Benefits of a Hybrid Side Impact Regulation

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Victoria Australia

CR 175
1998

Federal Office of Road Safety

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June 1998

FEDERAL OFFICE OF ROAD SAFETY
DOCUMENT RETRIEVAL INFORMATION

Report No.	Date	Pages	ISBN	ISSN
CR 175	June 1998	37	0 642 25507 5	0810-770X

Title and Subtitle

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Abstract

There are two fundamentally different dynamic side impact regulations in existence currently, namely FMVSS 214 in the USA and ECE Reg 95 in Europe. An earlier benefit study showed that both these regulations would be cost-beneficial if applied in Australia. Subsequently, Australia mandated a new Australian Design Rule ADR72 that calls for all new passenger cars to comply with one of two existing dynamic side impact regulations by 1999. There is general agreement around the world that it is undesirable to have two different regulations for side impact protection and that they need to be harmonised. A proposal for a hybrid side impact regulation was developed in Australia and a series of crash tests performed which demonstrated superior crash performance outcomes over the two existing regulations. This benefit study was conducted to revise the previous estimates of FMVSS 214 and ECE Reg 95 in the light of more recent evidence and to estimate the Harm benefits of the new hybrid standard. The results show that while the previous Harm reduction figures were slightly over-stated, they are still nevertheless likely to be cost-beneficial. More importantly, though, the hybrid proposal has the potential to provide far superior Harm reductions in side impacts to either of the two existing standards and would overcome the difficulty of having different side impact standards in different continents.

Keywords

SAFETY, ACCIDENT, SIDE IMPACTS, VEHICLE OCCUPANT, INJURY, COUNTER-MEASURE, COST-BENEFIT, ECONOMIC, HARM, EVALUATION

Notes

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(c) reports based on analysis of FORS statistical databases are published in the SR series;
(d) minor reports of research conducted by other organisations on behalf of FORS are published in the MR series.

ACKNOWLEDGMENTS

THE AUTHORS ARE INDEBTED TO THE FEDERAL OFFICE OF ROAD SAFETY, COMMONWEALTH DEPARTMENT OF TRANSPORT AND COMMUNICATIONS, AUSTRALIA, FOR THEIR SPONSORSHIP, INTEREST AND ASSISTANCE WITH THIS PROJECT.

THE STUDY TEAM ARE ALSO GRATEFUL TO THE INTERNATIONAL SPECIALISTS WHO WILLINGLY GAVE UP THEIR TIME TO ATTEND THE ONE-DAY WORKSHOP IN WASHINGTON DC AND CONTRIBUTE TO THE DISCUSSIONS AND OUTCOME OF THE MEETING AND THIS REPORT. THESE PEOPLE INCLUDED:

Mr. Keith Seyer, FORS, Australia (Chairperson)

Dr. Dainius Dalmotas, Transport Canada

Mr. Tom Hollowell, NHTSA, USA

Mr. Jim Hackney, NHTSA, USA

Dr. Ingo Kallina, Mercedes-Benz AG, Germany

Dr. David Zuby, IIHS, USA

Ms. Randa Radwan, NHTSA, USA

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EXECUTIVE SUMMARY

Introduction

There are two fundamentally different dynamic side impact regulations in existence currently, namely FMVSS 214 in the USA and ECE Reg 95 in Europe. An earlier benefit study (Fildes, Digges, Carr, Dyte and Vulcan (1995) showed that both these regulations would be cost-beneficial if applied in Australia. Subsequently, Australia mandated a new Australian Design Rule ADR72 that calls for all new passenger cars to comply with one of two existing dynamic side impact regulations by 1999.

There is general agreement around the world that it is undesirable to have two different regulations for side impact protection and that they need to be harmonised. A proposal for a hybrid side impact regulation was developed in Australia recently (Seyer & Fildes, 1996) and a series of crash tests were performed which demonstrated superior crash performance outcomes over the two existing regulations.

To demonstrate the likely cost effectiveness of the proposed hybrid side impact standard, a Harm benefit analysis was undertaken using the *Harm Reduction* method previously used in other side impact benefit analyses (see Fildes, Digges, Carr, Dyte & Vulcan, 1995; Fildes, Dyte, Carr, Digges & Seyer, 1996).

HYBRID STANDARD PROPOSAL

The current FORS proposal was outlined in Seyer & Fildes (1996) and contains features of the two existing side impact standards in Europe and the United States of America, including the FMVSS 214 crabbed movable barrier, the ECE R95 deformable barrier face, impact geometry as in FMVSS 214, BioSID dummies in the front and rear outboard seating positions, and ECE R95 injury criteria to the degree to which BioSID is capable of measuring.

The Federal Office of Road Safety have been working towards developing a hybrid side impact standard proposal, based on a crash test program undertaken at a crash test facility in Melbourne, Australia.

Data Sources Available

An Australia-wide database was necessary to assess the likely injury reductions for these standards. A detailed database was constructed in 1991 of national injury patterns by body regions, restraint conditions and contact sources, along with a series of resultant Harm matrices using BTCE human capital cost estimates (Monash University Accident Research Centre 1992). This comprehensive trauma analysis, based on over 500 real-world crashes examined in the Crash Vehicle File by the Monash University Accident Research Centre, offered a baseline trauma pattern upon which estimates of Harm reductions could be made.

Injury Reductions

As in the previous side impact benefit analysis in Fildes et al (1996), there was again very little published data available that reported on injury reductions associated with a hybrid standard, apart from the test results reported earlier in this study and some figures published by Dalmotas, Newman and Gibson (1994). Thus, it was deemed necessary again to assemble a panel of international experts to establish the likely injury benefits that would accrue to Australia for the hybrid standard.

A one-day workshop was organised in May 1997 in Washington DC comprising representatives from the car industry, government researchers, representatives of consumer groups and the study team. The workshop provided an up-to-date account of recent side impact regulation developments as well as the likely injury benefits to Australia by adopting the hybrid standard.

It was clear from the discussion at the meeting that many of the assumptions made in the earlier side impact benefit study (Fildes et al 1995) had not been substantiated by more recent published data and experience. This, it was decided that part of the task of assessing hybrid benefits should also involve adjusting the earlier figures for FMVSS 214 and ECE 95 in line with more recent expectations.

RelevanT Assumptions

A number of revised assumptions were agreed to for determining the likely benefits of a hybrid side impact regulation for Australia, as well as more recent expectations for the existing two dynamic side impact standards FMVSS 214 and ECE 95 and these are outlined below.

1. Each of the standards require a test at a crash severity of around 27km/h which will provide benefits at crash speeds up to 64km/h. No benefits are assumed above this speed.

2. The benefits will apply equally to both car-to-car and car-to fixed-objects in side impact collisions.

3. The benefits will apply equally to occupants involved in both non-compartment and compartment struck side impacts.

4. Near-side occupants who sustain AIS 5 or 6 fatal head injuries are excluded from any benefit from the standards. Reductions in chest injuries to occupants who sustain a non-fatal head injury are included

5. All head injuries (to survivors) in side impacts from contact with the door panel are reduced by 2 AIS and face injuries by 1 AIS over the crash severity range of 0-64km/h. For EuroSID (and BioSID), an additional benefit of 2 AIS applies for head contacts with the side rails.

6. Benefits will apply to the chest, pelvis, femur, shoulder, upper extremity, head and face injuries caused by contact with the door panel, hardware or armrest. Internal organ benefits will vary depending on the test dummy used.

7. An incremental reduction in TTI or V*C on injuries to the chest from door contacts for near-side occupants can be expressed as a crash severity change.

8. The injury risk curves for TTI and V*C apply to the range of impact speeds for side crashes at severities less than 64km/h for injuries of AIS 3 or greater.

9. Forty-five percent of AIS 3-6 and 90% of AIS 1-2 chest injuries over the crash severity range of 0 to 64km/h are expected to be affected by a side impact standard, based on NHTSA pre-standard crash tests.

10. A reduction of AIS 2 in chest injuries is expected by the use of SID and TTI over the crash severity range and an AIS 3 reduction is expected by the use of EuroSID and V*C measures.

11. It was assumed that there is some heart benefits approximating 25% of that relevant to the hard thorax for SID and EuroSID but 50% for BioSID given its superior injury criteria and test performance.

12. New Australian test data show that V*C is a more critical parameter than TTI and this should lead to additional countermeasures to protect the abdomen. Thus, an overall injury reduction for abdominal injuries of AIS 3 for V*C from EuroSID across the relevant crash severity range is expected (no benefit was claimed for FMVSS214 as SID does not measure abdominal injury).

13. Only upper extremity injuries from contact with the door panel or hardware at or below the crash severity range are relevant. As no test data were available on the likely reductions in contacts, a modest AIS 1 injury reduction is assumed.

14. A dynamic side impact standard will result in the elimination of all injuries with exterior contacts for far-side occupants, ejected through the far-side door over the severity range of 0-40km/h.

15. As the European test procedure does not include a rear seat dummy, no rear seat benefit should be awarded to the ECE Reg 95 standard and similar benefits would apply to front and rear seat occupants in both FMVSS 214 and the proposed Hybrid test.

Results of the Analysis

A detailed system of spreadsheets was assembled for calculating the benefits of both the existing and hybrid standards. Relevance figures were assigned by body region and seating position (near- or far-side of the vehicle) and the subsequent Harm units removed were computed. The savings by body region and seating position were then summed to arrive at the total estimate of savings for both standards. Annual Harm saved was converted into Unit Harm benefits using both a 5% and a 7% discount rates with fleet life estimates of 15 and 25 years. The results of the analysis are shown in Table 1 below and discussed below for each of the three regulations.

Revised FMVSS 214.

The revised benefit estimate for the US standard, FMVSS 214, assuming that all vehicles in the Australian fleet were to comply instantaneously was A$116.2 million. This is 84.5% of the original figure previously published (A$136 million) essentially due to reductions in expected savings in abdominal, chest and head injuries because of revised performance criteria. This still yields a 3.7% reduction in vehicle occupant trauma annually if FMVSS 214 were to apply in Australia. The unit benefit per car would be between $116 and $145.60 per car, depending on the discount rate and fleet life figures used in the calculation. At $100 expected installation cost per vehicle, adopting this standard would still be cost-beneficial.

Revised ECE 95.

The equivalent revised figure for the European standard is A$121.6 million each year if all vehicles in the Australia fleet instantly complied. This is also only 83% of the figure originally estimated based on more recent evidence of performance expectations. It should be noted that most of the reduced Harm for the European standard comes from exclusion of any rear seat benefit because of the lack of a rear seat dummy (this was not anticipated at the original workshop held in Munich in 1994). On this basis, the unit Harm benefit would be somewhere between $121.40 and $152.40 per car, would still be cost-beneficial, and would yield a slightly higher reduction in occupant trauma annually of 3.9%.

Hybrid Proposal.

Finally, the hybrid proposal is expected to save A$141.7 million annually, based on the assumptions listed by the expert panel. This is 16.5% greater than ECE 95 and 22% greater than FMVSS 214 because of the expected more stringent test procedure, the inclusion of a rear seat dummy and the likely improvements from the use of BioSID test dummies. This would amount to an improved 4.5% reduction in vehicle trauma annually and with a unit Harm benefit of between $141.40 and $177.50 per car, would yield a Benefit-Cost-Ratio of 1.5 or greater. The hybrid proposal is clearly superior to either of the two existing standards and would overcome the difficulty of having different side impact standards in different continents.

Table 1
Summary Table of Harm Benefits for FMVSS 214 and ECE Reg 95.

BODY REGION INJURED		U.S. STANDARD FMVSS 214 $million	EUROPEAN ECE Reg. 95 $million	HYBRID PROPOSAL $million
HEAD INJURIES	near-side	8.7	9.7	10.8
	far-side	16.1	16.3	18.1
FACIAL INJURIES	near-side	0.6	0.7	0.8
	far-side	0.1	0.1	0.1
CHEST INJURIES	near-side	43.3	43.8	48.8
	far-side	2.9	2.9	3.2
INTERNAL ORGANS	near-side	0.3	3.2	7.2
	far-side	0	0.4	0.4

ABDOMINAL INJURIES	near-side	0	5.3	8.4
	far-side	0	0	0
PELVIC INJURIES	near-side	4.4	3.9	4.4
	far-side	0.1	0	0.1
UPPER LIMB INJURIES	near-side	17.0	15.2	17.0
	far-side	3.6	3.2	3.6
LOWER LIMB INJURIES	near-side	17.6	15.8	17.6
	far-side	1.2	1.1	1.2
TOTAL NEAR-SIDE HARM SAVED ($million)		**92.0**	**97.6**	**114.9**
TOTAL FAR-SIDE HARM SAVED ($million)		**24.2**	**24.0**	**26.7**
TOTAL HARM SAVED ANNUALLY ($million)		**116.2**	**121.6**	**141.7**
UNIT HARM - $ per car (7% @ 15yrs)		**$116.00**	**$121.40**	**$141.40**
UNIT HARM - $ per car (5% @ 25yrs)		**$145.60**	**$152.40**	**$177.50**

Harmonised ECE 95

An alternative to the hybrid standard proposal outlined in this paper that might be a first step towards implementing the full hybrid proposal would be a modified ECE 95 regulation that included a rear seat EuroSID dummy. While not providing all the benefits expected with the hybrid standard, it would be a compromise over the two existing standards that might be acceptable to both regulation authorities.

It is difficult to know what additional benefits would accrue to the modified ECE 95 standard as limited current test results would suggest that most current cars would meet this requirement (see Ohmae, Sakurai, Harigae & Watanabe, 1989). Nevertheless, with a rear seat dummy installed in a ECE 95 test, some global improvement in rear seat protection might be expected as manufacturers respond to this requirement. Assuming a 15% improvement was achieved by this global improvement, the annual benefits in Australia would be A$129 million with a unit Harm saving of between $128.60 and $161.40 per car.

Recommendations

It is recommended, therefore, that the Federal Office of Road Safety take a lead in promoting the introduction of an international hybrid standard similar to that outlined by Seyer and Fildes (1996) by:

1. continuing to participate in international harmonisation and European Working Party meetings to gain international agreement for a single side impact regulation;
2. seeking to become involved in future research and discussions aimed at developing and improving further the proposed hybrid side impact standard;
3. examining the feasibility of Australia, Canada and possibly Japan working towards introducing the hybrid standard in these countries as a model for others to follow;
4. holding discussions with consumers groups such as the Australian New Car Assessment Program to investigate the possibility of the hybrid standard becoming the accepted side impact performance test in their evaluations; and
5. actively participate in other research effort aimed at reducing injuries in side impact crashes beyond regulation levels by developing injury reduction as a design criterion for new passenger cars manufactured and sold in this country.

Chapter 1 Introduction

In 1995, the Monash University Accident Research Centre (MUARC) completed a report for the Federal Office of Road Safety (FORS) on the likely societal benefits if Australia was to adopt either of the two existing international side impact standards FMVSS 214 and ECE Reg 95 (Fildes, Digges, Carr, Dyte & Vulcan 1995). The findings from this study showed that there would be benefits in reduced community Harm if either standard was adopted in this country, but that these benefits would not necessarily be optimal. A recommendation was included "*that further research be undertaken to examine whether a hybrid standard would lead to further improvements in occupant protection*".

Since then, the Federal Office of Road Safety have conducted a series of crash tests to determine the performance differences between the two existing standards and a hybrid combination of the two for a popular Australian passenger car and these results are due to be released later this year. Given that there were marked differences observed in structural and dummy performance measures between the existing two standards and the hybrid combination, it is important to attempt to quantify these differences in terms of the likely associated reduction in Harm.

This report outlines the results of a study aimed at assessing the additional Harm benefits of the hybrid side impact standard using the performance results from the FORS series of crash tests and a similar methodology to that used in the previous Side Impact Regulation Benefit study for the Federal Office of Road Safety.

1.1 Project Objectives

The project objective specified for this study was "to estimate the reduction in community Harm for Australia from adoption of a hybrid side impact standard over those based on existing US and ECE regulations."

Benefits were to be expressed in terms of the likely additional benefit of adopting the Hybrid standard over either of the existing two international standards. The form of the hybrid standard was to be developed during the course of the project but essentially similar to that developed by FORS during their recent series of comparative tests.

1.2 The Harm Reduction Method

The study used the Harm reduction method to compute the potential benefits of the proposed hybrid side impact requirement. Harm refers to the cost of trauma and is the product of the frequency of injury and cost to the community.

MUARC were the first agency in Australia to adopt this method developed by Malliaris in the US for use in this country in a previous report to FORS (CR100) describing the potential benefits of a series of frontal crash measures. Originally, it was used to specify the total injury savings by the introduction of a particular safety measure. However, in conjunction with Dr. Kennerly Digges of Kennerly Digges and Associates, 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.

The Harm reduction method has been previously used by MUARC on behalf of FORS to estimate the feasibility of a range of safety measures (CR100), the benefits of side impact regulation (CR154), a dynamic offset regulation (CR165) and head injury countermeasures (CR160).

The approach enables test and/or crash data findings, published in the road safety literature, to be incorporated in the calculations, thereby reducing the amount of guess-work normally required in calculations such as these. Where no published figures were available, however, the use the consensus view of a panel of experts in arriving at these body region and restraint condition savings was necessary. The amount of published data is normally a function of the attention a particular measure has received by the research community as well as its newness. As noted earlier, there has not been much published data on side impact improvements using either standard and so heavy reliance was made on test data figures available and expert panel assessments for computing the likely injury savings for the standard.

1.3 proposed hybrid standard

The Federal Office of Road Safety have been working towards developing a hybrid side impact standard proposal, based on a crash test program undertaken at a crash test facility in Melbourne, Australia. The current FORS proposal was outlined in Seyer & Fildes (1996) which can be summarised as containing the following features of the two existing side impact standards in Europe and the United States of America, namely:

- the FMVSS 214 crabbed movable barrier;
- the ECE R95 deformable barrier face;
- impact geometry as in FMVSS 214;

- BioSID dummies in the front and rear outboard seating positions; and
- ECE R95 injury criteria to the degree to which BioSID is capable of measuring.

Table 1.1 shows the proposed hybrid side impact standard proposal as outlined in Seyer and Fildes (1996) and how it compares with the existing two dynamic side impact regulations.

***Table 1.1** - Comparison of US and ECE Side Impact Standards with Hybrid Proposal*

Test Feature	FMVSS 214	ECE Reg 95	Hybrid
Barrier width	1676mm	1500mm	1676mm (1500 face)
Barrier weight	1365kg	950kg	1365kg
Barrier face	stiff honeycomb	Form or honeycomb	Foam or honeycomb
Ground clearance	279mm	300mm	279mm
Crash direction	crabbed at 27deg	90deg, perpendicular	crabbed at 27deg
Barrier speed	54km/h	50km/h	54km/h
Dummy placement	front & rear near-side	front only near-side	front & rear near-side
Dummy type	SID	EuroSID	BioSID
Chest injury criteria	TTI - 85-90g	60mm deflection	60mm deflection
Pelvic injury criteria	130g accelerometer	15kn load cell	15kn load cell
Head injury criteria	none	150g	1000HPC, 150g
Abdominal criteria	none	5kn (39mm below)	5kn

1.4 FORS Crash Test Program

A small crash test program was carried out by Autoliv, Melbourne, during 1996 and 1997 for the Federal Office of Road Safety in Australia to demonstrate the likely performance improvements of the hybrid standard over either of the two existing standards, FMVSS 214 or ECE Reg 95. Four tests were conducted on current model Ford Falcons involving:

- a std. FMVSS 214 test with crabbed movable barrier (1365kg) 2-SID test dummies in front and rear near-side positions, US homogeneous barrier face with protruding bumper and an impact speed of 54km/h;
- a std. ECE Reg 95 test involving a 90deg moving barrier (950kg), 1-EuroSID test dummy in front near-side position, 6-section aluminium honeycomb composite barrier face at 300mm height, and an impact speed of 50km/h;
- a hybrid test outlined above: and
- a 90deg perpendicular car-to-car side impact involving 2-Ford Falcons impacting the same region as specified by the US test at a speed of 54km/h.

The main results from the crash test program are summarised below.

1.4.1 Dummy Test Data

The comparative results of the dummy readings for all four tests are shown in Table 1.2. For the driver, TTI was minimum with the SID dummy (75%) compared to BioSID (89% and 104%) but all values were approximately equal to or below the critical value. Pelvic Gs were minimum for BioSID in the hybrid configuration (34%) whereas the values were approximately equal in the car-to-car and 214 test (73% and 71% resp.). Other dummy measures for the driver were only available for the EuroSID dummy in the ECE Reg 95 test configuration (BioSID figures were not available at this time but would be soon). These results show that they were all below acceptable criteria. Of special note, Head Protection Criteria or HIC was only 10% of that allowed while Relative Displacement Criteria (RDC) or V*C approached the critical value.

For the rear passenger, the values were all considerably below those of the driver for each dummy and crash configuration. This suggested that both test configurations emphasised the front seating position but that the European 95 test was significantly less testing on the rear dummy than the US 214 test configuration.

It should be noted that the car tested was one known to meet FMVSS 214 criteria and this was obvious from these results. The rather high RDC (V*C) and Peak Abdominal Force values, however, would almost certainly mean that the car would have failed ECE Reg 95 compliance.

It was not possible at this time to compare BioSID with EuroSID performance because of lack of computed data. However, it appeared that BioSID generally tended to be a more sensitive and responsive measure (US manufacturers have reported that EuroSID has been observed to “bind” in tests in other than purely perpendicular crash directions; see Minutes of the Hybrid Side Impact Workshop in Appendix 1).

Table 1.2 *- Summary of dummy test data, FORS Hybrid test series*

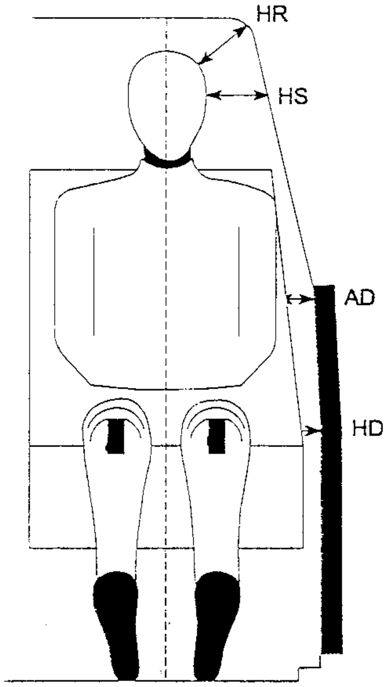
Dummy Measure	FMVSS 214 SID	ECE Reg 95 EuroSID	car-to-car BioSID	Hybrid test BioSID
Driver Seating Position				
TTI	75%	TBA	104%	89%
Pelvic G's	71%	51%	73%	56%
HPC	-	10%	TBA	15%
RDC	-	96%	70%	64%
V*C	-	102%	TBA	TBA
Peak pubic force	-	16%	84%	46%
Abd. peak force	-	88%	-	-
Rear Seating Position				
TTI	62%	-	51%	68%
Pelvic G's	71%	-	38%	34%
HPC	-	-	TBA	13%
RDC	-	-	25%	70%
V*C	-	-	TBA	TBA
Peak pubic force	-	-	116%	58%
Abd. peak force	-	-	-	-

Values are the percentages observed relative to the standard criteria for each regulation (hybrid relative to ECE Reg 95)

The hybrid standard used the European barrier face structure and material which was felt to be much softer and more realistic that the harder US barrier and this is reflected in these results. However, using the narrower European face on the wider 214 barrier meant that there was practically no force applied to rear structure in the hybrid test which was less desirable for ensuring rear seat occupant protection. The aluminium honeycomb material has been generally acknowledged as the preferred ECE R95 face material.

1.4.2 Side Intrusion Data

Figure 1.1 shows the summary of the side intrusion results obtained for the FORS series of crash tests. For the driver, the maximum intrusion occurred in the car-to-car crash configuration, especially the HS and HD head space intrusions, although the 214 test generally produced greater intrusions than either 95 or the hybrid test. This is probably a function of the harder barrier face used in the 214 test. For the rear passenger, the intrusion values were still quite considerable and interestingly, generally greater for the barriers than the car-to-car tests, especially the hybrid configuration. The hybrid test, in this position, seemed to be more like the FMVSS 214 than the ECE Reg 95 test and seemed to show that the crabbed barrier was a more severe test for rear seat occupants.



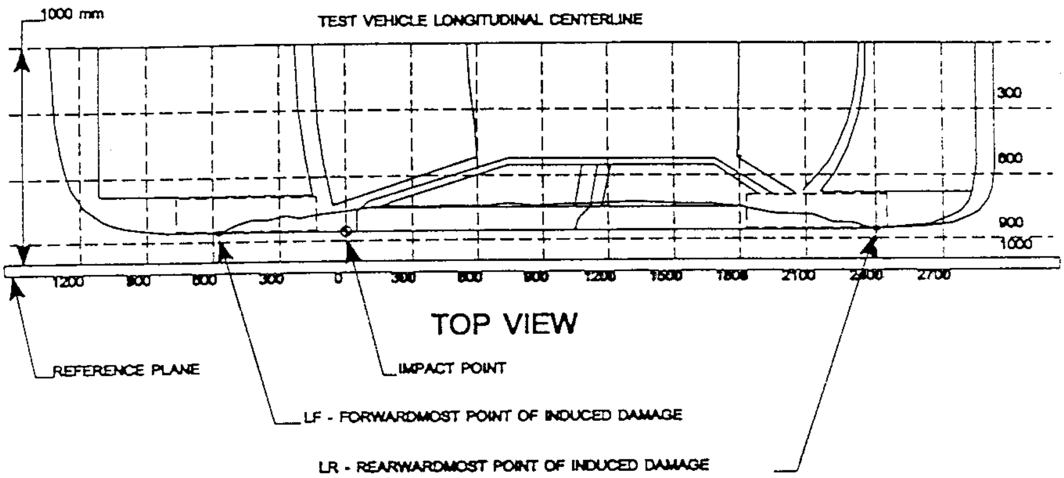
Driver Position

MEASUREMENT POSITION	CAR-TO-CAR Biosid	FMVSS214 Sid	ECE95 Eurosid	HYBRID Biosid
HR	100mm	180mm	79mm	104mm
HS	223mm	204mm	86mm	137mm
AD	106mm	150mm	84mm	109mm
HD	161mm	175mm	176mm	146mm

Rear Passenger

MEASUREMENT POSITION	CAR-TO-CAR Biosid	FMVSS214 Sid	ECE95 Eurosid	HYBRID Biosid
HR	100mm	158mm	nil	98mm
HS	139mm	195mm	nil	146mm
AD	92mm	128mm	nil	123mm
HD	157mm	180mm	nil	203mm

Figure 1.1 *Summary of intrusion data from the Hybrid side impact series of crash tests in Seyer and Fildes (1996) use0d in this benefit analysis.*



STATIC CRUSH (mm)	CAR-TO-CAR Biosid	FMVSS214 Sid	ECE95 Eurosid	HYBRID Biosid
LF=-300mm		0	0	0
300mm		312mm (2)	121mm (2)	60mm (2)
900mm		391mm (2)	330mm (2)	282mm (2)
1500mm		439mm (2)	299mm (3)	352mm (3)
2100mm		85mm (4)	77mm (3)	271mm (3)
LR=2400mm		0	0	0

Level 1 = side sill panel
Level 2 = front H-point
Level 3 = mid-door
Level 4 = window sill
Level 5 = window top

Figure 1.2 *Maximum crush profile measured in the Hybrid series of side impact crash tests in Seyer and Fildes (1996) and used in this benefit analysis.*

A cursory inspection of the series of cases in the Crashed Vehicle File at MUARC which contained over 500 representative crashes in Metropolitan Melbourne and rural Victoria was also undertaken to demonstrate which of the two main intrusion patterns from the 214 and the 95 tests most represented “typical” crash patterns. These results, though, were equivocal; the 214 pattern appeared to be more like a side impact crash with both cars moving, while the 95 configuration more like an oblique crash. Moreover, the frequency of these two crash types was approximately equal among these data.

1.4.3 Maximum Static Crush Profile

The maximum static crush profile results in Figure 1.2 show that the FMVSS 214 test generally resulted in greater intrusion that either the ECE Reg 95 of the Hybrid tests. The maximum crush profile was higher for the Hybrid (mid-door) than either of the other two tests(front H-point) and in roughly the same longitudinal position for the hybrid and 214 tests and further towards the rear of the car than the 95 test. Interestingly, the maximum amount of crush at the 2100mm position (near the C-pillar) was significantly greater for the hybrid than either of the others (270mm c.f. 77 and 85mm) suggesting that it was a more severe test for rear seat occupants.

1.5 Transport Canada test resultS

Transport Canada also commenced a comparative side impact crash test program in 1988 to throw light on what Canada should do for side impact regulation (Dalmotas, 1994). The primary objective of these tests was to provide comparative results on the likely outcome if Canada was to choose either one of them, as shown in Table 1.3.

Table 1.3 *- Summary of Canadian Activities Addressing Side Impact Protection*

Test Program	Objectives
1988-1990 Test Program	
8 - car to car tests 14 - MDB to car tests SID, PP EuroSID, BioSID	1. Generate comparative test data using US and European testing protocols 2. Assess appropriateness of proposed barriers 3. Quantify dummy-related differences
1991-1992 Test Program	
7 Ford Escort tests FMVSS 214 protocol SID, EuroSID, BioSID	1. Generate comparative test data using different test dummies. 2. Quantify sensitivity of results for different arm positions 3. Countermeasure development and evaluation.
1992-1993 Test Program	
4 - production cars 4 x 2 paired test matrix 1 - modified car test FMVSS 214 protocol EuroSID, BioSID dummies	1. Joint test program with NHTSA addressing advanced dummy designs and alternative injury criteria. 2. Generate comparative test data using EuroSID 1 and BioSID test dummies. 3. To assess the merits of FMVSS 214 alone for possible introduction to Canada.

In the first phase, 22 tests were conducted (14 involving MDBs) to FMVSS 214 and ECE Reg 95. The comparative barrier results showed that not only were they physically different but they provided markedly different deformation patterns and hence different effects on the dummies especially in the thoracic region. They concluded that of the two deformation patterns produced by these barriers, 214 more closely mirrored those they saw in vehicle to vehicle tests that they did to calibrate the barriers.

The second phase of TCs test program was to evaluate the three different dummies that were available at the time; the production SID dummy, the pre-production prototype EuroSID that was being developed in Europe, and a newly designed BioSID. Eighty-three Escorts were used in this phase of the research as well as some collaborative work with NHTSA. The initial findings are shown in Attachment 4. There was not much difference in TTI chest responses between the three dummies and re-test reliability was around 10% depending on seating position and barrier type. None of the vehicles tested showed particularly good results for abdominal loading and V*C using BioSID and there was considerable variation between models. One negative aspect of the results for the SID dummy was its lack of abdominal measurement and the fact that loading the abdomen actually caused TTI to reduce.

From demonstration studies carried out at TC, it was possible to show that with counter-measures aimed at reducing thoracic loads, TTI and pelvic acceleration could be reduced and abdomen criteria (as specified by the European std) could also be reduced. From these tests, it was apparent that BioSID was the only dummy able to demonstrate reliably where the load paths are hence able to help guide these improvements.

1.5 Transport Canada's Hybrid Proposal

From these results, Transport Canada also proposed a hybrid side impact test based on the best aspect of both procedures (see Table 1.4 below). It was argued that the crabbed barrier was preferred as it seemed to accurately represent real world crash types and realistic simulation of side impacts and would lead to more preferred countermeasures. The heavier weight and size of the US barrier, too, seemed to suit the Canadian vehicle fleet more than the European barrier. Unfortunately, Transport Canada tests did not systematically evaluate barrier faces. The BioSID was the preferred dummy, given its superior chest and abdomen performance and the fact that it promotes directionally correct design. The European test criteria also seem to be superior for minimising injury.

1.6 Outline of the STUDY

This benefit study was intended to build on the successful approach adopted in the previous side impact benefit study, CR154. The same research team was assembled for this study and the same database and approach for estimating likely injuries was used to ensure a degree of consistency in the findings between the previous study and these findings.

Some 3 years have elapsed since the previous side impact benefit study was undertaken and additional knowledge and data have become available since then to permit the likely injury savings of the two existing studies to be re-defined. Thus, it was deemed important to re-visit the previous side impact benefit results and re-adjust the earlier calculations in line with the more recent findings.

Table 1.4 *- Canadian Hybrid Side Impact Test Proposal (Dalmotas, 1996)*

Aspect	Item	Justification
Testing Protocol	FMVSS 214	Most realistic of car-to-car crashes
MDB Hardware	US Barrier	Most realistic of Canadian cars
		Most realistic lower load paths
		More desirable load path timings
ATD Hardware	GM BioSID	Most biofidelic
		Comprehensive assessment capabilities
		Relevant Injury criteria (defl'n, V*C, force)
		Promotes directionally-correct designs
		Reasonably "foolproof"
Performance Requirements	Chest	Deflection, V*C
	Abdomen	Deflection, V*C
	Pelvis	Force

Chapter 2 Harm Method & Previous Side Impact Benefits

Australia is soon to embrace a new Australian Design Rule ADR 72/00 which calls for all new passenger cars sold in Australia to comply with either the US dynamic side impact regulation FMVSS 214 or the European ECE Regulation 95. A previous report by FORS CR154 (Fildes et al 1995) reported that both of these standards would likely be cost-beneficial, although the authors argued that a combination or hybrid of these two standards would be even more preferred. This Chapter presents an analysis undertaken of the likely community savings in reduced trauma if Australia was to adopt the Hybrid side impact regulation, as outlined in the previous Chapter. The analysis used the ***Harm Reduction*** method developed previously by the Monash University Accident Research Centre in conjunction with Kennerly Digges and previously reported in Monash University Accident Research Centre (1992), Fildes Digges, Carr, Dyte & Vulcan (1995) and other reports.

2.1 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 Accident Sampling System (NASS) 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 this study represented a significant international advancement in the ability to assess injury mitigation effects of vehicle countermeasures.

2.1.1 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.

2.1.2 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.

2.1.3 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 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.

2.1.4 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 which 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 et al (1991) 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.

2.1.5 Relevance of 1991 Figures

It would have been preferable if recent injury patterns and costs were available for this analysis, given the sizeable reductions that have occurred in the road toll since 1991 and 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.

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 INJURED	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

From MUARC 1992

2.1.6 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 Harm savings of the hybrid side impact regulation. 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 side impact crashes, 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 the hybrid standard was to be introduced. This process is explained further in the next section.

2.2 PREVIOUS SIDE IMPACT REGULATION benefits

In computing the previous side impact benefits, a number of assumptions were made by an international panel of research, vehicle manufacture and government specialists of the expected injury reduction outcomes associated with these two standards. These assumptions formed the basis for calculating the Harm benefits of the two standards.

In arriving at these assumptions, the panel called upon all available published information on the likely body region injury outcome associated with the new standards from available international sources. The sources of test data available on the injury savings for a dynamic side impact standard came primarily from the USA, involving estimates of the effects of FMVSS 214. Other specialised research studies also provided more recent details on the effects of this regulation as well as some comparison test results involving both standard procedures. It was noted however, that the expected benefits of FMVSS 214 outlined in the Notice of Proposed Rulemaking (NHTSA 1990) have not been universally accepted, either outside or within the USA and therefore, these estimates may have been an over-statement. However, they were the only sizeable test database available at the time and provided some objective basis for estimating injury reductions.

2.2.1 Injury Reduction Assumptions

A total of 17 assumptions regarding the injury reduction potential of the two standards if applied in Australia were made by the original expert panel drawn together in this earlier study and these are listed below:

1: The two standards require a test at a crash severity of around 27km/h delta-V and will provide benefits at crash speeds up to 64km/h. No benefits were assumed above this speed.

2: Near-side occupants who sustain AIS 5 or 6 fatal head injuries were excluded from any benefit from the standards. Reductions in chest injuries to occupants who sustain a non-fatal head injury were included.

3: The benefits would apply to car-to-car and car-to-fixed-object in side impact collisions

4: Benefits applied to occupants injured in both compartment and non-compartment crashes.

5: The benefits apply to hard thorax (chest including liver, kidney and the spleen), pelvic, femur, shoulder, upper extremity, head and face injuries caused by contact with the door panel, hardware or armrest.

6: The injury risk curves for TTI and V*C apply to the range of impact speeds for side crashes at severities less than 64km/h for injuries of AIS 3 or greater.

7: The effectiveness of an incremental reduction in TTI on chest injuries from interior door contacts to near-side occupants was assumed to be equivalent to a reduction in crash speed as specified in CR 154.

8: The average TTI for Australian cars was estimated by comparing the hard thorax injury distribution for near-side occupants in Australian crashes with those in the NCSS and adjusting MUARC values to include more low severity crash

9: Injury reductions for the hard thorax in Australia was based on an Injury Assessment Function between delta-V and probability of an AIS3+ injury that was dervied from recently published US data.

10: A relevance factor of 0.45 was expected for AIS 3 to 6 hard thorax injuries over the crash severity range of 0 to 64 km/h. For the more minor AIS 1 and 2 injuries, a relevance factor of 0.90 was expected, based on some NHTSA evidence which suggested that low level injuries were twice as frequent as the more severe ones.

11: The reduction in hard thorax injuries by the use of SID and TTI measures was equivalent to an AIS 2 shift over the crash severity range 0-64km/h. The hard thorax injury reductions using EuroSID and V*C would be a higher AIS 3 shift across the same delta-V range.

12: The pelvic fracture relationship published by Haffner was used to derive the risk of pelvic injury for Australian vehicles. Injury reductions of AIS 1 were expected for a relevant percentage of side impact crashes.

13: The relevance factors for abdominal injuries were the same as those expected for the hard thorax. However, an overall injury reduction of AIS 1 was expected for SID and AIS 3 for EuroSID, assuming abdominal injury criteria is applied when using this test dummy.
14: All head injuries in side impacts from contact with the door panel were reduced by 2 AIS and face injuries by 1 AIS over the range 0 to 64km/h. For EuroSID, an additional benefit of AIS 2 was assumed to apply to head contacts with the side rails.
15: All upper extremity, shoulder and lower extremity injuries in side impacts from contact with the door panel and fittings were reduced by AIS 1 over the crash severity range.
16: The side impact standards would eliminate all injuries with exterior contacts for far-side occupants ejected through the far-side door over a 0-40km/h severity range.
17: Relevance figure for hard thorax to door panel contacts was the ratio of those injured at each AIS level at delta-Vs below 64 km/h to all injuries at each AIS for which delta-V is known. Similar relevance figures can be for other body regions where sufficient data exists.

2.2.2 Regulation Benefits

From these assumptions, it was then possible to compute the likely Harm saved for the two standards using the Harm distribution described earlier. Table 2.2 shows the summary of Harm benefits initially calculated in CR 154 assuming Australian vehicles were required to meet either the current United States FMVSS 214 side impact regulation or European ECE Regulation 95.

Table 2.2 *Summary of Harm Benefits (from CR 154, Fildes et al 1995)*

BODY REGION		*USA STANDARD FMVSS 214*	*EUROPEAN STANDARD ECE Reg 95*
Head	**near-side**	**9.7**	***10.8***
	far-side	***17.7***	***18.1***
Face	**near-side**	***0.7***	***0.8***
	far-side	***0.1***	***0.1***
Hard Thorax	**near-side**	***54.4***	***61.7***
	far-side	***3.2***	***3.6***
Abdomen	**near-side**	***6.5***	***8.4***
	far-side	***0.04***	***0.04***
Pelvis	**near-side**	***4.4***	***4.4***
	far-side	***0.1***	***0.1***
Upper limb & shoulder	**near-side**	***17.0***	***17.0***
	far-side	***3.6***	***3.6***
Lower limbs	**near-side**	***17.6***	***17.6***
	far-side	***1.2***	***1.2***
Near-side Harm saved annually ($million)		*110.3*	*120.7*
Far-side Harm saved annually ($million)		*25.8*	*26.7*

Total Harm saved annually ($million)	*136.1*	*147.4*
Unit Harm saved (7% discount method)	*$147.20*	*$159.40*

Chapter 3. Injury Reductions for the Hybrid Standard

The next phase of the hybrid side impact benefit study involved the assessment of what the likely injury savings would be if all new passenger cars sold in Australia were expected to meet this revised side impact proposal. This was to be considered in the light of the present ADR 72/00 which call for all new passenger cars to comply with either FMVSS 214 or ECE Reg 95. In other words, what the incremental benefit would be for Australia if they were to require manufacturers to meet this proposed hybrid standard beyond ADR 72/00.

3.1 One-Day Workshop

As before, there was little data available to make an objective assessment of injury savings for the hybrid side impact proposal beyond the test data reported earlier in Chapter 1. Thus, it was necessary once again to call upon a "*panel of experts*" to assist in making these assessments.

A meeting was held in Washington DC in May 1997 involving government, industry and research specialists in side impact design and testing to consider and agree on the likely body region injury savings. The panel discussion was chaired by Keith Seyer of FORS and consisted of Dainius Dalmotas of Transport Canada, , Tom Hollowell, Jim Hackney and Randa Radwan of NHTSA, Ken Digges of Kennerly Digges and Associates, Pryia Prasad of Ford, Guy Nusholtz of Chrysler, Ingo Kallina of Mercedes-Benz, David Zuby of the Insurance Institute for Highway Safety, and Brian Fildes of MUARC. Minutes from this meeting have been attached as Appendix 1 to this report.

3.2 Injury Mitigation Assumptions

The expert panel was asked to review each of the previous assumptions made in the earlier side impact benefit study (Fildes et al 1995) and decide if these assumptions needed to be varied in the light of the hybrid proposal. In addition, they were asked to consider whether the previous assumptions still held for the earlier FMVSS 214 and ECE Reg 95 benefits. From this review, a number of new and revised assumptions were specified for the likely injury mitigation of the hybrid standard and these are detailed below.

3.2.1 Assumption 1 - Crash Severity

Assumption 1 in CR 154 states that:

"The standard which requires a test at a crash severity of around 27km/h will provide benefits at crash speeds up to 64km/h. No benefits are assumed above this speed."

As there was no planned change in test speed for the hybrid side impact standard over the existing standards, no additional benefits were warranted. Hence, this assumption still holds for both the existing and the proposed hybrid standard.

3.2.2 Assumption 2 - Fatal Head Injuries

Assumption 2 in CR 154 states that:
"Near-side occupants who sustain AIS 5 or 6 fatal head injuries are excluded from any benefit from the standards. Reductions in chest injuries to occupants who sustain a non-fatal head injury are included."

It was felt that the hybrid standard would not make any change in severe injury outcome for those fatally injured, thus, no change in benefits is warranted.

3.2.3 Assumption 3 - Cars and Fixed Objects

Assumption 3 in CR 154 states that:
"The benefits will apply equally to both car-to-car and car-to fixed-objects in side impact collisions."
There was no evidence or reason to vary this assumption based on the level of current knowledge, therefore this assumption still holds.

3.2.4 Assumption 4 - Compartment & Non-Compartment Strikes

Assumption 4 in CR 154 states that:
"The benefits will apply equally to occupants involved in both non-compartment and compartment struck side impacts."
The panel felt that there is not likely to be any substantial difference in injury contacts for the hybrid standard over either of the two existing ones therefore no change in this assumption was warranted.

3.2.5 Assumption 5 - Body Region Benefits

Assumption 5 in CR 154 noted that:
"The benefits will apply to hard thorax (chest including liver, kidney, and the spleen), pelvis, femur, shoulder, upper extremity, head and face injuries caused by contact with the door panel, hardware or armrest."
There was consensus among the panel that the hybrid standard would not lead to any substantial differences in body region benefits over either of the two existing ones. However, there was some concern that any benefit to the internal organs (liver, kidney and spleen) would be dependent upon which dummy was included in the test.
TTI as an injury measure was of some concern. It was noted that the peak load timing often differed for lower spine and rib, yet in deriving TTI, it is necessary to sum these events which masks to some degree what is really happening. Moreover, following TTI alone would lead designers to do things which seemed counter-intuitive in terms of protecting occupants from injury. It was pointed out that TTI was the only measure that had been correlated with cadaver data.
There was also agreement that V*C was also not a very sensitive measure as it rarely failed threshold criteria. Moreover, it was claimed that V*C was deficient in that it relied on only one signal rather than two independent signals. This helps to explain why V*C measures are also extremely variable. This might be overcome to some degree by examining the signals from the displacement transducers and the accelerometer separately.
Thus, it was agreed that the injury reductions previously agreed to were probably somewhat over-stated especially for SID and there was a need to differentiate the benefits to these internal organs depending on which dummy was associated with the procedure. These are discussed further in assumptions 9 and 10 further on.

3.2.6 Assumption 6 - Head & Face Injuries Among Survivors

Assumption 14 in CR 154 stated that:
"All head injuries (to survivors) in side impacts from contact with the door panel are reduced by 2 AIS and face injuries by 1 AIS over the crash severity range of 0-64km/h. For EuroSID, an additional benefit of 2 AIS applies for head contacts with the side rails."
The panel felt that FMVSS 214 has not resulted in the extent of door padding expected. It is possible that some manufacturers have chosen countermeasures permitted by the SID dummy which do not provide injury reductions to the abdominal region. Moreover, head and face impacts to the unprotected region of the door would not be mitigated as a consequence of the standard. Thus, the initial benefits claimed for head and face injures among surviving occupants in side impact crashes were too generous. Therefore, all head and face injuries among survivors in side impacts from contact with the door panel should be reduced by 1 AIS over the crash severity range of 0-64km/h.

For EuroSID and BioSID, improvements from the inclusion of abdominal injury measurement are expected to reduce injuries from head and face contacts with the door panels also. The original assumption of a 2 AIS reduction for head and face contacts with the door panel is retained.

3.2.7 Assumption 7 - Dummy Chest Measures and Crash Severity

Assumptions 6 through to 9 relate to expected injury reductions to the chest from the two side impact standards and can be summarised as:

*An incremental reduction in TTI or V*C on injuries to the hard thorax from contacts with the door for near-side occupants can be expressed as a change in crash severity."*

Eppinger and Winnicki (1997) recently argued that it is possible to express injury reductions predicted from test dummy results in terms of a reduction in crash severity, thus the previous set of assumptions still holds.

3.2.8 Assumption 8 - Relevance of Hard Thorax Injuries

Assumption 10 in CR154 states that:

"45% of AIS 3-6 and 90% of AIS 1-2 hard thorax injuries over the crash severity range of 0 to 64km/h are expected to be affected by a side impact standard, based on NHTSA pre-standard crash tests."

New Australian test data show that V*C is a more critical parameter than TTI and that this is expected to lead to additional countermeasures to protect the abdomen. For Hard Thorax injuries, higher relevance figures may be warranted for EuroSID and BioSID measures because of the inclusion of rib deflection and abdominal measures. The panel concluded that since the SID dummy does not measure abdominal injury, there is no protection against injury induced by the arm rest. An arm rest which penetrates the SID abdomen without detection might cause abdominal injury to the liver. In addition, it might cause chest injuries to smaller statue people. Thus, they recommended that organ injuries which could be induced by aggressive arm injuries be separated from the hard thorax. These injuries would be less susceptible to injury reduction by the SID dummy than previously assumed. Therefore, the Harm from the liver, spleen and kidney needed to be included as a separate category of "Organ" from the hard thorax. In addition, the heart was also separated due to some concern that the present injury criteria does not adequately measure the potential for heart injury. The original assumptions for the hard thorax could be applied to all chest injury Harm not associated with the heart, liver, spleen and kidneys. The changes for the organs are discussed further in assumption 15.

3.2.9 Assumption 9 - Chest Injury Reductions

Assumption 11 in CR154 argued that:

*"A reduction of AIS 2 in chest injuries is expected by the use of SID and TTI over the crash severity range and an AIS 3 reduction is expected by the use of EuroSID and V*C measures."*

No change in this assumption was required with regard to applicable chest injuries. However, as noted above, the injury Harm to the heart, liver, spleen and kidney was excluded from this assumption.

3.2.10 Assumption 10 - Abdominal Injury Reductions

Assumption 13 in CR154 states that:

*"An overall injury reduction of AIS 1 is expected for TTI and SID measures and AIS 3 for V*C from EuroSID across the relevant crash severity range."*

based on the panel's recognition that the SID dummy does not measure abdominal injury and that arm rests may in fact induce abdominal injuries, the original abdominal benefit previously awarded to FMVSS 214 was removed.

3.2.11 Assumption 11 - Pelvic Injury Reductions

Assumption 12 in CR154 claimed that:

"The pelvic fracture and load relationship published by Haffner (1985) is valid and relevant for Australia. An AIS 1 Injury reduction is expected for all pelvic injuries across the crash severity range."

As no new data are available to justify any change over the previous procedure, the hybrid standard will adopt the benefits previously allowed.

3.2.12 Assumption 12 - Upper Extremity Injury Reductions

In assumption 15 in CR154 , it was argued that:

"Only upper extremity injuries from contact with the door panel or hardware at or below the crash severity range are relevant. As no test data were available on the likely reductions in contacts, a modest AIS 1 injury reduction is assumed."

Again, there were no recent data available to justify any change over the previous procedure and it was agreed that the hybrid standard will adopt the benefits previously allowed.

3.2.13 Assumption 13 - Far-Side Occupants & Ejections

Assumption 16 in CR154 stated that:

"A dynamic side impact standard will result in the elimination of all injuries with exterior contacts for far-side occupants, ejected through the far-side door over the severity range of 0-40km/h."

The benefit was based on the standard preventing door openings up to the test velocity but not above this figure. No new data are available to confirm or deny this previous assumptions.

3.2.14 Assumption 14 - Risk of Injury to the Hard Thorax

Assumption 6 in CR154 states that:

*"The injury risk curves for TTI and V*C apply to the range of impact speeds for side crashes at severities less than 64km/h for injuries of AIS 3 or greater."*

No new data are available to justify any change over the previous procedure. The hybrid standard will adopt the benefits previously allowed for ECE 95.

3.2.15 Assumption 15 - Injury to the Organs & Heart

In the previous benefit analysis in CR154, the Harm and Harm reductions for the liver, spleen, kidneys and heart was included with the Hard Thorax. However, the expert panel argued that this was no longer appropriate as recent evidence had shown that each of the three test dummies measured injury risk with varying degrees of reliability and biofidelity. Consequently, the better dummies should induce countermeasures which good not only for dummies but also for people. This difference needs to be reflected by a higher relevance for liver, spleen and kidney Harm for the better dummies (ie; BioSID and EuroSID) and a lower one for the less accurate SID dummy.

In addition, heart Harm is apparent in many of the cases examined from case by case analysis which was not apparent in the cadaver tests used in the development of SID and EuroSID. This is clearly a problem for all the tests and one that deserves additional attention in future research. For this analysis, though, it will be assumed that there is some heart benefits approximating 25% of that relevant to the hard thorax for SID and EuroSID but 50% for BioSID given its superior injury criteria and test performance.

3.2.16 Assumption 16 - Rear Seat Occupants

The previous benefit analysis did not differentiate between front and rear seat occupant Harm but simply lumped these together for near- and far-side occupants. However, the European test procedure does not include a rear seat dummy and the barrier width and crash configuration ensure that most of the impact is confined to the front compartment. This was apparent when examining the photographs from the ECE Reg 95 test in the FORS Crash Test Program. By contrast, the FMVSS 214 test photographs revealed a distinct kink in the rear door. The panel agreed that this was a common feature in most 214 tests and with the rear seat dummy, would ensure that manufacturers include rear seat countermeasures to comply with this test.

Thus, no rear seat Harm benefit should be awarded to the ECE Reg 95 standard and similar benefits would apply to front and rear seat occupants in both FMVSS 214 and the proposed Hybrid test.

3.3 calculating individual Vehicle Savings

The annual Harm saved by the requirement for manufacturers to meet these side impact regulations 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.

3.3.1 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 of course that the crashworthiness history of the vehicle fleet will not alter dramatically; an assumption that has some credibility based on recent evidence (Cameron, Newstead and others, 1994) if confined to the last 15 years.

The method, fully detailed Appendix B, 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:

$$\frac{H_3}{H} = \frac{F_3}{F} \quad \text{or} \quad H_3 = \frac{F_3}{F} \times H$$

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 for the new 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.

3.3.2 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 by the side impact standards 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.

3.3.3 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. Tables B.1 and B.2 in Appendix B show 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 over both a 15 and 25 year life period. Based on the results in Appendix B, the multipliers used for assessing the unit Harm benefits of the three side impact standards were:

	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$.

3.4 Benefit Calculations

All these assumptions were converted into relevance figures for the three side impact standards. The previous side impact Harm distribution was modified according to the changes in Hard Thorax Harm outlined above and a Harm Reduction analysis performed on these data.

The previous Harm Reduction analysis in CR154 was adapted in line to reflect these new assumptions and a second analysis was carried out to reflect these new criteria. As the previous FMVSS 214 and ECE Reg 95 benefits needed to be modified in line with the more recent data that are available, revised figures for these standards were also prepared. Tables 3.1 to 3.3 show the summary of body region benefits for each of the three standards and the resultant Total harm saved annually and Unit Harm per vehicle, based on a 5% and 7% discount rates for two different fleet life periods, 15 years and 25 years.

The derivation of the relevance figures used for each body region and the overall results will be discussed separately below.

3.4.1 FMVSS 214 Benefits

As a result of the revised assumptions made by the expert panel, there were a number of revisions made to the previous benefits calculated for the FMVSS 214 standard. Table 3.1 shows the results of the revised FMVSS 214 benefit calculations which included:

- head and face benefits reduced from a 2-AIS shift to a 1-AIS shift, representing a 7% reduction in Harm saved over the previous figures;
- there were no abdominal benefits allowed for at all for this standard for reasons detailed earlier;
- Only 25% of the previous Harm benefit to the liver, spleen, kidneys and heart for near-side occupants was allowed given the lack of an abdominal measure in SID;

With these modifications, the previous Total Annual Harm benefit of A$136 million was reduced to A$116 million, a 14.7% reduction in Harm saved from what was previously estimated. Even so, however, with an estimated installation Cost of A$100 per car, this standard would still be cost-beneficial (BCR=1.16-1.45).

Table 3.1 *- Summary of Harm Benefits for FMVSS 214*

Body Region		Total Harm CR154 $mil	CR154 Harm Benefit $mil	Revised Relevance	Revised Benefit $mil
Head	near-side	203.7	9.7	0.9	8.7
	far-side	234.4	17.7	0.91	16.1
Face	near-side	19.5	0.7	0.9	0.6
	far-side	14.3	0.1	0.91	0.1
Abdomen	near-side	10.4	6.5	0.00	0.0
	far-side	6.3	0.0	0.00	0.0
Pelvis	near-side	25.7	4.4	1.00	4.4
	far-side	3.1	0.1	1.00	0.1
Upper Limbs	near-side	46.8	17.0	1.00	17.0
	far-side	22.7	3.6	1.00	3.6
Lower Limbs	near-side	57.9	17.6	1.00	17.6
	far-side	22.2	1.2	1.00	1.2
Original Hard Thorax	near-side	165.7	54.4		
	far-side	41.2	3.2		
Front Thorax	near-side	118.0	38.8	1.00	38.8
	far-side	33.4	2.6	1.00	2.6
Front Organ	near-side	15.0	4.9	0.00	0.0
	far-side	4.2	0.3	1.00	0.3
Rear Thorax	near-side	13.6	4.5	1.00	4.5
	far-side	3.4	0.3	1.00	0.3
Rear Organ	near-side	2.1	0.2	0.00	0.0
	far-side	0.2	0.0	1.00	0.0
Heart	near-side	17.0	1.6	0.25	0.4
Near-Side Harm Saved Annually ($mil)			***110.3***		***92.0***
Far-Side Harm Saved Annually ($mil)			***25.8***		***24.2***
Total Side Harm Saved Annually ($mil)			***136.1***		***116.2***
Unit Harm per Car - 7% discount @ 15yr life			***135.8***		***116.0***
Unit Harm per Car - 7% discount @ 25yr life			***147.2***		***125.7***
Unit Harm per Car - 5% discount @ 15yr life			***153.4***		***131.0***
Unit Harm per Car - 5% discount @ 25yr life			***170.5***		***145.6***

3.4.2 ECE Reg 95 Benefits

Similarly, the ECE Regulation 95 benefits were also revised in light of the assumption changes recommended by the expert panel as shown in Table 3.2. Modifications to the benefits previously calculated for this standard included:

- no allowance at all for Harm reductions for rear seat occupants as the standard test does not include a rear seat dummy and the crash intrusion pattern would not facilitate rear seat countermeasures;
- abdominal Harm to near-side occupants reduced to 70% of the original benefits as EuroSID could still be fooled by aggressive arm rests. Thus, the resulting abdominal Harm relevance for ECE Reg 95 equates to 0.897 for no rear seat dummy times 0.7 which equals 0.626.
- Only 50% of the previous Harm benefit for the liver, kidney and spleen and 25% of the previous heart Harm benefit was included for reasons previously discussed.

As a result of these changes, the previous annual Harm saving of A$147 million reduces to A$122 million, which represents a 17% reduction in benefit over the previous figure. Again, however, this would still be cost-beneficial for a A$100 per car unit cost (BCR=1.21-1.52).

3.4.3 Hybrid Side Impact Proposal Benefits

This study was primarily interested in what the benefits would be if Australia was to adopt a hybrid side impact standard, consisting of the best features of both of the existing dynamic side impact regulations from the US and Europe. Using the assumptions derived by the expert panel, it is clear from Table 3.3 that there would be a significant reduction in side impact Harm over either of the two existing regulations. These comparisons are highlighted in Table 3.4 below.

Table 3.4 *- Comparison of the benefits of the hybrid side impact standard with FMVSS 214 and ECE Regulation 95.*

Benefit	Hybrid	ECE 95	FMVSS214
Annual Harm saved	$142 million	$122 million	$116 million
Minimum Unit Harm benefit per car	$141.40	$121.40	$116.00
Maximum Unit Harm benefit per car	$177.50	$152.40	$145.60

Figures quoted are in Australian dollars in 1995 prices

There are clear advantages in terms of Harm saved by the community if Australia was to adopt a hybrid side impact standard along the lines of that proposed by Seyer and Fildes (1996). An additional $20 million annually would accrue over the best that the existing standards can offer which represents an additional 0.6% reduction in vehicle occupant Harm each year in this country.

Table 3.2 *- Summary of Harm Benefits for ECE Reg 95*

Body Region		**Total Harm CR154 $mil**	**CR154 Harm Benefit $mil**	**Revised Relevance $mil**	**Revised Benefit $mil**
Head	near-side	203.7	10.8	0.90	9.7
	far-side	234.4	18.1	0.90	16.3
Face	near-side	19.5	0.8	0.90	0.7
	far-side	14.3	0.1	0.90	0.1
Abdomen	near-side	10.4	8.4	0.63	5.3
	far-side	6.3	0.0	0.63	0.0
Pelvis	near-side	25.7	4.4	0.90	3.9
	far-side	3.1	0.1	0.90	0.0
Upper Limbs	near-side	46.8	17.0	0.90	15.2
	far-side	22.7	3.6	0.90	3.2
Lower Limbs	near-side	57.9	17.6	0.90	15.8
	far-side	22.2	1.2	0.90	1.1
Original Hard Thorax	near-side	165.7	61.7		
	far-side	41.2	3.6		
Front Thorax	near-side	118.0	43.8	1.00	43.8
	far-side	33.4	2.9	1.00	2.9
Front Organ	near-side	15.0	5.6	0.50	2.8
	far-side	4.2	0.4	1.00	0.4
Rear Thorax	near-side	13.6	5.0	0.00	0.0
	far-side	3.4	0.3	0.00	0.0
Rear Organ	near-side	2.1	0.8	0.00	0.0
	far-side	0.2	0.0	0.00	0.0
Heart	near-side	17.0	1.6	0.25	0.4
Near-Side Harm Saved Annually ($mil)			***120.6***		***97.6***
Far-Side Harm Saved Annually ($mil)			***26.7***		***24.0***
Total Side Harm Saved Annually ($mil)			***147.4***		***121.6***
Unit Harm per Car - 7% discount @ 15yr life			***147.1***		***121.4***
Unit Harm per Car - 7% discount @ 25yr life			***159.4***		***131.6***
Unit Harm per Car - 5% discount @ 15yr life			***166.1***		***137.1***
Unit Harm per Car - 5% discount @ 25yr life			***184.7***		***152.4***

Table 3.3 *- Summary of Harm Benefits for Hybrid Standard*

Body Region		Total Harm CR154 $mil	CR154 Harm Benefit $mil	Revised Relevance $mil	Revised Benefit $mil
Head	near-side	203.7	10.8	1.00	10.8
	far-side	234.4	18.1	1.00	18.1
Face	near-side	19.5	0.8	1.00	0.8
	far-side	14.3	0.1	1.00	0.1
Abdomen	near-side	10.4	8.4	1.00	8.4
	far-side	6.3	0.0	1.00	0.0
Pelvis	near-side	25.7	4.4	1.00	4.4
	far-side	3.1	0.1	1.00	0.1
Upper Limbs	near-side	46.8	17.0	1.00	17.0
	far-side	22.7	3.6	1.00	3.6
Lower Limbs	near-side	57.9	17.6	1.00	17.6
	far-side	22.2	1.2	1.00	1.2
Original Hard Thorax	near-side	165.7	61.7		
	far-side	41.2	3.6		
Front Thorax	near-side	118.0	43.8	1.00	43.8
	far-side	33.4	2.9	1.00	2.9
Front Organ	near-side	15.0	5.6	1.00	5.6
	far-side	4.2	0.4	1.00	0.4
Rear Thorax	near-side	13.6	5.0	1.00	5.0
	far-side	3.4	0.3	1.00	0.3
Rear Organ	near-side	2.1	0.8	1.00	0.8
	far-side	0.2	0.0	1.00	0.0
Heart	near-side	17.0	1.6	0.50	0.8
Near-Side Harm Saved Annually ($mil)			***120.6***		***114.9***
Far-Side Harm Saved Annually ($mil)			***26.7***		***26.7***
Total Side Harm Saved Annually ($mil)			***147.4***		***141.7***
Unit Harm per Car - 7% discount @ 15yr life			***147.1***		***141.4***
Unit Harm per Car - 7% discount @ 25yr life			***159.4***		***153.3***
Unit Harm per Car - 5% discount @ 15yr life			***166.1***		***159.7***
Unit Harm per Car - 5% discount @ 25yr life			***184.7***		***177.5***

3.4.4 Alternative Hybrid Proposals

The hybrid standard proposed by Seyer and Fildes (1996) was only one possibility and should not be regarded as the only alternative. Indeed, Transport Canada also outlined a possible alternative harmonised standard which was briefly described in Chapter 1. This was not costed here, though, as it offered fewer additional benefits to this Hybrid proposal.

Another possible alternative would be if the current European standard ECE Regulation 95 was to be modified to include a rear seat dummy. While this would still not be optimal compared with the Hybrid proposal, it may be easier to implement, given that it is a variation on an existing standard, rather than an entirely new one. The added benefit of the modified ECE Reg 95 would accrue from the additional counter-measures that would be introduced in response to the presence of the dummy. It is difficult to know how manufacturers would respond to this proposal for two reasons.

First, the narrower European barrier caused little deformation to the rear door and damage was mainly confined to intrusion between the A- and B-pillars. By contrast, the 214 barrier did cause kinking in the rear door and was seen to be a more severe intrusion generally because of its wider surface and increased mass. Second, as a consequence of this, test results from rear seat dummies are generally lower and rarely rise about critical levels for the limited number of tests conducted so far. This is illustrated in Tables 3.5 which was derived from test results from side impact tests in the 1980s on a passenger car model, comparing crabbed and non-crabbed barriers and SID and EuroSID dummies. Moreover, this was further confirmed by the hybrid test results conducted in Australia, albeit with BioSID dummies, which were shown earlier in Table 1.2.

Table 3.5 *Comparative test results between NHTSA and EEVC side impact configurations (derived from data presented in Ohmae, Sakurai, Harigae & Watanabe, 1989)*

Dummy Measure	NHTSA (SID) Test N-0	ECE Reg 95 (EuroSID) Test E-0
TTI - front seat	101	108
Pelvic Accel. - front seat	151	56
TTI - rear seat	98	38
Pelvic Accel. - rear seat	132	47

While these data were derived from crash tests involving a single vehicle model, nevertheless these results suggest that there would be very little incentive for manufacturers to apply additional countermeasures to the rear doors or structures for compliance for the cars tested in both these programs. However, it may be that for smaller cars, the European barrier may be a more severe test for the rear seat dummy. In addition, the mere presence of a rear seat dummy in the test would be expected to cause manufacturers to include some additional counter-measures in the rear seat as this is generally where children travel. Thus, a “global” structural improvement could be expected in the rear, leading to a 15% reduction in rear seat occupant Harm if a rear seat EuroSID dummy was included in ECE Reg 95. This assumption, however, does require further research and substantiation.

Table 3.6 *- Summary of Harm Benefits for ECE Regulation 95 with the inclusion of a rear seat dummy*

Body Region		Total Harm CR154 $mil	CR154 Harm Benefit $mil	Revised Relevance $mil	Revised Benefit $mil
Head	near-side	203.7	10.8	0.91	9.8
	far-side	234.4	18.1	0.91	16.5
Face	near-side	19.5	0.8	0.91	0.7
	far-side	14.3	0.1	0.91	0.1
Abdomen	near-side	10.4	8.4	0.64	5.4
	far-side	6.3	0.0	0.64	0.0
Pelvis	near-side	25.7	4.4	0.91	4.0
	far-side	3.1	0.1	0.91	0.0
Upper Limbs	near-side	46.8	17.0	0.91	15.5
	far-side	22.7	3.6	0.91	3.3
Lower Limbs	near-side	57.9	17.6	0.91	16.1
	far-side	22.2	1.2	0.91	1.1
Original Hard Thorax	near-side	165.7	61.7		
	far-side	41.2	3.6		
Front Thorax	near-side	118.0	43.8	1.00	43.8
	far-side	33.4	2.9	1.00	2.9
Front Organ	near-side	15.0	5.6	0.50	2.8
	far-side	4.2	0.4	1.00	0.4
Rear Thorax	near-side	13.6	5.0	1.00	5.0
	far-side	3.4	0.3	1.00	0.3
Rear Organ	near-side	2.1	0.8	1.00	0.8
	far-side	0.2	0.0	1.00	0.0
Heart	near-side	17.0	1.6	0.25	0.4
Near-Side Harm Saved Annually ($mil)			***120.6***		***104.2***
Far-Side Harm Saved Annually ($mil)			***26.7***		***24.6***
Total Side Harm Saved Annually ($mil)			***147.4***		***128.8***
Unit Harm per Car - 7% discount @ 15yr life			***147.1***		***128.6***
Unit Harm per Car - 7% discount @ 25yr life			***159.4***		***139.3***
Unit Harm per Car - 5% discount @ 15yr life			***166.1***		***145.2***
Unit Harm per Car - 5% discount @ 25yr life			***184.7***		***161.4***

3.4.5 Modified ECE Reg 95 Proposal

The additional benefits for such a proposal are outlined in Table 3.6. The total Harm saved annually would increase by A$7.2 million to A$128.8 million over the estimated saving for this standard with only a front seat dummy (see Table 3.2). The unit Harm saved would increase by around 6% and range from A$128.60 to A$161.40, depending upon discount rate and expected life of the vehicle fleet.

It should be noted, though, that this variation is still far short of the expected savings in Harm for the hybrid side impact standard (A$128.8m c.f. A$141.7m) and still represents a less desirable regulation for ensuring optimal occupant protection in side impact crashes.

Chapter 4 General Discussion & Conclusions

This project set out to estimate what would be the reductions in community Harm if Australia was to adopt a hybrid side impact standard over the two existing dynamic side impact regulations FMVSS 214 and ECE Reg 95. The hybrid side impact standard defined by Seyer and Fildes (1996) was a combination of the US and European standards, comprising the FMVSS 214 crabbed movable barrier; the ECE R95 deformable barrier face; impact geometry as specified by FMVSS 214; BioSID dummies in the front and rear outboard seating positions; and ECE R95 injury criteria to the degree to which BioSID is capable of measuring.

A one-day workshop was held in Washington DC comprising international specialists in side impact protection to determine what the likely injury reductions would be of the proposed hybrid standard. Subsequently, a Harm Reduction analysis was carried out using the assumptions agreed to at the workshop and these results were reported in the previous Chapter. Finally, the additional Harm benefit for a modified ECE Regulation 95 (comprising two near-side EuroSID test dummies) was also calculated and reported in Chapter 3. There were several important aspects of these results that need to be discussed.

4.1 FMVSS 214 Regulation

Recent evidence suggests that the benefits calculated if Australia was to adopt the FMVSS 214 regulation in an earlier report CR 154 (Fildes, Digges, Carr, Dyte & Vulcan, 1996) were over-stated. Current best estimates now suggest that this benefit would be A$116.2 million annually for a fully compliant fleet which equate to a unit Harm saving of between A$116.00 to $145.60 per car across its expected lifetime. This is a reduction of A$20 million annually (14.7%) over the previous estimate brought about by a more conservative estimate of the likely head and abdominal injury savings from the use of the SID dummy in the light of more recent evidence of this dummy's failings and recent countermeasure experience.

The previous Harm benefits were calculated at a time when there was a scarcity of data available on the likely injury savings one could expect from the 214 procedure and contained the best estimate available at the time. Since then, a sizeable proportion of the US passenger car fleet now complies with this standard and there are more test data available and greater experience in how manufacturers are responding to this standard with on-board counter-measures to address this requirement.The recent expert panel assembled for the hybrid standard workshop noted that SID was especially weak in inducing head injury protection and, indeed, could lead to abdominal injury disbenefits given its complete lack of an abdominal injury criteria or measure. This was discussed at the Washington workshop and is reported more fully in Appendix 1.

It should be stressed, however, that recent estimates of the cost for Australian vehicles to comply with FMVSS 214 would be A$100 maximum (Fildes, Digges, Dyte & Seyer 1996). Thus, even for a reduced benefit of $116.00 to $145.60, it is likely that it would still be cost-beneficial for Australia to adopt this regulation (BCR=1.16-1.46).

4.2 ECE Regulation 95

Similarly, the original estimates for ECE Reg 95 also needed to be revised in the light of more recent experience with the EuroSID test dummy's performance characteristics and the fact that the European test barrier generally resulted in a less severe side impact test, especially for compact and intermediate sized cars typical found in Australia and the USA.

While EuroSID does include an abdominal measure in contrast to SID, it is still likely to be fooled on occasions by aggressive arm rests (this was confirmed by members of the expert group who had conducted multiple tests using EuroSID for a range of different cars and countermeasures). Thus, it was felt that only 70% of abdominal Harm initially calculated would be mitigated by ECE Reg 95. Moreover, with the narrower, lighter barrier and without a rear seat dummy, it was doubtful that any rear seat Harm would be saved for this regulation.

With these changes, the original annual Harm benefits calculated for ECE Reg 95 fell from A$147 million to A$122 million, a reduction in expected Harm saved of 17% over the figure originally estimated in CR 154. Even so, unit Harm would still be expected to range from A$121.40 to A4152.40 and be cost-beneficial for a A$100 installation cost.

4.2.1 Modified ECE Reg 95 Including a Rear Seat Dummy

A variation of ECE Reg 95 that would have marginally better Harm benefits over the current standard would be for a rear seat EuroSID dummy to be included in the test. This would help to ensure additional countermeasures are included to protecting rear seat occupants, although the less benign nature of the test for intermediate or large passenger cars would tend to mitigate against optimum protection. Nevertheless, the figures calculated here would suggest that a modest additional A$7 million annually (6%) would be saved by this variation over the existing configuration. This would seem to be a useful first step to take as it would only require a modification of an existing standard, rather than a whole new procedure. However, the assumption of a global benefit for rear seat passengers requires further research and substantiation.

4.3 The Hybrid Proposal

The results of this analysis showed that the hybrid proposal outlined by Seyer and Fildes (1996) would result in a saving of A$142 million each year in Australia which is approximately a 5% reduction in vehicle trauma annually once all vehicles in the fleet comply. This equates to a 16% additional benefit over ECE Reg 95 and a 20% improvement over FMVSS 214 and clearly demonstrates it would be a far superior regulation in terms of saving injuries to occupants involved in side impact crashes that both of the existing standards.

Adoption of the hybrid standard would require acceptance of a number of modifications to both standards. First, it would require agreement that BioSID is the preferred test dummy currently over either SID or EuroSID. While there is general acceptance among the crash test community that this is so, no government has yet to acknowledge BioSID as a suitable compliance test dummy. It seems that while manufacturers use BioSID in much of their development work on new cars because they feel it is a more credible instrument, this is not reflected among the regulators, either in the USA or Europe. It is not clear why this is so but would represent a major challenge for adoption of the hybrid standard internationally.

Second, Europe and the USA would also need to agree that the heavier, crabbed 214 MDB is a more preferred test over the perpendicular European one. The design of the barrier has been the subject of much contention in the past between regulation authorities on either side of the Atlantic and there has not been a will to compromise. The Europeans argued that the smaller barrier and a perpendicular crash better represent European crashes while the Americans and Canadians argue the opposite for 214 configuration. The comparative hybrid test data from Australia also support the North American contention. Clearly, there would need to be a change in thinking on this issue before such a compromise would be possible.

Third is the question of the barrier face. The European barrier at 300mm barrier height was used in the hybrid tests as it was felt that with its composite structure in aluminium honeycomb, it was more like a variable stiffness car than the US homogeneous foam face. Indeed, the test results seem to confirm that the deformations simulated a high proportion of real world side impact crashes. In the event that this barrier face was to be used on the 214 crabbed carrier, though, it would need to be longer than those used for the hybrid tests to ensure it fully fitted the wider barrier. This would provide a marginal improvement for the rear seat occupants by ensuring higher impact loads to the rear doors.

4.4 Optimum Side Impact Protection

One question that remains unanswered is whether a dynamic side impact regulation of any form will yield optimum side impact protection for passenger car occupants. The expert panel generally agreed that most manufacturers are more concerned with providing protection than they are about simply meeting regulations and that often countermeasures are adopted that provide superior protection to that required by the standard. To this end, it was generally felt that even the level of protection offered by the hybrid standard could be improved upon substantially with greater attention to mitigating injuries during the design process.

How this is debatable as it relies on individual manufacturers judgement of what is desirable and possible. The only available objective tests of the likely injury consequences of various side impact countermeasures involve either expensive crash tests or limited biomechanical models of car and occupant performance in a crash. These are performance based measures and do not always correlate well with real-world injuries. Indeed, there is a lack of definitive relationships between side impact dummies and population injury risk curves. Further research is clearly urgently needed in this area and the involvement of Harm Reduction as a design criterion would be a useful development towards optimum side impact protection.

4.5 CONCLUSIONS & recommendations

The results of this analysis have confirmed the desirability of the hybrid standard over the two existing side impact regulations FMVSS214 and ECE Reg 95 in providing improved protection for passenger car occupants in side impact collisions in Australia. The results obtained here are in general agreement with previous Canadian figures that showed that a harmonised standard would be more preferable for Canada that either of the two current side impact regulations. While a modified ECE Reg 95 with a EuroSID dummy in the rear outboard seating position would yield some additional benefit, nevertheless, it would only be a marginal improvement and still less desirable than the hybrid standard. Further research is warranted to improve knowledge of occupant performance in side impact crashes and identify additional methods of ensuring more optimal protection than that offered by regulations alone.

4.5.1 Recommendations

It is recommended, therefore, that the Federal Office of Road Safety take a lead in promoting the introduction of an international hybrid standard similar to that outlined by Seyer and Fildes (1996) by:

1. *continuing to participate in international harmonisation and European Working Party meetings to gain international agreement for a single side impact regulation;*
2. *by seeking to become involved in future research and discussions aimed at developing and improving further the proposed hybrid side impact standard;*
3. *examining the feasibility of Australia, Canada and possibly Japan working towards introducing the hybrid standard in these countries as a model for others to follow;*
4. *holding discussions with consumers groups such as the Australian New Car Assessment Program to investigate the possibility of the hybrid standard becoming the accepted side impact performance test in their evaluations; and*
5. *actively participate in other research effort aimed at reducing injuries in side impact crashes beyond regulation levels by developing injury reduction as a design criterion for new passenger cars manufactured and sold in this country.*

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