in Sydney, NSW from November 1995 involving 20 popular vehicles sold in

Australia. Force-deflection curves were plotted from in-vehicle measures where the peak force and peak deflection were extracted from the curves. These values are shown in Table 3.3 below.

Table 3.3 Stiffness analysis of ANCAP cars crash tested in frontal offset at 64km/h.

CAR DETAILS	Right-hand B-pillar measures			
	Test Crash Number	**Peak Force (N)**	**Peak Deflection (mm)**	**Time to Peak Force (msec)**
1997-Toyota Prado	7019	988.8	1552	63
1997-KIA Sportage	7018	727.1	1461	63
1997-Ford Falcon	**7029**	**725.6**	**1618**	**78**
1996-Mitsubishi Magda	6041	603	1512	80
1996-Honda Accord	**6039**	**589.5**	**1626**	**90**
1997-Toyota Camry	**7027**	**562.7**	**1500**	**88**
1996-Hyundai Lantra	6033	549.2	1546	77
1995-Ford Mondeo	5043	518	1424	81
1997-Toyota RAV4	**7033**	**510**	**1527**	**77**
1996-Honda Civic	**6032**	**486.1**	**1634**	**88**
1995-Toyota Camry	5044	447.7	1682	86
1996-Mitsubishi Mirage	**6036**	**394.3**	**1497**	**73**
1996-Nissan Pulsar	6031	393.8	1500	78
1996-Ford Laser	7008	363	1448	72
1996-Nissan Micra	6042	348.3	1778	67
1996-Holden Barina	6034	331.8	1432	68
1996-Daihatsu Charade	6045	319.7	1581	82
1995-Daewoo Cielo	5045	252.7	2178	70
1997-Holden Commodore	**7028**	**-**	**-**	**-**
1996-Toyota Starlet	**6035**	**-**	**-**	**-**

Vehicles in bold font are those that performed better in the ANCAP 64km/h test in Table 3.2. Data on the two cars listed at the bottom of the table was subsequently found to be faulty and hence, not included in this analysis.

In general terms, vehicles that exhibit high peak forces and/or short times to reaching peak force are generally considered to be stiffer vehicles than their lower value counterparts. Using these criteria, the vehicles listed at the top of Table 3.3 would be considered to be more stiff vehicles than those towards the bottom of the Table.

Overall, these results do not show any strong evidence of more stiff vehicles as a result of the 64km/h offset test. Indeed, many of the vehicles that were considered to have performed adequately in the 64km/h offset test were really relatively soft (eg; 1996 Honda Accord had a peak force of 590N after 90msecs and a peak deflection of 1626mm). As many of these cars would have been designed prior to the introduction of the 64km/h ANCAP offset test, it would be interesting, therefore, to continue to monitor these findings in the coming years as models come onto the market that may well have been influenced by the 64km/h test.

3.3.2 Effect of Stiffness in Side Impacts

The role of stiffness in promoting injuries in side impacts is still a rather contentious issue. There is considerable current debate in vehicle compatibility research as to whether the mass, stiffness or geometric structure of the striking vehicle in a side impact collision is the most pertinent feature in injury causation. Some have argued that mass is dominant (eg; Prasad, 1998) while others argue that geometry is more relevant (eg; Faerber, Cesari, Hobbs, Huibers, van Kampen, Paez & Wykes, 1998). Stiffness has generally been thought to be less important as most of the injury occurs very early in the crash sequence and a stiffer structure is considered to be of lesser relevance than either the mass (impact force) or the geometry of the striking object.

In front-to-side collisions, the bullet vehicle generally deforms less than the vehicle impacted in the side. Typically the deformation of the bullet vehicle is less than 0.25 meters. The force generated during the initial 0.25 meters of frontal crush for the bullet vehicle is more relevant than the maximum force that is generated in a barrier crash. It would be instructive to evaluate changes in stiffness during the initial crush for vehicles that perform well and poorly in the 64 km/h test. There is limited data for the combined vehicle and barrier stiffness in tests conducted by the IIHS.

The IIHS conducts crash tests for safety ratings. The tests are offset frontal, into a deformable barrier at 64 kph with a 40% overlap. The IIHS reported tests on six vehicles that have been redesigned. In January 2000, IIHS presented data comparing the stiffness of the original design and the redesign. Five of the six redesigned vehicles had better performance in the IIHS test. A comparison of the acceleration vs. combined vehicle and barrier crush of the five original vehicles and the five redesigned vehicles with improved performance is presented in Figures 3.1 through 3.5. In these figures, the acceleration was filtered with a cut-off frequency of 36 Hz. The combined crush was obtained by double integration of the acceleration. For the vehicles in Figures 3.1 to 3.6, the performance of the 1995, 1996, and 1997 vehicles was rated as poor. For all the 1999 and 2000 vehicles, the performance in the 64 km/h offset test was rated as acceptable or good. An additional vehicle comparison is included in Figure 3.6 from NCAP data.

Figures 3.1 through 3.5 show that the peak acceleration in the good performing vehicles is higher than in the poor performing vehicles. In all vehicles, this peak acceleration occurs after a combined crush of 1.0 meter. The peak accelerations for the redesigned vehicles were around 30 G's while the poorly performing vehicles had a peak at about 25 G's. An exception was the redesigned Honda Odyssey, which maintained the peak G at 25.

A comparison of the acceleration level at selected displacements is shown in Table 3.4. The table shows the acceleration levels in G's for the good and poor vehicles at four levels of combined crush. A *Lower* value in the table indicates that the redesign had lower acceleration than the original design. A *Higher* value indicates that the redesign had a higher acceleration than the original design. The force exerted by the structure is proportional to the acceleration. Consequently, the acceleration level is related to the vehicle compatibility in a crash. For displacements up to 1 meter of combined crush, the redesigned vehicles maintained low acceleration levels. The higher acceleration of the 2000 Cadillac at 0.75 meters of combined crush, was less than 2 g's. This difference is not significant. In general, the redesigned vehicles had a higher acceleration at a crush of 1.2 meters and higher. However, at lower values of combined crush, the redesigns had generally lower or similar acceleration levels. These results suggest the better performing vehicles also provide improvements in front to side compatibility, and in frontal crashes with less than one meter of combined crush.

Table 3.4 Comparison of vehicle accelerations (poor vs. good vehicles) at various crush displacements during identical crash tests

Vehicle and Performance		Acceleration at Displacements			
Poor	**Acceptable/Good**	**0.5 m.**	**0.75 m.**	**1 m.**	**1.2 m.**
96 Toyota Previa	98 Toyota Sienna	Same	Lower	Lower	*Higher*
97 Cadillac Seville	00 Cadillac Seville	Same	*Higher*	Lower	*Higher*
96 Honda Odyssey	99 Honda Odyssey	Lower	Lower	Lower	Same
95 Mitsubishi Galant	99 Mitsubishi Galant	Lower	Same	*Higher*	*Higher*
95 Saab 900	99 Saab 9-3	Same	Lower	Lower	*Higher*

Table 3.5 summarizes the acceleration levels at 1.0 metre of combined crush for the poor performing vehicles and for the acceptable/good performing vehicles. At crush levels of 1.0 meters, the acceptable/good performing vehicles have lower accelerations than the 24 g's produced by the 96 Previa and the 96 Odyssey that performed poorly in the 64 kph offset test. The consequence of the change is that in crashes with combined crush less than 1.0 meters, the redesigned vehicles are generally less aggressive then the vehicles that performed poorly. In very high severity crashes involving crush more than 1 meter of combined crush, the redesigned vehicles develop higher forces to protect their occupants. Overall the redesigned vehicles should be less aggressive in the large number of crashes with crush less than 1 meter but possibly more aggressive in the rare higher crash severities. A word of caution, however: care needs to be taken in interpreting this precisely the magnitude of 1 meter of combined crush. This quantity could reflect anything from 0.4 to 0.9 meters of vehicle crush, depending on how much the barrier crushed during the impact. However, the lack of precision of the vehicle crush level measured is unlikely to substantially alter the interpretation of these findings.

Table 3.5 Comparison of vehicle accelerations (poor vs. good vehicles) at crush displacement of 0.9 m. during identical crash tests

Vehicle performance		Acceleration at 1.0m crush	
Poor	**Acceptable/Good**	**Poor**	**Acceptable/Good**
96 Toyota Previa	98 Toyota Sienna	24	20
97 Cadillac Seville	00 Cadillac Seville	9.5	9
96 Honda Odyssey	99 Honda Odyssey	24	11
95 Mitsubishi Galant	99 Mitsubishi Galant	16	20
95 Saab 900	99 Saab 9-3	21	16

In earlier reports, IIHS compared the response of the good performing Taurus and the poor performing Contour. Pictures of the 2 were presented in our earlier report. A comparison of the Force vs. Displacement of the two vehicles is shown in Figure 3.6. The two vehicles have about the same peak force, but the Taurus exerts lower force levels at lower displacements. This tendency of lower force at lower displacements appears to hold for the five vehicles examined in Tables 3.4 and 3.5.

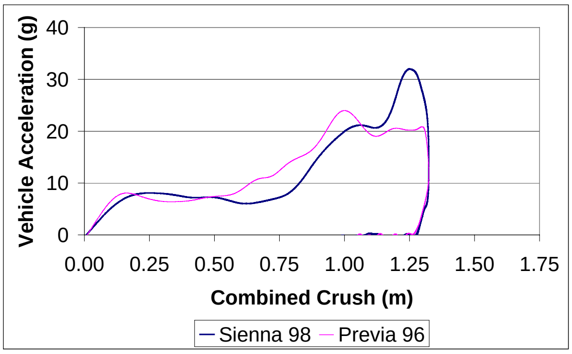

Figure 3.1 Acceleration by displacement of CG: 1996 Toyota Previa and 1998 Toyota Sienna

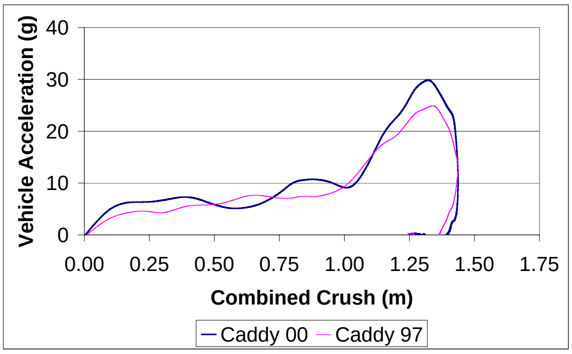

Figure 3.2 Acceleration by displacement of CG: 1997 and 2000 Cadillac Seville

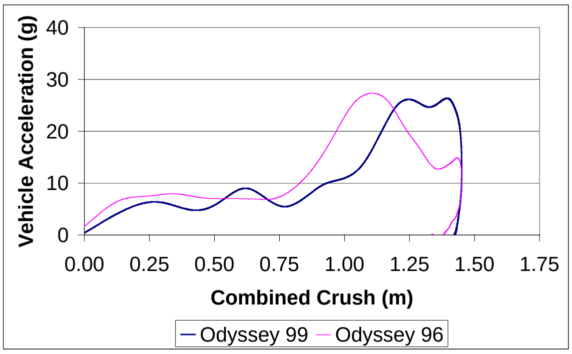

Figure 3.3 Acceleration by displacement of CG: 1996 and 1999 Honda Odyssey

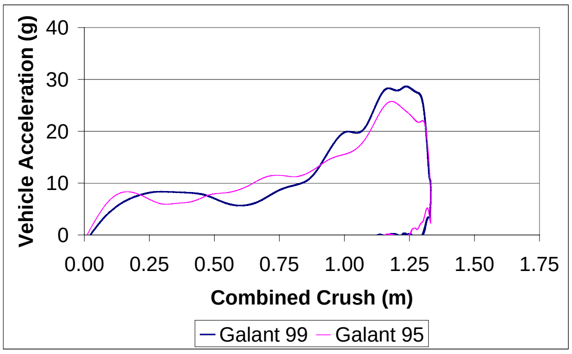

Figure 3.4 Acceleration by displacement of CG: 1995 and 1999 Mitsubishi Galant

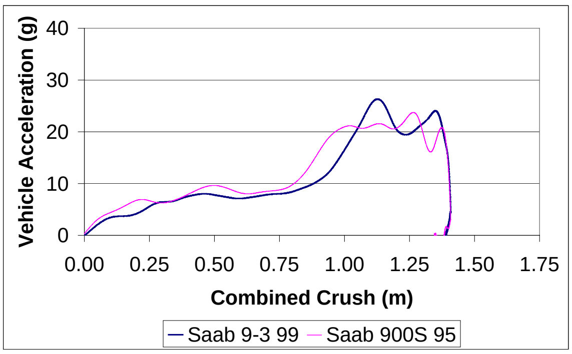

Figure 3.5 Acceleration by displacement of CG: 1995 Saab 900 and 1999 Saab 9-3

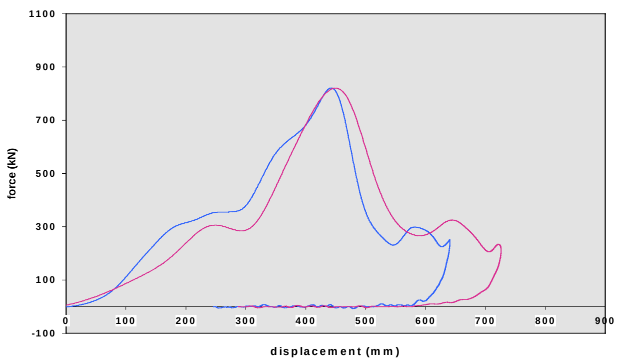

Figure 3.6 1993 Ford Taurus and 1995 Ford Contour NCAP force-displacement: Force from load cell barrier, displacement from vehicle acceleration

3.3.3 Summary of Disbenefit Analysis

While the results are somewhat inconclusive at this stage, there is not much evidence of a likely injury disbenefit from a 64 km/h crash test requirement. The results of the ANCAP analysis suggest that those vehicles which do well in the 64 km/h offset test would not be more aggressive in most frontal and side crashes than those that did less well, although these vehicles were pre-ANCAP designs. Furthermore, the role of stiffness in promoting additional injury in a side impact crash at low crash severities is questionable, based on the IIHS findings. It is difficult to argue that a higher crash test severity will lead to more injuries from these findings. Consequently, no allowance for any injury disbenefit has been included in this analysis. Further research is warranted, though, to confirm these findings as more conclusive data becomes available.

3.4 INJURY REDUCTION ASSUMPTIONS

The 64km/h frontal offset test is a severe test of the structure of a vehicle and is likely to lead to substantial changes in design of a passenger car. The analysis set out to use the best information available to estimate the benefits likely to accrue to passenger car occupants in compliant vehicles. As a result of the reviews of the earlier assumptions derived in the earlier study in Fildes et al (1996) and other evidence, the following assumptions were arrived at for use in the benefit analysis. As with the earlier calculations, the order in which these assumptions would apply to existing Australian Harm patterns was also important in determining the overall size of the benefit. These assumptions incorporate the existing body of test data, injury data, biomechanics criteria and expert opinion. As new information becomes available, these assumptions can be modified and the benefit estimates re-assessed.

3.4.1 Universal Benefit

An assumption based on the previous analysis of the benefits for the European offset test procedure at 56 km/h was that the safety improvements would provide a universal benefit over the range of crash severities to which it is applicable. For the 56 km/h test, a 10% reduction in Harm was assumed and for the 60 km/h test, a 15% reduction. The basis for these assumptions is discussed in more detail in the earlier report.

The basis for this was the opinion of the expert panel. They argued that in an offset test, the crash energy must be absorbed by engaging only part of the front structure, thus the structural deformation is more complex and intrusion into the passenger compartment is more difficult to control, compared with a full frontal test. Consequently, they felt that the offset test procedure would be expected to lead to designs better able to distribute energy more evenly across the vehicle's front structure.

For the 64km/h offset test, the crash energy will be approximately 30% higher than at 56 km/h. To absorb this additional energy without occupant compartment intrusion, manufacturers will have to design the frontal structure to absorb the energy more efficiently. For efficiently designed structures, it may be necessary to lengthen the front of the vehicle or increase its stiffness. Increases in stiffness may be detrimental to vehicle compatibility.

To determine the relationship between crash severity and injury probability, the NASS/CDS database for the years 1988-1998 was consulted. This United States database provides a nationally representative sample of about 95,000 crash involved car occupants, and 190,000 incurred injuries. The relationships between injury probability and crash severity are shown in Figure 3.7, based on published data by Malliaris, Digges & DeBlois (1997). These data are for restrained occupants in frontal crashes.

The average age of the exposed occupants is assumed to be 30 years old. Figure 3.7 also shows the percent Harm vs. delta-V relationship, based on unpublished data. In case of the Harm relationship, the crash severity was adjusted to account for the higher values of delta-V observed in crash tests, compared with calculated values in NASS/CDS.

The Harm vs. Delta-V relationship in Figure 3.7 shows that 69% of the frontal crash Harm occurs at crash severities below 64km/hr. It is assumed that a frontal-offset test at 64km/hr would address this fraction of the Harm. The 64km/h test would address approximately 25% more of the Harm than the 56km/h test and 12% more than the 60km/h test.

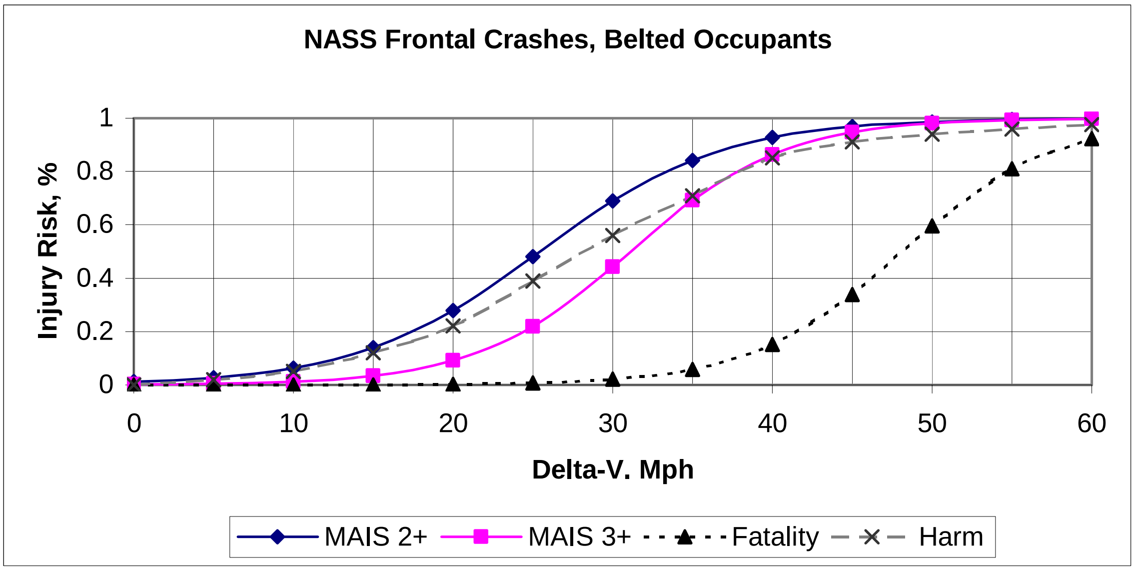

Figure 3.7 Harm distribution by crash severity for several injury severity outcomes (from Malliaris, Digges, & DeBlois, 1997).

BENEFIT: As previously assumed for the 56km/h test, the universal benefit is equivalent to a 10% in Harm over the range of relevant crashes. For the 64km/h test, the equivalent figures are a 15% reduction in Harm for 69% of the frontal offset Harm.

3.4.2 Increased Airbag Usage

Data presented in the earlier analysis (Fildes et al, 1996) showed that approximately 43% of new passenger cars sold during 1995 in Australia were fitted with at least a driver's side airbag as standard equipment. The frequency of airbags has increased substantially as standard equipment where, today, estimates place airbag sales are likely to be around 70% of new car sales (CR 165, Fildes et al, 1996). The original expert group were in complete agreement that frontal offset testing will ensure 100% fitment of airbags. This was essentially due to the additional head injury criteria of 80g (in addition to HIC in the current standard). Thus, it is legitimate to assume a 30% additional injury reduction benefit from the airbag brought about by the 64km/h offset test.

BENEFITS: After adjusting the CR100 benefits (MUARC, 1992) for full size driver airbags for head, chest, abdomen and facial Harm for the estimated non-airbag car sales in

1998, the resultant Harm is then the additional benefit that can be attributed to the offset standard. As no definitive figure is available on what the likely airbag sales are currently, sensitivity analysis involving a range of possible figures would be appropriate from today's figure of around 70% up to 100%.

3.4.3 Countermeasure Benefits

In assessing the benefits of the European frontal offset crash test at 64km/h, it was important to locate relevant data on which to base the likely fleet improvements expected to result from the introduction of the crash test. The only data available for this analysis were the results of 27 passenger cars, crash tested recently at the Transport Research Laboratories in the United Kingdom for EuroNCAP, up until 1999 (McDonough, 1999).

These results were presented as the various dummy measure scores observed in the test, as well as an overall score for each body region, based on criteria established by EuroNCAP as poor to excellent performance. Thus, for each model, body region scores were presented in terms of safety performance where 0=poor and 4=excellent outcome for each dummy test measure. These data provided the basis of the expected crash test performance of each make and model in a 64km/h frontal offset test and hence, could be interpreted as the scope for improved occupant protection, following the introduction of a 64km/h crash test. Two further assumptions had to be made about these data for use in this analysis.

1. First, that any score of 2 or less (marginal to poor) was equivalent to an undesirable performance level or "fail" and would be the potential injury mitigation available from the countermeasure benefits, following the widespread introduction of the 64km/h test.
2. Second, it was further assumed that these essentially European performance scores would be indicative of similar performance scores among the Australian fleet, given that many of these cars are currently sold in Australia.

Thus, it was possible to assign countermeasure benefits by body region using these data. These findings are presented below.

3.4.4 Additional Chest Benefits

The European offset procedure specifies a 50mm maximum deflection, a V*C<1.0m/sec and reduced steering column movements vertically to 80mm max and rearward to 100mm max. It was argued in CR165 (Fildes, et al, 1996) that this would reduce chest injuries essentially from contacts with the steering column and belt. Moreover, these benefits would be expected to accrue predominantly from small to medium cars. To meet these criteria, it was also argued that a 30% additional margin would be required when crash testing during vehicle design. Therefore, the resulting vehicle performance was assumed to be 35mm chest deflection, and V*C less than 0.7m/sec. For steering wheel displacement, the design was assumed at 70mm rearward, and 56mm upward.

The European 64km/h crash test data showed that 13 of the 27 vehicles (48%) "failed" the chest load criteria using TRL criteria and that 17 vehicles (63%) had unacceptable steering wheel displacements. For the chest load failures, the benefits were assumed to be relevant for all crashes up to 64km/h or 85% of the Harm for the reasons outlined in section 3.4.1.

From real-world frontal offset crash analyses undertaken in CR165 (Fildes et al, 1996), it was shown that steering wheel contacts only occurred at crash speeds above 40km/h.

Thus, the benefits of reduced steering wheel displacements, therefore, were assumed to be relevant for only 56% of this Harm, from data presented in CR100 (MUARC, 1992).

BENEFIT: A chest benefit relevance of 0.41 (85% x 48%) was assumed for all chest Harm, excluding Harm from contact with the steering wheel. For this Harm, the relevance was 0.35 (56% x 63%). For both chest benefits, an AIS 2 shift in the Harm distribution was assumed following the application of suitable countermeasures.

3.4.5 Pelvic & Thigh Injuries

The allowable femur load in the offset standard included a 9kN maximum peak load with 7.9kN for 10msec and above. In CR165 (Fildes et al, 1996), it was revealed that manufacturers would need to design for 5.4kN to meet this new requirement.

From the TRL findings, 11 of the 27 passenger cars (41%) were judged not to have performed satisfactorily by their criteria. Given that these benefits would accrue at all crash severities up to 64km/h, it was further considered that improvements to meet these test criteria would apply to the full 85% of the applicable pelvic and thigh Harm.

BENEFITS: A relevance of 0.35 (41% x 85%) will apply for all severity levels of pelvic and thigh Harm for compliance with a 64km/h crash test. An AIS 2 shift will apply to the Harm distribution as a result of the application of suitable injury countermeasures.

3.4.6 Knee Injuries

The frontal offset test has an A-P maximum tibia displacement of 15mm (assume a design criteria of 10mm for manufacturers). It was assumed that this criterion would provide a benefit for all knee Harm below the impact test speed.

The TRL report found that 20 of the 27 vehicles or 74% of the fleet had an unacceptable knee injury performance by their criteria. Based on the CR100 (Monash University Accident Research Centre, 1992) Harm distribution, this was judged to be relevant for 85% of the knee Harm observed.

BENEFITS: A relevance figure of 0.63 (74% x 85%) would apply to all knee Harm for a 64km/h test at all AIS levels with an AIS 2 injury shift.

3.4.7 Lower Leg

The applicable Tibia Index (TI) criterion specifies a maximum TI = 1.3. The TRL report only reported a TI score for 13 cars where 6 (46%) had sub-standard performance levels. Again, it is expected that benefits from the application of suitable countermeasures to ensure 100% compliance would apply to 85% of the applicable Harm.

BENEFIT: On this basis, the relevance figure for lower leg improvements would be 0.39 (46% x 85%) at all injury severities with an AIS 2 injury shift.

3.4.8 Ankle & Foot Benefits

The 64km/h offset test calls for an 8kN compressive force requirement as part of its lower leg injury criterion (6kN design requirement). TRL results showed that 21 of the 27 cars tested (or 78%) failed the test criterion. On this basis, it is likely that most manufacturers would respond to these figures by providing additional reductions in moment (M_y) below these figures.

In CR165 (Fildes et al, 1996), it was argued that Mercedes-Benz had gained a 27% reduction in ankle and foot injuries as a result of structural and padding improvements. On the basis that half of the benefit would be gained from structural improvement (already included in the universal benefit), the extra benefits of padding countermeasures to ensure compliance with these criteria would be expected to reap a 15% benefit in applicable Harm.

BENEFIT: A relevance figure of 0.12 (78% x 15%) for all AIS levels with an AIS 1 shift at 56km/h and a relevance of 0.15 for all AIS levels with an AIS 1 shift at 60km/h.

3.4.9 Neck Injury Benefits

The offset standard specifies 3 neck injury criteria for tension, shear and extension movement, based on figures reported by Mertz (1991). TRL test results showed that 4 of the 27 cars tested had unsatisfactory neck injury criteria. The Harm distribution for the neck in CR100 showed that 90% of the Harm occurred at speeds up to 64km/h.

BENEFIT: A relevance of 0.14 is assumed for all AIS levels with an AIS 1 injury shift.

3.4.10 Front Left Passenger Benefits

It was previously assumed in CR165 (Fildes et al, 1996) that while the standard was primarily aimed at improving occupant protection for drivers (it is a 40% offset on the driver's side only), there would nevertheless be some additional benefit to be gained to front left passengers from the universal benefit from improved structural integrity and compatibility. In addition, some additional benefit would be expected to the chest and abdomen (from seatbelt and dashboard) and lower limbs assuming that counter-measures would apply equally to all front seat occupants.

BENEFIT: Again, it seems reasonable to assume that the benefits outlined for the body regions stipulated apply to front occupant Harm, rather than just drivers.

3.5 HIERARCHICAL APPLICATION OF BENEFITS

It was noted earlier that meeting a 64km/h test would require a substantial re-engineering of a passenger car. On this basis, it could be expected that there would be considerable benefits involving both structural improvements and the addition of new countermeasures. Moreover, it would be expected that all compliant cars would provide at least a driver airbag.

In calculating the final benefit, therefore, it is important that the order in which these assumptions would apply to existing Australian Harm patterns be maintained to ensure that double-counting does not apply. As the structural improvement would apply independent of any added countermeasure, this benefit would be applied first, followed by the airbag benefit. The extra benefit from the body region countermeasures would then be applied to the Harm that is left.

i.e., Universal benefit ➡ airbag benefit ➡ countermeasure benefit.

The next Chapter outlines the likely Harm saved if all the vehicle fleet was to comply with a 64km/h frontal offset crash requirement.

CHAPTER 4 HARM BENEFITS

The previous chapter described the assumptions used for calculating the benefits of a 64km/h frontal offset requirement for Australia. This chapter shows the resultant benefits summed from individual body regions and seating positions, assuming that cars sold in this country met this requirement at the end of 1998.

The previous report (Fildes et al, 1996) examined the benefits of the vehicle fleet complying with a frontal offset standard at two levels of crash severity, namely 56km/h and 60km/h. This report was intended to extend these earlier findings for a 64km/h test (approximately 15% higher crash severity than the 56km/h standard, typically used by consumer tests). The benefits were calculated in 1996 dollars to be consistent with the earlier findings, but then inflated by 2.6% to bring these up to 1999 dollar values.

Benefits have been expressed two ways. First, as an annual savings in Harm assuming that all vehicles in the total vehicle fleet were to meet this standard (this can be expressed as both a savings in A$ for the population each year as well as a proportional reduction in Harm). Second, as a unit Harm figure for each vehicle over its life, based on 5% and 7% discount factors, assuming vehicle life and write-off rates similar to those of the immediate past.

4.1 DETAILED HARM CALCULATIONS

The assumptions were subsequently converted into relevance figures and applied to the existing Harm distributions in arriving at the likely body region and contact source benefits for the standard. As noted at the end of the previous chapter, the computation process was undertaken in ***THREE*** separate stages:

1. The Universal benefit was first deducted from the original Harm distribution leaving a modified (lesser) Harm distribution.

2. The airbag benefit (from zero to a 30% increase in the usage of airbags in 1998 due to the offset test procedure) was then subtracted from the modified Harm distribution.

3. The individual countermeasure benefits were then subtracted from the remaining Harm.

It was argued that this procedure was necessary to minimise the chance of double counting these benefits. The order was deemed to reflect the manner in which the benefits would accrue to the population from the introduction of the standard. Because of its cascading nature, the size of each of the three benefit components is dependent upon its position in the process. Thus, its size of effect will be somewhat dependent on its position in the computation process.

Spreadsheets were developed around a series of body regions and contact sources for front seat occupants in frontal crashes. While it was assumed that most of the benefits from the offset standard would be to the lower limb regions, nevertheless, given the range of test criteria, there would be some benefits for all body regions. Injury and contact source relevance was judged on the basis of the likelihood of a particular countermeasure being introduced as a consequence of the regulation. This was in line with the previous analysis carried out in CR165 (Fildes et al, 1996).

One-page summaries of the spreadsheets are shown in Appendix A which detail the benefits by body region and contact source for the various countermeasures and airbag sales. These body region benefits are summed in Table 4.2 and 4.3 to show the total amount of Harm saved by the offset test procedures each year (in A$ millions) as well as the discounted unit value per car over its life. The discounting procedure is explained in the next section.

4.2 CALCULATING INDIVIDUAL VEHICLE SAVINGS

The annual Harm saved by the requirement for manufacturers to meet these offset test procedures assumes that all vehicles on the road instantaneously meet this standard. In fact, of course, it can take many years for this situation to arise as 15% of cars involved in crashes are more than 15 years old and there are many vehicles aged 25 years or more still operating in this country. In establishing benefit-cost relationships, it is necessary to convert annual Harm saved (a community benefit) into a saving spread across the life of an individual vehicle to compare this with the cost of having to meet this new requirement.

This is achieved by estimating the average risk of a vehicle being involved in a crash for each year of its life and multiplying that risk by the annual Harm saved per crash for that time period. The average Harm savings can then be summed across the life of the vehicle. There are alternative methods for making these estimates, each with their particular strengths and weaknesses and these have been reviewed in Vulcan and Fildes (1998).

4.2.1 Immediate Past History

In these calculations, it was assumed that the immediate past history of crashworthiness, new car sales and crash patterns would continue and therefore be the best predictor of future crash risk, vehicle population size and salvage rates. This eliminates the need for tenuous subjective predictions and has credibility in that the past is often the best predictor of the future in dealing with human behaviour. It does assume that the crashworthiness history of the vehicle fleet will not alter dramatically; an assumption that has some credibility based on recent evidence (Cameron, Newstead, Le & Finch, 1994) if attention is confined to the last 15 years.

The method assumes that the risk of a new car being involved in a casualty crash during, say the 3rd year of its life, is the same as the risk of a car which was first registered 3 years ago having a crash this year. To calculate this yearly risk, the frequency of crashes for 3-year-old cars is divided by the total number of cars sold 3 years ago. The risk of a crash across the lifetime of a car then is the sum of each year's crash experience over the number of new cars sold. The process of focussing on each crash year and the number of vehicle sales each year takes account of vehicles that exit from the vehicle fleet through wreckage, wear and tear, etc. as well as the lower distances travelled by older cars and the different characteristics of those who driver older cars.

The next step is to assume that the proportion of total Harm saved for all cars of a certain age group is equal to the percent of total relevant casualty crashes involving that age group. The formula used helps explain this:

$$\frac{H_3}{H} = \frac{F_3}{F} \qquad \text{or} \qquad H_3 = \frac{F_3}{F} \, x \, H$$

where H_3 = Harm reduction for all cars in their third year
H = total annual Harm reduction for all cars
F_3 = number of cars involved in casualty crashes in third year
F = total number of cars involved in casualty crashes in one year

The average Harm reduction for any one car in its third year is calculated by dividing H_3 by the number of new cars registered three years ago. The total benefit for a single car from the new offset standard is then obtained by adding up the Harm reductions for each year of its life and discounting these benefits back to the first year. This is explained in more detail in the previous report (Fildes et al, 1996).

4.2.2 Discounting Procedure & Rate

When predicting the likely benefits of a new countermeasure, it is normal to discount future benefits back to the present so that they can be compared with present day costs of the measure. The discounting procedure used in these calculations first takes the annual Harm saved for the offset standard and attributes this (discounted) to for one car over its expected lifetime. The selection of an appropriate discount rate is really a matter of opinion (there is no magic number). Traditionally, the Commonwealth Government has used 7% as an appropriate rate, while other state governments, however have used a range of different values (the Victorian Government, for instance, has used 4%). A smaller discount rate gives greater weight to future benefits and is thus less conservative.

Department of Finance (1991) recommend that where possible, sensitivity analysis be undertaken involving a range of different discount rates. Current practice is to compare the benefits at 5% and 7% to gauge the likely usefulness of any new countermeasure. It is acknowledged that the choice of the discount rate has a marked effect on the calculation. Not only does it influence the BCR, but also the cost of death or serious injury [Steadman & Bryan 1988 used a 7% discount rate in determining the cost of injury for each injury severity level and noted that a 4% rate would increase the cost of injury overall by 17%]. For these calculations, injury costs have been taken at the BTCE 7% discount rate but the Harm benefits have been calculated for both 5% and 7% discount rates.

4.2.3 Life Period of Vehicle Fleet

Another issue involves deciding what constitutes the life period of the vehicle fleet over which the benefits are to be claimed. It was shown in CR165 (Fildes et al, 1996) that approximately 99% of casualty crashes involve vehicles 25 years old or less, which seems to be a reasonable vehicle fleet age. On the other hand, it has been argued that it is more reasonable to use a shorter period of say 15 years (which accounts for around 85% of casualty crashes) particularly as repairs and replacement costs for the safety features have been ignored in determining their benefits.

A recent study by Cameron et al (1994), which examined the role of vehicle age and crashworthiness, showed that the risk of severe injury has not changed all that markedly over the last 15 years or so. Accordingly, benefits for the frontal offset standard have been calculated for both a 15 and 25-year life period. The multipliers used for assessing the unit Harm benefits of the 64km/h frontal offset crash test requirement are shown in Table 4.1 below.

Table 4.1 Multipliers used for calculating unit benefits for the 64km/h crash test

Discount Rate	15 year Fleet Life	25 year Fleet Life
5% discount rate	1.1274	1.2532
7% discount rate	0.9984	1.0873

Multiplier figures by 10^{-6} to convert from A$ millions to A$.

4.3 HARM BENEFITS

The study set out to calculate the Harm benefits assuming all vehicles complied with a 64km/h crash test requirement, used by the Australian and European New Car Assessment Program (NCAP) and the Insurance Institute for Highway Safety (IIHS) in the USA in publishing their consumer safety ratings of new passenger cars. This could then be compared with similar figures calculated for the 56km/h frontal offset requirement, soon to be mandated in Australia.

In the original study, it was judged that for the year 1998 (the proposed introductory period for the frontal offset standard) at least 70% of new cars would have driver airbags fitted regardless of the offset standard. Thus, the difference between the expected rate in 1998 and 100% could be attributed to the benefits of the offset standard procedure.

A summary of the benefits due specifically to the vehicle fleet meeting the frontal offset crash test requirement for a 56km/h and a 64km/h crash test speed, assuming variable fleet life periods and discount rates are shown in Tables 4.2 and 4.3. The individual Tables showing the summed benefit by type of benefit and body region for each test speed and airbag sales proportion is shown in Appendix A.

Table 4.2 Summary of Harm reductions for the various outcomes dependent upon driver airbag fitment rates achieved

PERCENT DRIVER AIRBAGS IN NEW CARS	56km/h TEST SPEED		64km/h TEST SPEED	
	ANNUAL HARM	% FRONT TRAUMA	ANNUAL HARM	% FRONT TRAUMA
70%	$418m	21%	$520m	26%
80%	$377m	19%	$481m	24%
90%	$337m	17%	$443m	22%
100%	$297m	15%	$404m	20%

NB: Prices expressed are in A$1996 values

Table 4.3 Summary of Unit Harm reductions for the various outcomes dependent upon discount rate, fleet life and driver airbag fitment rates

PERCENT AIRBAGS IN NEW CARS	56km/h TEST SPEED				64km/h TEST SPEED			
	15yr FLEET		25yr FLEET		15yr FLEET		25yr FLEET	
	5%	7%	5%	7%	5%	7%	5%	7%
70%	$471	$417	$523	$454	$586	$519	$651	$565
80%	$425	$376	$472	$410	$542	$480	$603	$523
90%	$380	$336	$422	$366	$499	$442	$555	$482
100%	$334	$296	$372	$322	$456	$404	$507	$440

NB: Prices expressed are in A$1996 values

4.4 OVERVIEW OF THE RESULTS

The results of the Harm analysis undertaken in this study illustrate what the benefits would be if all vehicles were compliant with either a 56km/h or a 64km/h crash test speed. The former figure is what is specified in the new Australian Design Rule ADR73/00, recently implemented in this country, while the latter is that used by ANCAP in publishing their new car safety ratings. Both figures show a community benefit in reduced societal Harm.

Table 4.2 shows the resulting Harm benefits for the European offset standard applied to the Australian passenger car fleet for a 56km/h test speed with airbag sales from 70% to 100%. These figures have been previously published in CR165 (Fildes et al, 1996). The total Harm saved varies from A$297 million annually (a 15% reduction in total frontal crash Harm) up to A$418 million annually or a 21% reduction in Harm, depending on the ultimate level of driver airbag sales.

UNIT HARM: Table 4.3 shows that the unit Harm benefit at the lower crash test speed varies somewhere between $296 and $523 depending upon which figures are selected for the life of the vehicle fleet and for discount rate. The break-even cost for manufacturers to meet this test is, therefore, equivalent to this unit Harm benefit figure.

At the higher test speed of 64km/h, the equivalent total frontal Harm benefit varies from A$404 million to A$520 million annually (from 20% to 26% of total frontal Harm) depending on the level of airbag fitment in 1998 (see Table 4.2). Most of the specific countermeasure benefits were either for the torso or lower limb injury reductions.

UNIT HARM: The unit Harm reduction per car at the higher 64km/h crash test speed is again depending on fleet life period and discount rate chosen. Table 4.2 shows that this figures varies from $404 to $651.

The added benefit of the 64km/h crash test requirement over the equivalent 56km/h regulation figure is an additional annual Harm saving of A$76million or an 18% increase. It should be stressed that the benefit computed for the 64km/h crash test assumes no disbenefit based on any adverse effects from an increase in stiffness to meet this requirement. No evidence was found for such an effect, although this should not be taken as positive proof that there is none.

4.5 BENEFITS IN 1999 DOLLAR VALUES

The figures shown in Tables 4.2 and 4.3 relate to the savings estimated in 1996 dollar values. These were included for consistency with the earlier published figures in CR165 (Fildes et al, 1996). The equivalent 1999 values are shown in Tables 4.4 and 4.5, reflecting a 2.6% increase in the Consumer Price Index (CPI) in Australia over that time period.

Table 4.4 Summary of Harm reductions for the various outcomes dependent upon driver airbag fitment rates achieved in A$1999 prices

PERCENT DRIVER AIRBAGS IN NEW CARS	56km/h TEST SPEED		64km/h TEST SPEED	
	ANNUAL HARM	% FRONT TRAUMA	ANNUAL HARM	% FRONT TRAUMA
70%	$429	21%	$534	26%
80%	$387	19%	$494	24%
90%	$346	17%	$455	22%
100%	$305	15%	$415	20%

NB: Prices expressed are in A$1999 values

Table 4.4 Summary of Unit Harm reductions for the various outcomes dependent upon discount rate, fleet life and driver airbag fitment rates in A$1999 prices

PERCENT AIRBAGS IN NEW CARS	56km/h TEST SPEED				64km/h TEST SPEED			
	15yr FLEET		25yr FLEET		15yr FLEET		25yr FLEET	
	5%	7%	5%	7%	5%	7%	5%	7%
70%	$483	$428	$537	$466	$601	$533	$668	$580
80%	$436	$386	$484	$420	$556	$493	$619	$537
90%	$390	$345	$433	$376	$512	$454	$569	$495
100%	$343	$304	$382	$330	$468	$415	$520	$451

NB: Prices expressed are in A$1999 values

CHAPTER 5 GENERAL DISCUSSION

This study set out to estimate the annual and unit Harm benefits likely to accrue to Australia if all vehicles complied with an offset frontal impact standard, similar to that currently specified by ADR 73, but at a higher crash severity speed of 64km/h. The 64km/h test is currently undertaken as part of the New Car Assessment Program in Australia and Europe. The study adopted the same Harm Reduction method and approach as an earlier analysis of benefits in a frontal offset crash test, conducted for the Federal Office of Road Safety in Australia when determining the need for introducing ADR73/00 (Fildes et al, 1996). The benefits were calculated in much the same way for reasons of consistency.

5.1 THE NEW CAR ASSESSMENT PROGRAM

The New Car Assessment Program in Australia and Europe, as well as a similar program conducted by the Insurance Institute for Highway Safety (IIHS) in the USA, routinely carry out offset crash tests of new passenger cars using the European offset test procedure, but at a higher 64km/h test speed. These independent test are carried out to provide information to the general public on the safety performance of new vehicles to help consumers choose safe cars. A 15% higher test speed that that regulated by governments has been adopted by these organisations to provide a more severe test of vehicle crash performance.

The 64km/h test procedure adopts exactly the same criteria specified in ADR73/00 only at the higher crash severity. The impact configuration calls for a 40% overlap using a deformable barrier face on the driver's side of the car at an impact speed of 64km/h. Two Hybrid III test dummies are placed in the front outboard seating position and injury performance criteria are specified for the head, neck, chest, upper and lower limbs. In addition, maximum intrusion criteria for the steering wheel rearward and upward are also included. It is commonly accepted that a 40% frontal offset crash test requirement is a more severe test of a passenger car structure than other frontal crash requirements.

5.2 INJURY REDUCTION ASSUMPTIONS

In computing the benefits of a proposed new countermeasure, it is necessary to rely on scant test data and expert panel assessments in estimating the likely injury reductions. The earlier study provided a basis for many of the assumptions required. In addition, crash test data available from NCAP in Europe and Australia enabled these to be adjusted for the higher impact speed. A total of 9 revised assumptions were outlined as summarised in Table 5.1 below.

5.2.1 Disbenefits

It is important to ensure that in introducing a new safety countermeasure, the benefits acquired by the measure are not offset by any disbenefits. Some manufacturers have argued that the higher crash test speed associated with the 64km/h frontal offset crash test requirement leads to more stiffer structures and hence are potentially harmful to other crash partners, especially in side impact collisions.

Table 5.1 The nine critical assumptions used in the 64km/h benefit analysis

No.	Assumption
1	A universal benefit would accrue from a general crashworthiness design improvement (15% reduction for 69% of the frontal Harm).
2	There would be an added benefit from 100% fitment of a driver airbag, which would be accelerated by mandating the offset test.
3	There would be fewer chest injuries from more stringent criteria, mainly for small to medium sized car occupants.
4	Fewer pelvic and thigh injuries from more stringent femur load and time dependent injury criteria.
5	New knee criteria would lead to fewer knee injuries for all crashes up to the test speed.
6	Fewer tibia and fibula fractures from inclusion of Tibia Index.
7	Fewer ankle-foot injuries from structural improvement to the floor and toepan areas.
8	A reduction in neck injuries by including a neck injury criterion.
9	Equal effectiveness would apply to occupants in all front seating positions.

Evidence was reviewed from the ANCAP program, which failed to show any signs of particularly stiff front structures in these crash test results. However, it was noted that many of these car designs preceded the 64km/h NCAP test and that they performed, at best, at only average or marginal performance (see discussion on pages 10 and 11 of this report).

Furthermore, the assumption that stiffer frontal structures would lead to greater injuries was questioned with the results published by the Insurance Institute for Highway Safety (IIHS) in the USA. They claimed from a series of comparative crash tests that geometry and mass are likely to be more injurious in a side impact crashes, not stiffness.

On this basis, then, it seemed that there was little evidence of a likely injury disbenefit from a 64km/h crash test requirement and hence no allowance was provided in this analysis.

Caveat. This is not to say that the 64km/h test requirement does not result in any injury disbenefit to either the vehicle's occupants or its partners in a crash, only that there is no evidence at this stage to suggest it does. It would be worth monitoring this closely in the years ahead, both in the stiffness levels of cars sold in Australia as their performance against the test improves and their compatibility performance in the fleet. In the event that any additional evidence becomes available, it is possible to modify the benefits at a later date, in line with these findings.

5.3 BENEFITS OF THE STANDARD

The likely benefits for Australia were then computed using the Harm Reduction method previously developed for these purposes by the Monash University Accident Research Centre in conjunction with Kennerly Digges and Associates of Charlottesville, Virginia.

Annual Harm Benefit calculations were made using a step-wise approach where the universal benefit was calculated first, followed by the increased airbag usage benefit and then the countermeasure benefits were computed. This was to prevent double counting and was the same procedure adopted earlier in CR 165 (Fildes et al, 1996).

Unit Harm benefits (the expected savings per car) were then computed assuming future saving discount rates of both 5% and 7%. These figures are typically used in benefit studies across Australia and comply with the recommendations by the federal Department of Finance (1991). Fleet life periods of 15 and 25 years were also adopted in these calculations as before.

5.3.1 Annual Harm Benefits

The results shown in Table 4.2 in the previous Chapter demonstrated the range of annual benefits that would accrue for both a 56km/h test speed (ADR73/00) and for a 64km/h speed (in A$1996 prices). As reported earlier, the least annual Harm reduction that would accrue from the 64km/h offset test was estimated to be a minimum of A$404 million (a 20% reduction in frontal Harm) and at best, A$520 million or a 26% reduction in frontal Harm. These savings represent an increase in Harm saved of between 24% and 36% over that expected from ADR73/00. Naturally, these savings would only apply when (and if) all passenger cars in the fleet complied with this test requirement.

5.3.2 Unit Harm Benefits

Unit Harm benefits (the average savings per car across its lifetime) were determined using 5% and 7% discount rates and fleet life periods of 15 and 25 years. Again, Table 4.3 in Chapter 4 revealed a unit Harm savings of between A$404 and A$651 across the life of the car. In other words, the break-even cost for having to meet this new requirement would be somewhere between these figures.

5.4 DISCUSSION OF THE RESULTS

In the earlier report, it was noted that the expert panel used in arriving at the likely injury reductions at 56km/h and 60km/h, claimed that the benefits to be derived for Australia would come from three sources; a universal structural improvement, an increase in the provision (and subsequent benefits) of driver side airbags as a result of this requirement, and from specific measures aimed at meeting the stringent new test criteria.

Using the assumptions agreed to by this expert panel and modifying these in the light of recent 64km/h test results, the subsequent Harm benefits appear to be sizeable in addition to ADR73.

The most conservative estimate was for a 20% reduction in frontal Harm attributed directly to this standard with no benefit from increased airbag use. The minimum break-even cost to achieve this benefit would be A$404 per vehicle, which seems very reasonable indeed (industry estimates to achieve the side impact standard improvements in Fildes et al (1996), were A$100 per car).

The question of any disbenefit resulting from the 64km/h was not substantiated by any available evidence at this time. The benefits computed here can always be amended subsequently in the light of any additional data becoming available which demonstrates an increase in injury from compliance with the 64km/h test requirement.

The assumptions and the basis for them are clearly stated throughout the report based on the existing body of test data, scant injury data, biomechanics criteria, and expert opinion. These were the best information available at the time on which it was possible to estimate these benefits. As new information becomes available, these assumptions may be further refined and the benefits adjusted accordingly.

The strength of the Harm Reduction method used here is that the basis for arriving at these benefits is objective and transparent and subject to close scrutiny. If one wishes to challenge any of the assumptions, it is possible to re-calculate the benefits based on alternative outcomes. Indeed, the analysis performed here included a number of sensitivity tests on the basis of alternative crash test speeds, airbag usage figures in Australia pre-standard, and varying discount factors and time period over which the benefits are calculated.

5.5 CONCLUSION

On the basis of the evidence presented here, the 64km/h crash tests seems to provide considerable benefit to Australia in addition to that expected from ADR 73/00. The total benefit likely to accrue if all cars were to comply with the 64km/h test would be somewhere between A$404 million and A$520 million annually with 100% fleet compliance. The break-even cost per car across its lifetime would be on average somewhere between A$404.00 and A$651.00. The additional benefit above ADR 73/00 would be of the order of 24% to 36% in reduced Harm in frontal crashes. No data was available on any likely disbenefit resulting from designing for the higher crash test and further research is needed to confirm this assumption.

Caveat

The Bureau of Transport Economics in Canberra recently revised their estimates of the costs of injury in Australia based on more recent cost data available. These costs are between two and three times greater than those used in this report. Unfortunately it was not possible to use these latest costs in computing the benefits of a 64 km/h offset crash test in Australia as unit body region by injury severity costs are unknown at this stage. Hence, the benefits calculated here are very conservative estimates of those resulting from this test requirement.

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APPENDIX A

EUROPEAN FRONTAL OFFSET TEST BENEFIT FOR AUSTRALIA

SUMMARY OF HARM BENEFITS @ 56 KM/H SPEED (70% AIRBAG SALES)

BODY REGION	ORIGINAL FRONTAL HARM	UNIVERSAL BENEFIT (10%x55%)	AIRBAG BENEFIT (70% sales)	COUNTERMEASURE BENEFIT					TOTAL HARM SAVED
				Percent Fleet Applicable	Relevance	AIS Shift Applicable	AIS Weighting Factor	Total C'Measure Benefit	
HEAD	680.6	37.4	76.0	nil					113.5
FACE	169.5	9.3	17.8	nil					27.2
NECK	53.6	2.9		15%	90%	1		1.9	4.8
CHEST - dummy measures	123.36	6.8	9.5	48%	85%	2		34.7	51.0
CHEST - steering assy	97.01	5.3	22.7	63%	56%	2		32.1	60.1
ABDOMEN	92.33	5.1	4.6	48%	85%	2		30.5	40.2
PELVIS	46	2.5	1.5	41%	85%	2		7.1	11.1
SPINE	83.8	4.6		nil					4.6
UPPER LIMBS	204.7	11.3		nil					11.3
THIGH	117.8	6.5		41%	85%	2		35.4	41.9
KNEE	88.2	4.9		74%	85%	2		18.8	23.7
LOWER LEG	134.4	7.4		46%	85%	2		10.5	17.9
ANKLE-FOOT	135.8	7.5		78%	15%	1		10.3	17.8
TOTAL HARM ($million) (% total frontal Harm saved)	1891.3	102.4 5.4%	133.8 7.1%					181.3 9.6%	417.5 22.1%
UNIT HARM PER VEHICLE in $s per car (5% discount method)								**15yr fleet life** **25yr fleet life**	**$470.6** **$523.2**
UNIT HARM PER VEHICLE in $s per car (7% discount method)								**15yr fleet life** **25yr fleet life**	**$416.8** **$453.9**

NOTES:

1. Original frontal Harm from the 1991 analysis updated to 1995 prices.
2. Universal benefit for 56km/h test speed assumes a 10% benefit overall applying to 55% of crashes between 20 and 65km/h.
3. Airbag benefit assumes a proportion of that calculated in CR100 for increased airbag use because of new offset test procedure.

   Assume 70% of vehicles sold in 1998 would have airbags fitted without the new offset test procedure (100% fitment rate with procedure).
4. Same airbag benefit assumed for both restrained and unrestrained occupants.

EUROPEAN FRONTAL OFFSET TEST BENEFIT FOR AUSTRALIA

SUMMARY OF HARM BENEFITS @ 56 KM/H SPEED (80% AIRBAG SALES)

BODY REGION	ORIGINAL FRONTAL HARM	UNIVERSAL BENEFIT (10%x55%)	AIRBAG BENEFIT (80% sales)	COUNTERMEASURE BENEFIT					TOTAL HARM SAVED
				Percent Fleet Applicable	Relevance	AIS Shift Applicable	AIS Weighting Factor	Total C'Measure Benefit	
HEAD	680.6	37.4	50.6	nil					88.0
FACE	169.5	9.3	11.8	nil					21.1
NECK	53.6	3.0		15%	90%	1		1.9	4.9
CHEST - dummy measures	123.36	8.0	12.6	48%	85%	2		39.5	60.1
CHEST - steering assy	97.01	6.2	10.0	63%	56%	2		31.0	47.2
ABDOMEN	92.33	5.1	3.1	48%	85%	2		30.9	39.1
PELVIS	46	2.5	1.0	41%	85%	2		7.2	10.7
SPINE	83.8	4.6		nil					4.6
UPPER LIMBS	204.7			nil					0.0
THIGH	117.8	6.5		41%	85%	2		35.4	41.9
KNEE	88.2	4.9		74%	85%	2		18.8	23.7
LOWER LEG	134.4	7.4		46%	85%	2		10.5	17.9
ANKLE-FOOT	135.8	7.5		78%	15%	1		10.3	17.8
TOTAL HARM ($million) (% total frontal Harm saved)	1891.3	102.4 5.4%	89.1 4.7%					185.5 9.8%	377.0 19.9%
UNIT HARM PER VEHICLE in $s per car (5% discount method)								**15yr fleet life**	**$425.0**
								25yr fleet life	**$472.5**
UNIT HARM PER VEHICLE in $s per car (7% discount method)								**15yr fleet life**	**$376.4**
								25yr fleet life	**$409.9**

NOTES:

1. Original frontal Harm from the 1991 analysis updated to 1995 prices.
2. Universal benefit for 56km/h test speed assumes a 10% benefit overall applying to 55% of crashes between 20 and 65km/h.
3. Airbag benefit assumes a proportion of that calculated in CR100 for increased airbag use because of new offset test procedure.

   Assumes 80% of vehicles sold in 1998 would have airbags fitted without the new offset test procedure (100% fitment rate with procedure).
4. Same airbag benefit assumed for both restrained and unrestrained occupants.

EUROPEAN FRONTAL OFFSET TEST BENEFIT FOR AUSTRALIA
SUMMARY OF HARM BENEFITS @ 56 KM/H SPEED (90% AIRBAG SALES)

BODY REGION	ORIGINAL FRONTAL HARM	UNIVERSAL BENEFIT (10%x55%)	AIRBAG BENEFIT (90% sales)	COUNTERMEASURE BENEFIT					TOTAL HARM SAVED
				Percent Fleet Applicable	Relevance	AIS Shift Applicable	AIS Weighting Factor	Total C'Measure Benefit	
HEAD	680.6	37.4	25.3	nil					62.7
FACE	169.5	9.3	5.9	nil					15.2
NECK	53.6	2.9		15%	90%	1		1.9	4.8
CHEST - dummy measures	123.36	8.0	6.3	48%	85%	2		41.6	55.9
CHEST - steering assy	97.01	6.2	5.0	63%	56%	2		32.7	43.9
ABDOMEN	92.33	5.1	1.6	48%	85%	2		31.3	38.0
PELVIS	46	2.5	0.5	41%	85%	2		7.4	10.4
SPINE	83.8	4.6		nil					4.6
UPPER LIMBS	204.7			nil					0.0
THIGH	117.8	6.5		41%	85%	2		35.4	41.9
KNEE	88.2	4.9		74%	85%	2		18.8	23.7
LOWER LEG	134.4	7.4		46%	85%	2		10.5	17.9
ANKLE-FOOT	135.8	7.5		78%	15%	1		10.3	17.8
TOTAL HARM ($million) (% total frontal Harm saved)	1891.13	102.4 5.4%	44.6 2.4%					189.9 10.0%	336.9 17.8%
UNIT HARM PER VEHICLE in $s per car (5% discount method)								**15yr fleet life**	**379.8**
								25yr fleet life	**422.2**
UNIT HARM PER VEHICLE in $s per car (7% discount method)								**15yr fleet life**	**336.3**
								25yr fleet life	**366.3**

NOTES:

1. Original frontal Harm from the 1991 analysis updated to 1995 prices.
2. Universal benefit for 56km/h test speed assumes a 10% benefit overall applying to 55% of crashes between 20 and 65km/h.
3. Airbag benefit assumes a proportion of that calculated in CR100 for increased airbag use because of new offset test procedure.

   Assume 90% of vehicles sold in 1998 would have airbags fitted without the new offset test procedure (100% fitment with procedure).
4. Same airbag benefit assumed for both restrained and unrestrained occupants.

EUROPEAN FRONTAL OFFSET TEST BENEFIT FOR AUSTRALIA

SUMMARY OF HARM BENEFITS @ 56 KM/H SPEED (100% AIRBAG SALES)

BODY REGION	ORIGINAL FRONTAL HARM	UNIVERSAL BENEFIT (10%x55%)	AIRBAG BENEFIT (100% sales)	COUNTERMEASURE BENEFIT					TOTAL HARM SAVED
				Percent Fleet Applicable	Relevance	AIS Shift Applicable	AIS Weighting Factor	Total C'Measure Benefit	
HEAD	680.6	37.4	0.0	nil					37.4
FACE	169.5	9.3	0.0	nil					9.3
NECK	53.6	2.9		15%	90%	1		1.9	4.8
CHEST - dummy measures	123.36	8.0	0.0	48%	85%	2		43.7	51.7
CHEST - steering assy	97.01	6.2	0.0	63%	56%	2		34.3	40.5
ABDOMEN	92.33	5.1	0.0	48%	85%	2		31.7	36.8
PELVIS	46	2.5	0.0	41%	85%	2		7.6	10.1
SPINE	83.8	4.6		nil					4.6
UPPER LIMBS	204.7			nil					0.0
THIGH	117.8	6.5		41%	85%	2		35.4	41.9
KNEE	88.2	4.9		74%	85%	2		18.8	23.7
LOWER LEG	134.4	7.4		46%	85%	2		10.5	17.9
ANKLE-FOOT	135.8	7.5		78%	15%	1		10.3	17.8
TOTAL HARM ($million) (% total frontal Harm saved)	1891.3	102.4 5.4%	0.0 0.0%					194.2 10.3%	296.6 15.7%
UNIT HARM PER VEHICLE in $s per car (5% discount method)								**15yr fleet life** **25yr fleet life**	**334.4** **371.7**
UNIT HARM PER VEHICLE in $s per car (7% discount method)								**15yr fleet life** **25yr fleet life**	**296.1** **322.5**

NOTES:

1. Original frontal Harm from the 1991 analysis updated to 1995 prices.
2. Universal benefit for 56km/h test speed assumes a 10% benefit overall applying to 55% of crashes between 20 and 65km/h.
3. Airbag benefit assumes a proportion of that calculated in CR100 for increased airbag use because of new offset test procedure.

   Assume 100% of vehicles sold in 1998 would have airbags fitted without the new offset test procedure (100% fitment rate with procedure).
4. Same airbag benefit assumed for both restrained and unrestrained occupants.

EUROPEAN FRONTAL OFFSET TEST BENEFIT FOR AUSTRALIA

SUMMARY OF HARM BENEFITS @ 64 KM/H SPEED (70% AIRBAG SALES)

BODY REGION	ORIGINAL FRONTAL HARM	UNIVERSAL BENEFIT (15%x69%)	AIRBAG BENEFIT (70% sales)	COUNTERMEASURE BENEFIT					TOTAL HARM SAVED
				Percent Fleet Applicable	Relevance	AIS Shift Applicable	AIS Weighting Factor	Total C'Measure Benefit	
HEAD	680.6	70.4	72.1	nil					142.6
FACE	169.5	17.5	16.9	nil					34.5
NECK	53.6	5.5		15%	90%	1		1.5	7.0
CHEST - dummy measures	123.36	12.8	9.5	48%	85%	2		28.0	50.3
CHEST - steering assy	97.01	10.0	22.7	63%	56%	2		26.1	58.8
ABDOMEN	92.33	9.6	4.4	48%	85%	2		24.6	38.5
PELVIS	46	4.8	1.4	41%	85%	2		6.7	12.9
SPINE	83.8	8.7		nil					8.7
UPPER LIMBS	204.7	21.2		nil					21.2
THIGH	117.8	12.2		41%	85%	2		33.5	45.7
KNEE	88.2	9.1		74%	85%	2		48.7	57.8
LOWER LEG	134.4	13.9		46%	85%	2		27.8	41.7
ANKLE-FOOT	135.8	14.1		78%	15%	1		11.4	25.5
TOTAL HARM ($million) (% total frontal Harm saved)	1891.3	195.7 10.3%	127.0 6.7%					196.9 10.4%	519.6 27.5%
UNIT HARM PER VEHICLE in $s per car (5% discount method)								**15yr fleet life** **25yr fleet life**	**$585.7** **$651.2**
UNIT HARM PER VEHICLE in $s per car (7% discount method)								**15yr fleet life** **25yr fleet life**	**$518.7** **$564.9**

NOTES:

1. Original frontal Harm from the 1991 analysis updated to 1995 prices.
2. Universal benefit for 64km/h test speed assumes a 15% benefit overall applying to 69% of crashes between 20 and 70km/h.
3. Airbag benefit assumes a proportion of that calculated in CR100 for increased airbag use because of new offset test procedure.

   Assume 70% of vehicles sold in 1998 would have airbags fitted without the new offset test procedure (100% fitment rate with procedure).
4. Higher countermeasure benefits assumed over those in CR165 based on the 64km/h impact speed requirement.
5. Same airbag benefit assumed for both restrained and unrestrained occupants.

EUROPEAN FRONTAL OFFSET TEST BENEFIT FOR AUSTRALIA

SUMMARY OF HARM BENEFITS @ 64 KM/H SPEED (80% AIRBAG SALES)

BODY REGION	ORIGINAL FRONTAL HARM	UNIVERSAL BENEFIT (15%x69%)	AIRBAG BENEFIT (80% sales)	COUNTERMEASURE BENEFIT					
				Percent Fleet Applicable	Relevance	AIS Shift Applicable	AIS Weighting Factor	Total C'Measure Benefit	TOTAL HARM SAVED
HEAD	680.6	70.4	48.0	nil					118.4
FACE	169.5	17.5	11.2	nil					28.7
NECK	53.6	5.5		15%	90%	1		1.5	7.0
CHEST - dummy measures	123.36	12.8	6.4	48%	85%	2		29.1	48.3
CHEST - steering assy	97.01	10.0	15.1	63%	56%	2		28.2	53.3
ABDOMEN	92.33	9.6	2.9	48%	85%	2		25.1	37.6
PELVIS	46	4.8	0.9	41%	85%	2		6.8	12.5
SPINE	83.8	8.7		nil					8.7
UPPER LIMBS	204.7	21.2		nil					21.2
THIGH	117.8	12.2		41%	85%	2		33.5	45.7
KNEE	88.2	9.1		74%	85%	2		48.7	57.8
LOWER LEG	134.4	13.9		46%	85%	2		27.8	41.7
ANKLE-FOOT	135.8	14.1		78%	15%	1		11.4	25.5
TOTAL HARM ($million) (% total frontal Harm saved)	1891.3	195.7 10.3%	84.5 4.5%					200.7 10.6%	480.9 25.4%
UNIT HARM PER VEHICLE in $s per car (5% discount method)								**15yr fleet life** **25yr fleet life**	**$542.1** **$602.7**
UNIT HARM PER VEHICLE in $s per car (7% discount method)								**15yr fleet life** **25yr fleet life**	**$480.1** **$522.8**

NOTES:

1. Original frontal Harm from the 1991 analysis updated to 1995 prices.
2. Universal benefit for 64km/h test speed assumes a 15% benefit overall applying to 69% of crashes between 20 and 70km/h.
3. Airbag benefit assumes a proportion of that calculated in CR100 for increased airbag use because of new offset test procedure.

   Assumes 80% of vehicles sold in 1998 would have airbags fitted without the new offset test procedure (100% fitment rate with procedure).
4. Higher countermeasure benefits assumed over those in CR165 based on the 64km/h impact speed requirement.
5. Same airbag benefit assumed for both restrained and unrestrained occupants

EUROPEAN FRONTAL OFFSET TEST BENEFIT FOR AUSTRALIA

SUMMARY OF HARM BENEFITS @ 64 KM/H SPEED (90% AIRBAG SALES)

BODY REGION	ORIGINAL FRONTAL HARM	UNIVERSAL BENEFIT (15%x69%)	AIRBAG BENEFIT (90% sales)	COUNTERMEASURE BENEFIT					TOTAL HARM SAVED
				Percent Fleet Applicable	Relevance	AIS Shift Applicable	AIS Weighting Factor	Total C'Measure Benefit	
HEAD	680.6	70.4	24.0	nil					94.4
FACE	169.5	17.5	5.6	nil					23.1
NECK	53.6	5.5		15%	90%	1		1.5	7.0
CHEST - dummy measures	123.36	12.8	3.2	48%	85%	2		30.2	46.2
CHEST - steering assy	97.01	10.0	7.6	63%	56%	2		30.4	48.0
ABDOMEN	92.33	9.6	1.5	48%	85%	2		25.6	36.7
PELVIS	46	4.8	0.5	41%	85%	2		7.0	12.3
SPINE	83.8	8.7		nil					8.7
UPPER LIMBS	204.7	21.2		nil					21.2
THIGH	117.8	12.2		41%	85%	2		33.5	45.7
KNEE	88.2	9.1		74%	85%	2		48.7	57.8
LOWER LEG	134.4	13.9		46%	85%	2		27.8	41.7
ANKLE-FOOT	135.8	14.1		78%	15%	1		11.4	25.5
TOTAL HARM ($million) (% total frontal Harm saved)	1891.13	195.7 10.3%	42.4 2.2%					204.7 10.8%	442.8 23.4%
UNIT HARM PER VEHICLE in $s per car (5% discount method)							**15yr fleet life** **25yr fleet life**		**499.2** **554.9**
UNIT HARM PER VEHICLE in $s per car (7% discount method)							**15yr fleet life** **25yr fleet life**		**442.0** **481.4**

NOTES:

1. Original frontal Harm from the 1991 analysis updated to 1995 prices.
2. Universal benefit for 64km/h test speed assumes a 15% benefit overall applying to 69% of crashes between 20 and 70km/h.
3. Airbag benefit assumes a proportion of that calculated in CR100 for increased airbag use because of new offset test procedure.

   Assume 90% of vehicles sold in 1998 would have airbags fitted without the new offset test procedure (100% fitment with procedure).
4. Higher countermeasure benefits assumed over those in CR165 based on the 64km/h impact speed requirement.
5. Same airbag benefit assumed for both restrained and unrestrained occupants.

EUROPEAN FRONTAL OFFSET TEST BENEFIT FOR AUSTRALIA

SUMMARY OF HARM BENEFITS @ 64 KM/H SPEED (100% AIRBAG SALES)

BODY REGION	ORIGINAL FRONTAL HARM	UNIVERSAL BENEFIT (15%x69%)	AIRBAG BENEFIT (100% sales)	COUNTERMEASURE BENEFIT					TOTAL HARM SAVED
				Percent Fleet Applicable	Relevance	AIS Shift Applicable	AIS Weighting Factor	Total C'Measure Benefit	
HEAD	680.6	70.4	0.0	nil					70.4
FACE	169.5	17.5	0.0	nil					17.5
NECK	53.6	5.5		15%	90%	1		1.5	7.0
CHEST - dummy measures	123.36	12.8	0.0	48%	85%	2		31.3	44.1
CHEST - steering assy	97.01	10.0	0.0	63%	56%	2		32.6	42.6
ABDOMEN	92.33	9.6	0.0	48%	85%	2		26.1	35.7
PELVIS	46	4.8	0.0	41%	85%	2		7.1	11.9
SPINE	83.8	8.7		nil					8.7
UPPER LIMBS	204.7	21.2		nil					21.2
THIGH	117.8	12.2		41%	85%	2		33.5	45.7
KNEE	88.2	9.1		74%	85%	2		48.7	57.8
LOWER LEG	134.4	13.9		46%	85%	2		27.8	41.7
ANKLE-FOOT	135.8	14.1		78%	15%	1		11.4	25.5
TOTAL HARM ($million) (% total frontal Harm saved)	1891.3	195.7 10.3%	0.0 0.0%					208.6 11.0%	404.3 21.4%
UNIT HARM PER VEHICLE in $s per car (5% discount method)								**15yr fleet life** **25yr fleet life**	**455.8** **506.7**
UNIT HARM PER VEHICLE in $s per car (7% discount method)								**15yr fleet life** **25yr fleet life**	**403.6** **439.6**

NOTES:

1. Original frontal Harm from the 1991 analysis updated to 1995 prices.
2. Universal benefit for 64km/h test speed assumes a 15% benefit overall applying to 69% of crashes between 20 and 70km/h.
3. Airbag benefit assumes a proportion of that calculated in CR100 for increased airbag use because of new offset test procedure.

   Assume 100% of vehicles sold in 1998 would have airbags fitted without the new offset test procedure (100% fitment rate with procedure).
4. Higher countermeasure benefits assumed over those in CR165 based on the 64km/h impact speed requirement.
5. Same airbag benefit assumed for both restrained and unrestrained occupants.