AIRBAG AND FACEBAG BENEFITS AND COSTS

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ABSTRACT

*There is debate about the appropriate design of supplementary airbags for passenger car occupants with high levels of seatbelt use. A theoretical analysis was performed to demonstrate the likely costs and benefits of US fullsize driver airbags and the smaller European style facebag. This study undertaken for the Federal Office of Road Safety in Australia builds upon previous work in this area. Benefits were determined using **Harm Reductions** for front seat occupants involved in frontal crashes. A sensitivity analysis was undertaken for different benefit scenarios for the facebag, given the lack of available performance data. Likely costs of the components were derived from information provided by the local automobile manufacturers, part suppliers, and vehicle importers, with adjustments made for fitting to Australian vehicles. The results demonstrate the advantage of fullsize airbags over facebags, even when seatbelt wearing rates are high.*

1. INTRODUCTION

Occupant restraint in Australia has been primarily dependent upon vehicle occupants wearing 3-point manual seatbelts for the last 20 years and consistent police enforcement of seatbelt wearing has led to Australians having one of the highest seatbelt wearing rates in the world (currently around 94 percent in the front seat). Nevertheless, the proportion of unbelted occupants amongst front seat occupants hospitalised or killed from crashes in Australia is still of alarming proportions (17% and 37% respectively; Fildes, Lane, Lenard, and Vulcan, 1991; Ryan, Wright, Hinrichs and McLean 1988).

Moreover, Fildes et al (1991) reported that a substantial number of **belted** front seat occupants in Australian vehicles were severely injured in relatively low delta-V crashes and a high number of head, face, and chest injuries from contact with the steering assembly. They argued for the need for supplementary airbag systems (at least for the driver) as a minimal requirement for improved occupant protection in these vehicles. However, they noted that the cost effectiveness of these devices is yet to be established.

The design of a suitable supplementary airbag restraint systems is still somewhat unclear. Supporters of the *Eurobag* unit (40litre, 24km/h firing threshold, slow deployment) argue that it is more relevant as a supplementary restraint because a belted occupant doesn't need such a rapid deployment airbag and therefore it is less likely to be injurious to occupants

(Aldman 1983; Mackay 1990). However, others claim that the American fullsize airbag (70litre, 16km/h threshold, rapid deployment) is able to offer both supplementary restraint for belted occupants and passive restraint for unbelted occupants and therefore more likely to be beneficial in reducing occupant trauma (Campbell 1987; Digges and Morris 1991). Moreover, it is claimed by at least one manufacturer that any cost advantage for the cheaper Eurobag unit would be more than offset by the savings of a larger production run if these fullsize units were to be standardised on all vehicles throughout the world (Kallina 1990).

Cost-benefit analysis is often used for demonstrating the need or desirability of new road safety countermeasures. Assessing the likely injury reduction benefits of a new safety measure requires three sources of information; injury frequencies, costs, and likely mitigation effects. The concept of *Harm Reduction* was developed for quantifying these benefits. Harm is the product of the unit cost and frequency of a particular type of injury and provides a total cost for that injury in millions of dollars. Thus, Harm reduction from the introduction of a countermeasure can be computed provided information is available on the likely effectiveness of the measure in reducing injuries.

A project was undertaken recently for the Federal Office of Road Safety in Australia to help determine priorities for additional regulations aimed at improving occupant protection. An analysis of the costs and benefits of fullsize driver airbags and driver facebags as a restraint "*supplementary*" to the mandatory wearing of 3-point seatbelts was of particular interest. Harm analysis was the basis for assessing likely benefits from each device and information on costs was obtained from the Australian automotive manufacturers, international retail prices, and local and overseas component manufacturer costings.

2. ASSESSMENT OF BENEFITS

The most suitable Australian database for this analysis was the "*Crashed Vehicle File*" reported in Fildes et al (1991). These data comprised injury and contact source details from 369 crashes where an occupant was either killed or hospitalised using the National Accident Sampling System (NASS) method of crash investigation. To make these data representative of all occupant injuries in Australia, it was necessary to (1), adjust the frequencies to national levels of restraint use, impact direction, seating position, and speed zone, and (2), expand this severely injured database (killed and hospitalised cases only) to include all injuries to vehicle occupants of all severity levels.

The first task used national fatal statistics, police crash report data from all Australian states, and Victorian injury compensation data. The second task presented something of a challenge as data on minor injury contact sources were not available anywhere in Australia. However, the Transport Accident Commission in Victoria (a state-wide no-fault injury compensation authority) records up to 5 injuries sustained by non-hospitalised medically treated occupants. These injury frequencies were adjusted as above and the contact source for each of them were determined from similar injuries sustained by those hospitalised for only one or two days in the existing crashed vehicle file. (Full details on how these adjustments were made can be found in Monash University Accident Research Centre, 1992).

This resulted in an estimated 77,194 passenger car occupant casualties involving 284,540 injuries annually at a rate of 3.7 injuries per occupant casualty. It should be noted that it was not possible to estimate the AIS1 injuries for killed occupants, due to their absence in fatal statistics in Australia. However, this was not considered to be important as these injuries were expected to be relatively few in number compared with survivors' AIS 1's and thus would only have a minor effect on the estimates of the total cost of occupant injuries.

2.1 AUSTRALIAN HARM

Harm mitigations were based on the likely annual savings for future Australian passenger car occupants using national frequencies of occupant injuries and contact sources, and cost of injury by maximum AIS as outlined in Steadman and Bryan's (1988) "*Cost of Road Crashes in Australia*". These costs include allowances for forgone income, pain and suffering, hospital, medical, rehabilitation, legal and court costs, and community losses. Property damage charges were deleted. As this source did not break down injury costs by specific body regions, data published by Miller, Pindus, Leon and Douglass (1991) were used to derive Australian equivalent unit injury costs by AIS and body region.

2.2 BENEFIT ASSUMPTIONS

A number of assumptions were necessary to estimate the likely benefits of fullsize driver airbags and facebags. Where possible, these assumptions were based on available test or performance data. However, facebags are a relatively recent development and specifications (and indeed working production models) of these units have only become available in the last 12 months or so with little (if any) available test data on their likely injury performance. Thus, it was necessary to make "*expert group*" assessments of expected injury reductions for these units (the make-up of the international expert panel is described fully in Monash University Accident Research Centre, 1992). Given divergent views on their likely effectiveness, a sensitivity analysis involving different benefit scenarios was also undertaken for this measure and the assumptions made for each are described below.

2.2.1 Fullsize Driver Airbags

Performance data were available on expected injury reductions from the introduction of fullsize driver airbags in conjunction with seatbelts (c.f., Evans 1988; Zuby and Saul 1989; Highway Loss Data Institute 1991; Zador and Ciccone 1991). From these reports, it was possible to make the following assumptions:

. that these 70 litre airbags would reduce injuries to front seat occupants in frontal crashes from 10-40mph (16-64km/h),

. that injury reductions to restrained occupants would come from fewer head and face contacts with the steering wheel, instrument panel, windscreen, and A-pillar,

. that there would be fewer injuries from chest contacts with the steering wheel, instrument panel, and seatbelt, and abdominal contacts with the steering assembly,

. that injury reductions for unrestrained occupants involved the same body areas and contacts as for restrained occupants plus reduced contacts from exterior objects,

. that benefits would be mainly to the driver, except for front passenger contacts with the steering wheel,

. that AIS 1 and 2 injuries were concentrated at lower impact speeds while AIS 3's and above were more common at higher delta-V's, and

. that airbags as a supplementary restraint would produce a 2 AIS injury reduction to restrained occupants, and a 3 AIS reduction for head and chest injuries to unrestrained occupants.

2.2.2 *Maximum* Facebag Benefits

The most optimistic prediction of facebag performance assumed that these units would be three-quarters as effective as fullsize driver airbags for both restrained and unrestrained drivers and (where relevant) front seat passengers. This view has been expressed by a number of commentators in Europe.

The assumptions for this scenario, therefore, were similar to those expressed for fullsize airbags, except that a 75 percent relevance factor was applied to the subsequent benefits calculated for each body region and contact source. Implicit with this scenario is the major assumption that facebags will offer a sizable passive benefit for unrestrained occupants (75% of that offered by fullsize airbags), which is not normally associated with these units.

2.2.3 *Intermediate* Facebag Benefit

A more conservative scenario of facebag injury mitigation assumed a greater benefit for restrained than unrestrained occupants but still some injury reductions for the latter group from contacts with instrument panel, windscreen and header, and A-pillar, as well as a minor restraint benefit from reduced ejections. These assumptions include:

. a lower firing threshold of 16km/h (10mph),

. the same reduction in head, face, and chest injuries from contact with the steering wheel as the minimum facebag, but a 30 percent reduction in all other body region contacts (excluding abdominal injuries), and

. a more conservative injury reduction of 2 AIS for unrestrained head and chest injuries and 1 AIS for restrained face injuries.

2.2.4 *Minimum* Facebag Benefit

The minimum facebag benefits were based on the expected performance of Facebags, in the absence of safety standards. Under such conditions, economic and styling considerations dominate the design in the direction of smaller bags with higher deployment thresholds. Zuby and Saul (1989) conducted a data analysis of facial injuries suffered by restrained drivers in the United States and reported a large fraction of the facial Harm occurred at speeds between 16 and 24km/h (10 and 15mph). This analysis suggested that the deployment speed can have a significant influence on its effectiveness in reducing facial injuries.

The minimum facebag benefit were based on the assumption that these units would only provide protection from the steering wheel and hub (the fundamental design philosophy behind facebags as a supplementary restraint). Thus, injury mitigations were confined to the head, face, and chest only for both restrained and unrestrained front seat occupants and no benefits were allowed for contacts other than with the steering wheel itself (no exterior benefits were permitted for unrestrained occupants either). In addition, the firing threshold was set at 24km/h (15mph), the level commonly accepted as appropriate in Europe to ensure a softer (less injurious) inflation.

FIGURE 1 SAMPLE HARM SPREADSHEET: CHEST INJURIES TO RESTRAINED FRONT SEAT OCCUPANTS IN FRONTAL CRASHES

TABLE A HARM DIST. BY CONTACT

			COUNTERMEASURE OPPORTUNITIES				
CONTACT	FRONTAL HARM	% HARM FT.OCC.	DRIVER AIRBAG	PASS. AIRBAG	MAXIMUM FACEBAG	INTER. FACEBAG	MINIMUM FACEBAG
STEER A	78.24	45.04%	45.04%		45.04%	45.04%	45.04%
INS.PANEL	18.16	10.45%	10.45%	10.45%	10.45%	10.45%	
WINDSCR.	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	
A PILLAR	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	
B PILLAR	0.00	0.00%					
HEADER	0.00	0.00%					
DOOR	11.99	6.90%					
BELT	64.14	36.92%	36.92%	36.92%	36.92%	36.92%	36.92%
NON-CONT.	0.34	0.20%					
OTHER	0.84	0.48%					
TOTAL	173.71	100.00%	92.42%	47.38%	92.42%	92.42%	81.96%
		-3 AIS					
SENSITIVITY ANALYSIS		-2AIS	92.9	10.0	67.4		31.6
		-1 AIS	69.8			31.5	26.4

TABLE B SAMPLE HARM CALCULATION - AIRBAG FOR STEERING ASSEMBLY CONTACTS

INJURY SEVERITY DISTRIBUTION			INJURY REDUCTION		RESIDUAL
AIS	DIST.	% DIST.	RELEVANCE	BASIS	-2AIS
1	1.3	1.6%	0.60	0.01	0.01
2	6.3	8.0%	0.60	0.05	0.04
3	18.4	23.5%	0.80	0.19	0.05
4	19.6	25.1%	0.80	0.20	0.03
5	13.4	17.1%	0.80	0.14	
6	19.3	24.6%	0.80	0.20	
UNK.	0.0	0.0%			
TOTAL	78.2	100.00%		0.78	0.13
			HARM UNITS REMOVED		50.40

TABLE C SAMPLE INJURY REDUCTION ASSUMPTIONS

1. FULLSIZE AIRBAG DEPLOYS AT 10 MPH
2. RELEVANT INJURY RANGE FOR FULLSIZE AIRBAG = 10 TO 40 MPH
3. 40% OF AIS 1 INJURIES OCCUR BELOW 10 MPH
4. 60% OF AIS 1 & 2 INJURIES OCCUR BETWEEN 10 AND 40 MPH
5. 80% OF AIS 3+ INJURIES OCCUR BETWEEN 10 AND 40 MPH
6. INJURY REDUCTION FOR ALL RELEVANT CRASHES IS 2 AIS

TABLE D HARM DIST. BY CONTACT

CONTACT	FRONTAL HARM	%HARM F.S.OCC.	DRIVER AIRBAG	PASS. AIRBAG	MAXIMUM FACEBAG	INTER. FACEBAG	MINIMUM FACEBAG
STEER A	78.24	45.04%	50.4		37.7	11.4	11.4
INS.PANEL	18.16		9.9	2.3	7.5	2.4	
W'SCREEN	0	0.00%	0	0	0	0	
DOOR	11.99	0.00%					
BELT	64.14	0.00%	32.6	7.7	22.2	17.7	15
NON-CONT	0.34	0.20%					
OTHER	0.84	0.48%					
TOTAL	173.71	100.00%	92.9	10	67.4	31.5	26.4
BENEFIT ASSUMED			2 AIS	2 AIS	2 AIS	1 AIS	1 AIS

2.3 HARM CALCULATIONS

A computer spreadsheet was developed for the detailed Harm calculations by body region and restraint condition. Figure 1 shows a typical Harm spreadsheet summary page for chest injuries to restrained front seat occupants in Australian passenger cars. Table A shows the adjusted national distribution of chest Harm by contact sources and the opportunities available for each countermeasure to reduce chest Harm to these occupants. For example, it was assumed that fullsize driver airbags will reduce chest injuries to restrained drivers from steering assembly, instrument panel, windscreen, A-pillar, and seatbelt contacts.

The likely injury reductions for each of these opportunities was then analysed separately in another section of the spreadsheet. Table B shows a sample of one such calculation (fullsize driver airbags with steering assembly injuries) and Table C, the assumptions made in that calculation. The opportunity for injury reduction at each AIS level was reduced through the use of a *relevance* factor (0.6 for AIS 1 up to 0.8 for AIS 3 and above injuries). This relevance factor is used to include only that Harm which is within the injury mitigation capability of the measure and is determined by the proportion of chest Harm within the crash severity range for which the measure is judged to be effective.

The *Basis* column is the product of relevance and % Harm and is the actual Harm expected to be saved by the measure for that particular AIS level. However, as the Harm reduction is a shift in the Harm distribution of 2 AIS rather than a total mitigation of injury, the *basis* therefore needs to be corrected for the *Residual Harm.* This is done in the column headed *-2 AIS* where the Residual of say existing AIS 3 is shifted to AIS 1 injuries and adjusted to reflect reduced cost of injury at that level (0.19 basis at AIS 3 is shifted to AIS 1 and multiplied by 4/78 which is the cost of AIS 1 over AIS 3 injuries to the chest leaving a 0.1 residual). The total *Harm Units Reduced* is then the product of the total Harm experienced ($78.2 million) by the difference between total basis and residual Harm:

i.e., 0.78 - 0.13 = 0.65 x 78.2 = $50.4 million

The assumptions in Table C show what injury reductions the airbag was expected to achieve for that specified contact source. The injury reduction was assumed to occur over the crash severity range of 16 to 64km/h (10-40mph) and 20 percent of AIS 3 and above injuries to the chest for these vehicle contacts were assumed to occur outside this severity range. Therefore, 80% of these AIS 3 and above injuries would be reduced by 2 AIS. A relevance factor of 0.8 was therefore used in Table B. It is recognised that some injuries will be reduced more, and others, less. However, based on airbag crash tests with dummies, a 2 AIS injury reduction seemed appropriate. Accident experience supports this order of injury reduction. Relevance factors were selected for the other AIS levels in a similar way. The airbag had the lowest relevance factors (0.6) for AIS 1 chest injuries because many of them occur below 16km/h, the threshold for airbag deployment.

The benefit for each measure is finally summarised in Table D, where the Harm mitigated by individual contact source was added to provide total Harm saved for that body region and restraint condition. Again for the fullsize driver airbag, Table D shows that this measure was judged likely to save A$92.9 million annually from reduced chest injuries to restrained front seat occupants, a large proportion of which would be derived from reduced driver contacts with the steering wheel (A$50.4 million). The total Harm reduction for each countermeasure was eventually obtained by adding together the results of all the body region and restraint conditions applicable for each measure (this is shown in Table 1 in the results).

2.4 HARM SAVINGS PER VEHICLE

The total Harm saved for each measure was converted into a Harm saving per car. This was done by summing the Harm attributed to the measure for one car over its life (notionally 15 to 20 years) and then discounting the benefits in future years back to the present using the *"Discounted Present Value"* method. An allowance was also made for a percentage of scrappage during this period. In Australia, discount rates of 7% annually are not uncommon as it is argued that they typically reflect average investment rates minus inflationary allowances.

An alternative is the *"Equilibrium"* method of assigning unit benefits which assumes that a new device is instantaneously fitted to all vehicles on day one. This approach places value on the benefits for all future generations for a simple annual maintenance cost and thus the Harm saved per vehicle is simply total Harm divided by the annual number of new vehicles. The arguments for and against each method are fully outlined in Monash University Accident Research Centre (1992) and will not be elaborated upon here.

The project specification called for benefits to be calculated using the Discounted Present Value method for calculating unit Harm and the benefit-cost ratio's present here reflect these figures. It should be noted, however, that the equivalent Equilibrium benefits are approximately 60 percent higher than those presented here, thus the BCR's expressed in this paper can be viewed as conservative.

3. ASSESSMENT OF AIRBAG COSTS

In assessing the likely costs and prices of the countermeasures on the Australian market, information was sought from the Australian automotive manufacturers, and use was made of international retail price comparisons and local and overseas component manufacturers' costings (see Monash University Accident Research Centre 1992 for a full explanation of the costing procedure).

3.1 AIRBAG AND FACEBAG ASSUMPTIONS

In estimating the best retail price for these measures, assumptions were made about annual volumes, testing requirements for compliance, configurations, vehicle modifications, component costs and retail mark-ups. These assumptions are detailed below.

. a fully integrated single sensor electro-mechanical system currently available in Australia from particular facebag and airbag suppliers (fullsize airbags would be 70 litre, and facebags 40 litre, capacity),

. annual production volume of 30,000 vehicles and a six year product cycle,

. extensive testing involving 60 barrier crash tests and 150 sled tests for each model,

. vehicle modifications similar to those published by NHTSA,

. a A$10 assembly cost for fitting to the vehicle, and

. a retail price to cost ratio of 1.7.

TABLE 1 SUMMARY OF AIRBAG AND FACEBAG HARM REDUCTIONS

BODY REGION	DRIVER AIRBAG	DRIVER FACEBAG MAXIMUM	DRIVER FACEBAG INTERMEDIATE	DRIVER FACEBAG MIMIMUM
HEAD - restrained	192.7	146.3	120.1	102.7
HEAD - unrestrained	56.2	47.5	34.5	28.3
CHEST - restrained	92.9	67.4	31.5	26.4
CHEST - unrestrained	19	14.2	4.3	3.7
ABDOMEN - restrained	9.2	6.9	0	0
ABDOMEN - unrestrained	7.5	5.6	0	0
FACE - restrained	70.5	52.8	44.6	42.6
FACE - unrestrained	19.9	14.9	10.3	7.9
UPPER EXT - unrestrained	7.6	5.7	2.7	1
REST. HARM ($million)	365	273	196	172
UNREST. HARM ($million)	110	88	52	41
TOTAL HARM ($million)	476	361	248	213
UNIT HARM ($ per car)	514	391	268	230

3.2 PLAN PRODUCER VOLUME ADJUSTMENT

Current plans are to reduce the number of models manufactured in Australia to eight *plan production models* to ensure a viable manufacturing industry. These models currently account for around 330,000 vehicle sales annually and are likely to grow. Costs derived using this typical production run vehicle of 30,000 were subsequently adjusted by the "*weighted mean volume*" of the eight production models planned for Australia. [This was undertaken to ensure that annual production volumes were realistic for future Australian manufacturing conditions]. Finally, the best retail price was discounted by 22% to account for sales tax and duty on imported items (the *Economic Cost* estimates).

4. RESULTS

4.1 AIRBAG & FACEBAG BENEFITS

The summary of the Harm benefits derived by body region and restraint condition for the fullsize airbag and the three facebag scenarios is shown in Table 1. These benefits range from a Total Harm reduction of $476million ($A 1991) for the fullsize driver airbag to A$213million for the most conservative facebag scenario. These figures represent an annual reduction in vehicle occupant trauma cost in Australia of 15% and 7% respectively. The Unit Harm reduction figures range from A$514 to A$230 per car over its life.

TABLE 2
ESTIMATE OF BEST LIKELY RETAIL PRICE AND ECONOMIC COST
FULLSIZE DRIVER AIRBAG AND FACEBAG

Cost of Components	Driver Facebag	Driver Airbag
Fully integrated single sensor system (electro-mechanical)	A$240*	na
Full testing program of 150 sled tests, 60 barrier tests, and computer simulation	A$ 30	na
Modifications to suit a hypothetical vehicle	A$ 13	na
Assembly costs	A$ 10	na
Manufacturers on-costs, profits, retail margins, etc (1.7 ratio)	A$207	na
Estimated Retail Price	A$500	A$550**
Adjusted to suit the eight plan production models for Australia	A$480	A$528
Economic cost (83% adjusted retail)	**A$400**	**A$440**

* *This cost is based on a figure provided by a component manufacturer who currently offer a 40litre facebag in Australia of these specifications.*

** *Industry sources have indicated that an equivalent single-sensor 70litre airbag is unlikely to add more than A$50 to the retail price of a facebag.*

4.2 AIRBAG & FACEBAG COSTS

Table 2 shows the estimate of best likely retail price and economic cost for the fullsize driver airbag and facebag calculated here. The economic cost of a fully integrated single sensor electro-mechanical fullsize (70litre) driver airbag system would be $440 per car, while a similar 40litre facebag would be A$400.

4.3 ECONOMIC ANALYSIS

The benefits, costs, Benefit-Cost-Ratio (BCR), Net Present Worth (NPW), and % Vehicle Trauma saved annually for each of the measures and scenarios are shown in Table 3. The Benefit-Cost-Ratio is the future Harm reduction benefits per car (discounted to present day values) divided by the economic cost per car and is used as a measure of the economic desirability of a particular countermeasure. Net Present Worth is the benefit minus the cost per car multiplied by the total number of new vehicles annually in Australia and represents the economic worth to the community of equipping new vehicles with the new safety measure. Percent trauma saved represents what the annual reduction in vehicle trauma would be if these devices were fitted to the total vehicle fleet.

TABLE 3
BENEFIT-COST RATIO AND NET PRESENT WORTH FOR THE FULLSIZE DRIVER AIRBAG AND FACEBAG

Countermeasure	Benefit	Cost	BCR	NPW	% Trauma
Fullsize airbag	$514	$440	1.17	+A$43m	15%
Maximum facebag	$391	$400	0.98	-A$5m	12%
Intermediate facebag	$268	$400	0.69	-A$76m	9%
Minimum facebag	$230	$400	0.58	-A$98m	7%

5 DISCUSSION

This study was carried out for the Federal Office of Road Safety to estimate the likely occupant injury savings to vehicle occupants and economic effectiveness if all passenger cars in Australia were fitted with driver airbags (fullsize and facebags) supplementary to the existing 3-point manual belt system. Harm reduction was adopted as the means of assessing injury benefits while costs were determined from available component prices factored up to economic costs by the addition of design and testing, assembly, and margin charges. The results showed substantial Harm reductions (7 to 15 percent reduction in vehicle trauma annually) if supplementary driver airbag systems were fitted to the whole vehicle fleet.

Fullsize driver airbags were superior to facebags in all economic analyses. They were the only unit to produce a Benefit-Cost-Ratio greater than unity and, therefore, the only one likely to result in a positive Net-Present-Worth to the community (+A$43million annually). Moreover, fitting the fleet with fullsize airbags is likely to produce the highest reduction in vehicle occupant trauma annually of all measures considered (15%). Facebags benefits were less clear than fullsize airbags benefits because of a lack of available information on their injury mitigation effects. However, for the ***three*** facebag scenarios examined here (from optimistic to conservative), they were likely to produce benefits of between half and three-quarters the Harm reduction of fullsize airbags, mainly because of the limited ability of facebags to provide a passive restraint benefit for unrestrained occupants. It should be stressed that considerable difficulty was encountered in defining the performance standards of the facebag. In the absence of performance standards, the expected benefits can vary substantially. The minimum facebag benefit scenario is considered representative of the benefits expected from facebags designed primarily for styling and cost. The other two scenarios demonstrate the larger benefits that would result if the deployment speed was reduced to 16km/h and if these units are subsequently shown to offer more injury reductions than the benefits claimed in minimum scenario.

While fullsize driver airbags were initially developed as a passive restraint alternative to seatbelts, they still offer a large potential for Harm reduction as a supplementary seatbelt system in a country like Australia which has had consistently high levels of seatbelt wearing (around 94 percent). The amount of vehicle trauma likely to be saved annually from these units as a supplementary restraint is impressive and cannot be ignored in a climate where large savings in road trauma are becoming significantly more difficult to achieve.

The research was also useful in demonstrating how Harm reduction can be used in determining injury mitigation benefits for benefit-cost analysis. The technique was particularly useful for computing Harm reduction for a specific countermeasure from the summation of individual injuries by AIS level, body region, contact source, and restraint condition. Expected AIS reductions were used as a basis for estimating Harm mitigation. Where no test or crash data was available on expected injury savings, assessments were made using a group of experts experienced in occupant protection research.

This was the first known instance where Harm reduction has been computed in the manner performed here. While the success of the technique is yet to be firmly established, it is of interest to note that the estimated Harm reduction for a fullsize driver airbag of 15 percent annually is not grossly different to other published figures. The Insurance Institute for Highway Safety (Zador and Ciccone 1991) recently reported that "*Relative to comparable cars with manual belts only, driver fatalities in frontal crashes were reduced in airbag cars by 28 percent*." This order of discrepancy is not alarming, given that Harm reductions and fatalities are not necessarily perfectly correlated. Moreover, the Highway Data Loss Institute (1991) further suggest drivers in airbag cars experienced 28 percent lower severe injury rates and 24 percent lower hospital inpatient rates than drivers of automatic belt cars, standardized for differences in car size. With large differences in seatbelt wearing rates between the two countries, these comparisons seem to suggest that the figures quoted in this study are not unreasonable, albeit perhaps slightly conservative.

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