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BENEFITS OF AIRBAG REFITMENT IN SECOND-HAND CARS IN NEW ZEALAND

Brian Fildes

Peter Vulcan

Magda Les

Andrew Morris

Monash University
Accident Research Centre

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Benefits of airbag refitment in second-hand cars in New Zealand

Author(s)

Brian Fildes, Peter Vulcan, Magda Les, and Andrew Morris

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Abstract:

The Land Transport Safety Authority (LTSA) have a policy of allowing second-hand vehicles to be imported into New Zealand. Current policy in this country requires airbags to be reinstalled when they have been deployed, following a crash or for some other reason if the vehicle was originally certified to comply with a frontal impact standard. Given the governments policy of "*Safety at Reasonable Cost*", it is important to demonstrate the likely benefits and costs associated with this policy. The Monash University Accident Research Centre (MUARC) undertook an economic analysis of re-fitting airbags in vehicles where they had been fitted as original equipment but since were not operative or replaced following a crash. Using a similar procedure developed in Australia during the 1990s, a Harm analysis was undertaken to estimate the likely benefits for New Zealand. A number of assumptions were made about the level of injury savings expected to drivers in these target vehicles. Airbag replacement costs were derived from average industry figures provided as well as for expected future values, based on overseas experience. Findings showed that the break-even figure for mandating airbag replacement varied from between 5 and 16 years, depending on the cost of replacement and the discount rate for future earnings. The total system-wide benefits of airbags in both new and used vehicles in New Zealand was shown to vary from a Benefit-Cost-Ratio (BCR) of 2.4 to 3.4 for the same figures.

Key Words:

Drivers, Safety, Vehicle Occupant, Injury, Cost-benefit, Economic, Harm, Evaluation, Countermeasures.

Monash University Accident Research Centre,
Wellington Road, Clayton, Victoria, 3800, Australia.
Telephone: +61 3 9905 4371, Fax: +61 3 9905 4363

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EXECUTIVE SUMMARY

Current policy in New Zealand requires airbags to be reinstalled when they have been deployed, following a crash or for some other reason, only if the vehicle was originally certified to comply with a frontal impact standard.

At present, Class MA passenger cars manufactured after March 1999 are required to comply with a frontal impact standard, and must therefore have airbags reinstalled if the vehicle was originally manufactured with airbags. All other vehicles may be operated without airbags, even if originally fitted with them.

The policy applies irrespective of whether the airbags are deployed whilst the vehicle is in service or prior to being imported into New Zealand. Policy makers in New Zealand have been considering a change in policy, which would require airbags to be reinstalled in all vehicles, which originally had them, with a possible cut off date when the vehicle has reached a certain age.

The fitment of a replacement airbag can be expensive, as replacement parts are not cheap on a one-off basis. The question arises whether the retrofitting of driver airbags is cost-beneficial for New Zealand and therefore, whether it should be mandated or rather simply recommended. New Zealand has adopted a "safety at reasonable cost" philosophy towards vehicle safety, which dictates that safety requirements must be assessed against community savings above implementation costs.

This report describes an analysis of the benefits of retrofitting airbags to second-hand cars and vans where they had an airbag fitted as original equipment but not replaced, or found to be inoperative subsequently.

Analysis Method

The analysis undertaken was based on best estimates of societal Harm to drivers in New Zealand, which adopted "Willingness-To-Pay" values of injury cost in the early 1990s. Benefit-Cost-Ratio (BCR) calculations were performed for varying vehicle ages for fitment up to 30 years and a break-even figure where costs=benefits is provided.

The calculation of benefits and costs is carried out assuming these figures apply to both imported second-hand cars as well as cars where the airbag has been deployed on New Zealand roads. In addition, a total systems-wide airbag benefit was also calculated to demonstrate what the total airbag benefit would be assuming all vehicles in the New Zealand fleet were to have airbags fitted. It was argued that the total systems-wide benefit provides an overview of what the total benefits would be to drivers in New Zealand and hence the total BCRs of airbag technology.

Replacement airbag costs were derived from information provided by the auto industry. Average cost of replacement was estimated across the range of different figures provided and future airbag replacement cost estimated by assuming that current Australian values are likely to represent future New Zealand equivalents.

Several Benefit-Cost-Ratios were computed assuming three replacement cost estimates and two different discount rates. Current scrappage rates were used to predict future fleet estimates.

Assumptions for the Analysis

A number of assumptions needed to be made in calculating the benefits and costs of replacement airbags in New Zealand. These are listed below.

- While airbags are currently being fitted to many different vehicle types, only benefits to occupants in passenger cars were considered here.
- It was assumed that the Australian distribution of injury frequency by body region and severity modified for the local market was applicable, as no New Zealand equivalent data were available.
- Willingness-To-Pay injury cost figures published by the LTSA in 1999 and used in current calculations was again used for calculating New Zealand Harm estimates.
- The total annual Harm for vehicle occupant injuries in New Zealand amounted to NZ$2.9billion.
- Seat belt wearing rates in New Zealand have been observed to be 89% for front seat occupants. On the basis of overseas equivalents, it was assumed that the level of unrestrained occupants injured in crashes in New Zealand was 25%.
- Expected injury reductions for airbags reported in a previous Australian benefit-cost study (MUARC, 1992) were used as a basis for the benefit calculation in New Zealand.
- Three replacement costs were used for the calculation, based on average figures reported by the automotive industry in New Zealand now and adjusted for expected future values.
- Relevant crashes were assumed to be frontal impacts where a driver was injured. It was expected that airbag deployment rates would be below the expected injury level.
- The Harm benefit per vehicle was assumed to be the expected annual Harm saved for the total fleet, divided by the average number of crashes in New Zealand.
- Historical vehicle scrappage rates were assumed to be representative of future scrappage rates.
- While current New Zealand policy decisions call for a 10% discount rate of future benefits, a 5% value was also included to provide sensitivity figures (a 5% discount rate is routinely as a basis for policy decisions in a number of overseas countries).
- Total fleet benefits of airbags included both new and second-hand vehicle savings.
- New car airbag fitment costs would be NZ$800. The average marginal cost for a second-hand vehicle with an airbag already fitted was assumed to be NZ$400.
- A 10% fitment rate was assumed for imported cars requiring an airbag refitment.

Individual Break-Even BCR Figures

The break-even number of vehicle years for a BCR = 1 (i.e., where the costs outweigh the benefits) are shown below in Table 1 for both 5% and 10% discount rates. These include both current and future replacement costs for an airbag in New Zealand.

Table 1 *Break-even year (BCR=1) for retro-fitting airbags by age of second-hand vehicle in New Zealand*

Replacement Cost	**5% Discount Rate**	**10% Discount Rate**
NZ$1,320	10 years	5 years
NZ$950	14 years	12 years
NZ$770	16 years	14 years

Figures rounded to nearest whole year

Total System-Wide Benefits

The total system-wide benefits (BCRs) for mandating airbags in new and second-hand cars in New Zealand are shown in Table 2 below. It was argued that while the marginal BCRs for airbag replacement on some older cars is less than 1, this ignores what the overall BCR is for the total system.

Table 2 *System-wide benefits in New Zealand for airbags in new and used vehicles*

Cost of Used Airbag	**Discount Rate**	
	5%	**10%**
NZ$770	3.39	2.51
NZ$950	3.33	2.47
NZ$1,320	3.21	2.38

Conclusion

On the basis of the data on the future expected cost of airbags in New Zealand, it seems reasonable to conclude that it would be cost-beneficial for cars to be refitted with airbags when they are not replaced after a crash for up to 14-years of their life.

The benefits would be higher for a less conservative future discount rate than 10%, which is the current practice in New Zealand. Other countries, however, use less conservative rates, ranging from 4% in the USA to 5% or 7% in Australia.

It is conceivable that the estimates provided here of the future cost of airbags might be even less as efficiencies and exposure increase substantially in the years ahead.

The total system-wide BCRs support the overall benefit of airbags as a cost-beneficial safety feature in all New Zealand passenger cars. It is expected that these benefits would also apply to other vehicles, such as 4WDs and passenger vans.

Chapter 1 Introduction

1.1 BACKGROUND

Current policy in New Zealand requires airbags to be reinstalled when they have been deployed, following a crash or for some other reason, only if the vehicle was originally certified to comply with a frontal impact standard. At present, Class MA passenger cars manufactured after March 1999 are required to comply with a frontal impact standard, and must therefore have airbags reinstalled if the vehicle was originally manufactured with airbags. All other vehicles may be operated without airbags, even if originally fitted with them. The policy applies irrespective of whether the airbags are deployed whilst the vehicle is in service or prior to being imported into New Zealand. Policy makers in New Zealand have been considering a change in policy, which would require airbags to be reinstalled in all vehicles, which originally had them, with a possible cut off date when the vehicle has reached a certain age.

The fitment of a replacement airbag can be expensive, as replacement parts are not cheap on a one-off basis. The question arises whether the retrofitting of driver airbags is cost-beneficial for New Zealand and therefore, whether it should be mandated or rather simply recommended. New Zealand has adopted a "safety at reasonable cost" philosophy towards vehicle safety, which dictates that safety requirements must be assessed against community savings above implementation costs.

This report describes an analysis of the benefits of retrofitting airbags to second-hand cars and vans where they had an airbag fitted as original equipment but not replaced, or found to be inoperative subsequently. It is based on best estimates of societal Harm in New Zealand, which adopted "Willingness-To-Pay" values of injury cost in the early 1990s. Benefit-Cost-Ratios analysis was performed for varying vehicle ages for fitment up to 30 years and a break-even figure where costs equal benefits is provided. The calculation of benefits and costs is carried out assuming these figures apply to both imported second-hand cars as well as cars where the airbag has been deployed on New Zealand roads.

1.2 PREVIOUS RESEARCH BY MUARC

The benefit-cost ratio of airbags as original equipment was first estimated for Australia by the Monash University Accident Research Centre (MUARC, 1992). They showed using the *Harm Reduction* method of calculating benefits that a driver airbag was a cost-beneficial investment for Australia that would reduce occupant trauma by up to 15%. Subsequently, the Federal Office of Road Safety mandated Australian Design Rule ADR69 to encourage the fitment of airbags to all Australian vehicles.

Benefits were calculated using human capital approach to costing injury benefits and probably somewhat inflated component prices. Moreover, a 7% discount rate and a 25-year vehicle life were used for calculating unit Harm benefits initially. The replacement costs for an airbag deployed in a crash were not considered in these calculations. The question arises whether these units would still be cost-beneficial if replaced in second-hand cars with less than an expected 25-year life period, using New Zealand's "Willingness-To-Pay" cost estimates for fatal and non-fatal injuries.

1.3 PROJECT OBJECTIVES

This research set out to estimate the likely Harm benefits of retrofitting a driver's airbag to second-hand vehicles where an airbag had been supplied as original equipment but had subsequently not been replaced after a crash or was shown to be inoperative. This was to apply to vehicles, which crash in New Zealand as well as imported vehicles. A number of specific objectives were to be addressed, namely:

- to estimate the benefits and costs (BCR) by vehicle age when the airbag is fitted retrospectively;
- estimates should include different discount rates of future benefits (5% and 10% values) as well as current and future airbag fitment costs; and
- to estimate the total system-wide benefits of mandating airbag fitment in suitable vehicles.

A number of assumptions and constraints were needed to address these objectives and these are described throughout the report where relevant. In addition, it was specified that local Willingness-To-Pay (WTP) injury values be included in the analysis as is common practice in New Zealand.

The analysis was to use the same method as that used in an earlier study by the Monash University Accident Research Centre (MUARC, 1992) for the Federal Office of Road Safety in Australia, with a number of revisions to take account of the special nature of the task.

1.4 OVERVIEW OF THE HARM METHOD

The Harm Reduction method used in MUARC (1992) was developed from earlier research in the USA and assesses benefits by comparing current Harm distributions with those expected to exist once a new safety countermeasure is implemented. In predicting the expected Harm distribution, a number of injury savings are calculated using available real-world or test data or, if none exist, by the use of expert panels to make these assessments.

Harm reductions by body region and injury severity are computed to estimate the annual Harm saved, if all vehicles comply with the proposed safety feature. Using this estimate, unit Harm is then computed by calculating the expected Harm saved per vehicle, and the probability of any one vehicle being involved in a crash across its lifetime.

These unit Harm benefits can then be equated with the cost of fitting an airbag, based on an average fitment cost for New Zealand to estimate the BCR. Because of the variable age of these vehicles, the expected life diminishes with its age, and hence the benefits for older vehicles are generally less than for newer ones.

1.5 SYSTEM-WIDE CALCULATIONS

While it is necessary to show whether any new countermeasure is likely to be cost-effective, it is equally important to consider the system-wide effects. For example, in the original Harm analysis undertaken for the Federal Office of Road Safety in Australia, the BCR for fitment of an airbag into a car was supplemented with the total expected Harm saved each year to illustrate the magnitude of the saving to Australia.

An extra component to the study therefore was to estimate what the total system-wide benefits would be to New Zealand of fitting driver airbags and replacing them, irrespective of the age of the vehicle. The system-wide benefits were calculated by dividing the overall savings by the estimated depreciated costs of the original airbags, plus the cost of replacement of airbags in all crashed cars, which are not written off.

1.6 USE OF THE REPORT

This report is a scientific evaluation of the benefits to New Zealand of mandating airbag fitment in suitable second-hand vehicles. It is based on the best information available at the time of analysis and all assumptions and limitations of the analyses are detailed in relevant sections of the document. The benefits are calculated in terms of Willingness-To-Pay costs of injury in New Zealand for different future discount rates. It is hoped that the process is sufficiently transparent that the reader should be able to assess the merit of the assumptions and the process and to gauge the effect of possible variations. The strength of the approach is its ability to re-calculate the benefits at any time, should more recent data or better assumptions be forthcoming.

The report has been prepared to provide guidance to the Land Transport Safety Authority in New Zealand and the New Zealand Government in deciding whether to mandate fitment of airbags or simply recommend this practice. While the results and recommendations are based on the findings of the analysis, it is ultimately a policy decision of the Land Transport Safety Authority and the New Zealand Government whether to mandate or not. This decision is beyond the scope of this technical document.

Chapter 2 Harm Reduction Method

The concept of "Harm" was first developed in the US and applied to the 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 (MUARC, 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 and cost of injuries sustained, expressed in terms of community costs. The Harm method adopted here embraced the original approach outlined in MUARC (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 the original report (MUARC, 1992).

2.1.2 National Statistics & Harm Estimates

The first step in the process was to develop National Harm patterns for New Zealand. 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 is described fully in Chapter 3 of the report but essentially involved adapting the Australian Harm pattern to suit New Zealand crash numbers, proportions of vehicle crashes and crash types, and differences in seat belt wearing rates. It draws heavily on the original analysis method and assumptions where they are shown to be relevant for New Zealand.

2.1.3 The Australian Harm database

A comprehensive Australia-wide database of vehicle occupant injuries and their causes was constructed for the original study by 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 used in the construction of 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 relevant for the earlier analysis. Second, MUARC's "Crashed Vehicle File" (CVF) which 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 (TAC) 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 (based on Australian Bureau of Statistics casualty statistics). 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.

Subsequently, these data were broken down by the key factors, relevant for this analysis (eg: seating position, restraint use, and type of frontal impact). Data were also disaggregated by the frequency of injuries to these occupants, categorised by the body region and Abbreviated Injury Scale (AIS), and 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 injury 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: Head injuries among restrained drivers 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, Pindus, Leon, & Douglass (1991) and explained in detail in MUARC (1992).

These figures were then converted into Australian average injury costs in 1991 $A. 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, especially as it would be ultimately converted into 1999 prices in New Zealand.

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. 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 frontal impacts crashes was broken down by contact source of the injury, for both restrained and unrestrained occupants respectively. This provided the baseline Harm figures used to calculate the potential savings of airbag benefits. This process is explained further in the next section.

2.1.7 Injury Reductions

In computing the previous airbag benefits, a number of assumptions were made by using whatever available real world and test data were available at the time to gauge what injury mitigations to expect from airbags. In addition, an international panel of research, vehicle manufacture and government specialists was formed to assist with estimating the expected injury reduction outcomes associated with the airbag. The assumptions forming the basis for calculating the Harm benefits are outlined in detail in Chapter 4.

Chapter 3 Harm Distribution in New Zealand

There was insufficient detailed in-depth crash data available for use in determining the body region and injury severity distributions in New Zealand. However, the earlier Australian study (MUARC, 1992) used human capital costs while New Zealand is committed to use Willingness-To-Pay figures. Thus, two assumptions were deemed necessary to undertake this study in a timely manner:

1. that the body region and injury severity patterns in New Zealand are similar to those in Australia, albeit of lower overall frequency to match differences in the number of injured occupants between both countries; and

2. that the Harm distribution calculation should be based on cost of injury using Willingness-To-Pay and Willingness-To-Accept methods suitable for New Zealand.

In addition, New Zealand traditionally uses a 10% discount rate for future earnings which is higher than that used in the earlier study. Moreover, fleet life figures do vary considerably between New Zealand and Australia, requiring local figures to be used for calculating unit Harm from annual Harm savings.

3.1 HARM DISTRIBUTION

To calculate a New Zealand equivalent of the Australian Harm distribution used in MUARC (1992), the following steps were undertaken.

3.1.1. Revised Injury Frequency

The Australian injury distribution, published in MUARC (1992) is shown in Table 3.1 below. Zeros show either that there were no injuries for a particular body region by AIS cell or that injury severity levels did not apply (upper limb injuries for example do not offer a threat to life beyond AIS 3).

Table 3.1 *Frequency of injury by body region and severity level in Australia (MUARC, 1992)*

	INJURY SEVERITY						
BODY REGION	Minor (AIS = 1)	Moderate (AIS = 2)	Serious (AIS =3)	Severe (AIS = 4)	Critical (AIS = 5)	Maximum (AIS = 6)	TOTAL
External*	0	521	7	0	10	19	557
Head	6201	11890	5395	3127	1599	149	28361
Face	48167	8193	742	52	0	0	57154
Neck	9731	1438	638	12	150	8	11977
Chest	21678	7709	6000	2637	869	205	39098
Abdomen-Pelvis	23518	7854	3864	562	425	6	36229
Spine	2467	2832	571	7	77	55	6009
Upper Extremity	31205	10198	2495	0	0	0	43898
Lower Extremity	41586	13055	6122	10	2	0	60775
TOTAL	184553	63690	25834	6407	3132	442	284058
No. Occupants Sustaining Injury							77194

* Injuries to the external parts of the body which were not assigned to specific body regions (Fatal File only).

This injury matrix was compiled from Australian statistics collected during the early 1990s, involving an annual casualty rate of over 77,000 injured occupants who sustained around 284,000 injuries. In New Zealand, there were on average 10,264 injured occupants during the mid-1990s from passenger car crashes (LTSA statistics, 1999). This represents 13.3% of the Australian figures. Applying this reduction to the Australian matrix, the equivalent body region by injury severity distribution for New Zealand is shown in Table 3.2.

Table 3.2 *Derived frequency of injury by body region and severity level in New Zealand, based on Australian relativities and New Zealand occupants injured.*

	INJURY SEVERITY						
BODY REGION	Minor (AIS = 1)	Moderate (AIS = 2)	Serious (AIS =3)	Severe (AIS = 4)	Critical (AIS = 5)	Maximum (AIS = 6)	TOTAL
External*		69	1		1	3	74
Head	825	1581	717	416	213	20	3771
Face	6404	1089	99	7			7599
Neck	1294	191	85	2	20	1	1593
Chest	2882	1025	798	351	116	27	5199
Abdomen-Pelvis	3127	1044	514	75	57	1	4817
Spine	328	377	76	1	10	7	799
Upper Extremity	4149	1356	332				5837
Lower Extremity	5529	1736	814	1			8081
TOTAL	24539	8468	3435	852	416	59	37769
No. Occupants Sustaining Injury							10264

*Injuries to the external parts of the body which were not assigned to specific body regions (Fatal File only)

3.1.2. Revised Cost Distribution

To arrive at a modified cost distribution, Willingness-To-Pay (WTP) figures currently used in New Zealand (1999 update) were available for use (Leung & Guria, 1999). These specify the cost of a fatal injury (AIS6) at NZ$2.4783 million, a serious non-fatal injury at NZ$261,100 and a minor survivable injury at NZ$13,500. Unfortunately, though, no breakdown of body region by injury severity for WTP costs was available. Hence, it was necessary to estimate this using other available data.

Comprehensive societal injury costs by body region and injury severity are published by Miller, Pindus, Douglass, & Rossman (1995). Their distribution for fatal and non-fatal injuries is shown in Table 3.3.

Table 3.3 *Comprehensive injury costs in USA in US$000s (source: Miller et al ,1995)*

	INJURY SEVERITY					
BODY REGION	Minor (AIS = 1)	Moderate (AIS = 2)	Serious (AIS =3)	Severe (AIS = 4)	Critical (AIS = 5)	Maximum (AIS = 6)
External*	3.95	*27.76*	*272.92*	*437.13*	*580.10*	2385.09
Head	6.95	165.58	392.99	1235.04	2421.89	2385.09
Face	8.27	47.37	295.31	836.45	1233.57	2385.09
Neck	8.27	47.37	295.31	836.45	1233.57	2385.09
Chest	5.16	27.76	297.84	607.85	580.10	2385.09
Abdomen-Pelvis	5.16	27.76	297.84	607.85	580.10	2385.09
Spine	5.16	27.76	315.91	1349.89	2522.41	2385.09
Upper Extremity	8.28	58.92	272.92			2385.09
Lower Extremity	5.21	55.61	429.08	437.13		2385.09

*Injuries to the external parts of the body which were not assigned to specific body regions (Fatal File only)

Fatal injury costs differed by a factor of 1.039 between New Zealand (1999 dollars) and those of Miller et al's in the USA (1995 dollars). By factoring up the USA figures to equate fatal injury costs, an equivalent WTP New Zealand injury cost matrix is produced , as shown in Table 3.4 below. It is important to recognise that this assumes similar AIS by body region relativities, not only between these two countries, but also between the different Willingness-To-Pay and Comprehensive costing models. This may require further testing ultimately, but was considered an acceptable first approximation.

Table 3.4 *WTP Cost of injury (NZ$000s) by body region and severity level in New Zealand*

	INJURY SEVERITY					
BODY REGION	Minor (AIS = 1)	Moderate (AIS = 2)	Serious (AIS =3)	Severe (AIS = 4)	Critical (AIS = 5)	Maximum (AIS = 6)
External*	4.10	*28.84*	*283.59*	*454.21*	*602.77*	2478.30
Head	7.22	172.05	408.35	1283.31	2516.54	2478.30
Face	8.59	49.22	306.85	869.14	1281.78	2478.30
Neck	8.59	49.22	306.85	869.14	1281.78	2478.30
Chest	5.36	28.84	309.48	631.60	602.77	2478.30
Abdomen-Pelvis	5.36	28.84	309.48	631.60	602.77	2478.30
Spine	5.36	28.84	328.26	1402.64	2620.99	2478.30
Upper Extremity	8.60	61.22	283.59			2478.30
Lower Extremity	5.41	57.78	445.85	454.21		2478.30

*Injuries to the external parts of the body which were not assigned to specific body regions (Fatal File only)

3.1.3. Revised NZ Harm Distribution

The final step was to simply multiply the amounts in Tables 3.2 and 3.4 together to derive the overall New Zealand Harm distribution. However, multiple injuries per injured occupant did present a problem as it overstated the total Harm (Miller's costs were based on single, not multiple, injuries). Thus, it was necessary to make one further and final adjustment to ensure that the total Harm for frontal crashes was equivalent with the value expressed for New Zealand (78% of NZ$2.9 billion in 1999 prices). All Harm cells were then discounted to yield NZ$2.267 billion total Harm, as shown in Table 3.5 below.

Table 3.5 *WTP Harm distribution (NZ$million) by body region and severity level in New Zealand*

	INJURY SEVERITY						
BODY REGION	Minor (AIS = 1)	Moderate (AIS = 2)	Serious (AIS =3)	Severe (AIS = 4)	Critical (AIS = 5)	Maximum (AIS = 6)	TOTAL
External*		1.2	0.2		0.5	3.9	5.8
Head	9.6	168.6	181.6	330.8	331.7	30.4	1052.6
Face	34.1	33.2	18.8	3.7			89.8
Neck	6.9	5.8	16.1	0.9	15.8	1.6	47.2
Chest	9.6	18.3	153.0	137.3	43.2	41.9	403.3
Abdomen-Pelvis	10.4	18.7	98.6	29.3	21.1	1.2	179.2
Spine	1.1	6.7	15.4	0.8	16.6	11.2	52.0
Upper Extremity	22.1	51.5	58.3				131.9
Lower Extremity	18.6	62.2	225.0	0.4			306.1
TOTAL	112.4	366.3	767.0	503.1	428.9	90.3	2267.9
No. Occupants Sustaining Injury							10264

*Injuries to the external parts of the body which were not assigned to specific body regions (Fatal File only)

Chapter 4 Injury Reductions and Annual Harm Saved

The detailed assumptions (and information source) used for Harm reduction by each body region injury, and contact source for the driver airbag in the original MUARC airbag analysis are outlined below. Relevant data sources for these injury mitigations come from Zuby and Saul (1989), Highway Loss Data Institute (1991), Zador and Ciccone (1991) and Yoganandan, Sances, Pintar, Reinartz and Haffner (1991). From these reports, the following assumptions were made:

4.1 SCOPE OF BENEFIT

It was estimated that a full size driver airbags would reduce injuries to front seat occupants in frontal crashes between crash severities from 16-64km/h (10-40mph). Below these speeds, the airbag would not deploy, hence there would be no benefit and above 64km/h, it was unlikely that the airbag would be of any benefit, given the high impact severity and associated energy displaced. This is illustrated graphically in Figure 4.1 below.

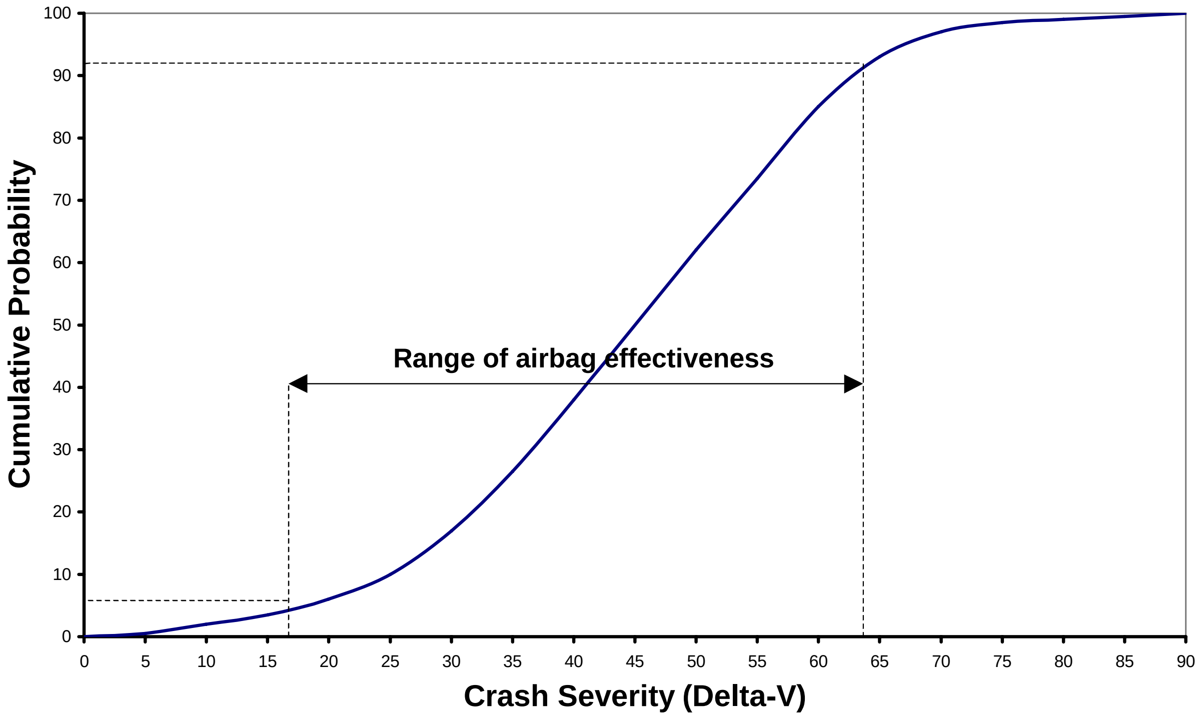

Figure 4.1 *Airbag range of effectiveness assumption (from MUARC, 1992)*

4.2 RELEVANT BODY REGIONS

Based on all available evidence at the time, it was assumed that injury reductions to occupants in the original study (MUARC, 1992) would come from a number of body region and injury source contacts. These were:

- that there would have been 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 restrained and unrestrained occupants involved the same body areas and contacts 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 2AIS injury reduction to restrained occupants, and a 3AIS reduction for head and chest injuries to unrestrained occupants.

4.2.1 Restrained and Unrestrained Occupants

While Supplementary Restraint System (SRS) airbags are designed primarily for added benefits to restrained occupants, it was expected that these units would also provide benefit to unrestrained occupants. For the latter, an extra benefit would be gained from fewer ejections from the vehicle.

Australia has had a consistent seatbelt wearing rate for front seat occupants of 94% for most of the ninetees (Ove Arup, 1995). Fildes, Lane, Lenard, & Vulcan (1991) reported that unrestrained occupants were three times overrepresented among hospitalised casualties, illustrating both the benefits of wearing seatbelts in a crash and an increased likelihood of crash involvement among unrestrained occupants.

New Zealand’s seat belt wearing rate for front seat occupants is 89% (LTSA, 1999). While there are no published figures of restraint wearing levels among hospitalised crash occupants in this country, it would reasonably be expected to be over-represented for similar reasons to those in Australia. A larger unrestrained population, however, is also likely to have an equal injury disbenefit but a smaller crash-involvement proportion (more of the unrestrained would simply be forgetful individuals). Therefore, it was assumed that the equivalent unrestrained rate in New Zealand casualties was around 25% (1.39 times the equivalent rate in Australia).

4.2.2 Recent Evidence

There have been a few additional evaluation studies carried out of airbag performance since the original MUARC analysis was conducted. Generally these all tend to show even greater benefits than were originally expected in Australia (eg: Fildes et al, 1996; Morris, Barnes, Fildes, & Bentivegna, 2000). As it would have been an expensive exercise to repeat the original injury reduction analysis for only marginal additional benefit, it was not undertaken in this study. It should be noted, however, that based on later research, the benefits calculated in this study for New Zealand are likely to be conservative.

4.2.3 Relevant Body Regions

In estimating the benefits of airbags in reduced injury to drivers, it was assumed that only a select few body regions would benefit from fitment of an airbag. These included reduced injury to the head, chest, abdomen, and face for both restrained and unrestrained occupants. Some extra benefit was also expected to the upper limbs but only for unrestrained occupants through fewer severe injuries from exterior contacts during ejections.

Given the nature of airbag designs, they were not expected to provide any injury reductions to upper limbs for restrained occupants or to the lower limbs for either restrained or unrestrained occupants. Indeed, recent evidence in Fildes et al (1996) and Morris et al (2000) shows that these assumptions were generally correct, although there has been a slight increase in upper limb AIS 1 injuries from airbag abrasions during deployment.

4.3 ANNUAL HARM SAVINGS

These assumptions were then applied systematically to the existing Harm distributions by body region, injury severity and contact source to arrive at the annual Harm savings. In calculating the relevant figures for New Zealand, the Australian Harm distributions were adjusted based on the ratios derived between New Zealand and Australian equivalents. These are shown in Table 4.1 below.

Table 4.1 *Ratios of New Zealand to Australian Harm*

	INJURY SEVERITY						
BODY REGION	Minor (AIS = 1)	Moderate (AIS = 2)	Serious (AIS =3)	Severe (AIS = 4)	Critical (AIS = 5)	Maximum (AIS = 6)	TOTAL
External*		0.29	0.82		0.99	0.63	0.5
Head	0.75	1.45	0.84	1.14	0.63	0.62	0.87
Face	0.34	0.41	0.63	1.33			0.42
Neck	0.34	0.41	0.63	1.43	0.97	0.63	0.59
Chest	0.29	0.29	1.10	1.38	0.91	0.62	0.89
Abdomen-Pelvis	0.29	0.29	1.10	1.38	0.91	0.61	0.75
Spine	0.29	0.29	0.50	0.23	0.39	0.61	0.42
Upper Extremity	0.34	0.35	0.69				0.44
Lower Extremity	0.29	0.33	0.85	0.62			0.59
TOTAL	0.34	4.10	7.14	7.52	4.80	3.71	0.72

Ratios calculated by dividing values in Table 3.6 in Chapter 3 with those in Table 5.6 in MUARC (1992).
*Injuries to the external parts of the body which were not assigned to specific body regions (Fatal File only)

4.3.1 Harm Summary

The various body region savings were then adjusted for differences in the level of restraint wearing among the injured driver population and summed across the relevant body regions to arrive at the expected annual Harm saved in New Zealand if all vehicles were fitted with airbags. These results are shown in Figure 4.2.

As noted above, airbags were only expected to provide limited benefits to particular body regions and for a select speed range of crashes. The savings were derived from estimating a shift in the injury distribution for airbag fitted vehicles and the subsequent cost savings.

Table 4.2 *Summary of Body Region Harm Benefits in Australia and New Zealand ($mil)*

Body Region	**Australian Figures**	**NZ Equivalents**	**NZ seatbelt adjusted**
Head – restrained	192.7	168.1	153.7
Head – unrestrained	56.5	44.5	61.8
Chest – restrained	92.9	73.1	66.8
Chest – unrestrained	19.0	14.4	20
Abdomen – restrained	9.1	8.6	7.9
Abdomen – unrestrained	7.5	6.9	9.5
Face – restrained	70.5	30.3	27.7
Face – unrestrained	19.9	8.5	11.8
Upper Extremity – unrestrained	7.6	3.4	4.7
Restrained Annual Harm	**365**	**280**	**256**
Unrestrained Annual Harm	**111**	**78**	**108**
Total Annual Harm Saved	**476**	**358**	**364**

These figures show that the total expected annual Harm saved in New Zealand if all vehicles were fitted with a driver airbag would be NZ$364 million. This represents 76.5% of the equivalent Australian figure, ignoring any differences in currency values.

As the New Zealand vehicle population is only approximately 22% of that in Australia, it can be assumed that the bulk of the proportional increase in Harm saved in New Zealand over Australia can be attributed to the use of Willingness-To-Pay injury costs over Human Capital equivalents.

For calculating Benefit-Cost-Ratios, it is necessary to convert the expected annual Harm (H) saved into unit Harm (h) savings (the expected savings over the life of a single vehicle). This process is explained further in Chapter 6.

Chapter 5 After-Market Airbag Fitment Costs

The replacement cost of an airbag in New Zealand was derived from discussions with a number of informed organisations in New Zealand. These groups were visited by the project team in New Zealand and are listed in Table 5.1 below.

Table 5.1 *Organisations visited in New Zealand to derive airbag replacement costs.*

Organisation	Contact	Organisation	Contact
Honda New Zealand	Neli Butterfield	Collision Repair Association	Andrew Garrett
Whittleston Panels, Wellington	Paul Wittleston	Independent Motor Vehicle Dealers Association	John Nicholls
Motor Industry Association	Perry Kerr	Holden Australia, Auckland	Simon Whiteley
Motor Trade Association	Garry Williams	Nissan New Zealand, Auckland	Simon Whiteley

From these discussions and some additional telephone calls, a sample of replacement airbag costs was derived as shown in Table 5.2.

Table 5.2 *Airbag replacement costs in New Zealand, November, 1999*

Make & Model	Driver Airbag $	Sensor/ECU $	Labour $max	Other $	Total $
Holden Commodore	1,500	700[1]	200[2]		2,400
Ford Falcon	427	700[1]	200[2]		1,327
Alfa Romeo	2,480	1,840	200[2]	415	4,935
Honda (all models)	840	1,180	200[2]		2,220
Toyota (most models)	934	1,349	200[2]		2,438
Subaru Legacy	1,600	incl.	200[2]		1,800
BMW – 3 series	720	400	200[2]		1,320
Jaguar					4,000
VW (all models)					3,500
Porche (all models)					3,500
Audi (all models)					3,500
Suzuki	600	500[1]	200[2]		1,300
Nissan Primera	1,886	550	200[2]		2,636
Nissan Pulsar	1,800	550	200[2]		2,550

[1] *best estimate, verified from Australian component suppliers*
[2] *labour times provided by industry representatives*

5.1 COMMENTS DURING VISITS

A number of relevant comments regarding the replacement of airbags and their costs were elicited during the various discussions with the industry representatives and these are listed below for additional information.

- Consensus seemed to be that some cars are repaired in Japan without replacement of driver airbag in airbag-specification vehicles but this is not a common procedure.
- Both repaired and un-repaired cars do turn up in New Zealand - if in an un-repaired state, the airbags are usually 'hanging' out of the steering wheel in which case the motor body repairer would normally replace the airbag.
- There is a possibility that the frequency of importing cars from Japan may alter in the years ahead because Europe (and especially the UK) is to open its doors to second-hand Japanese vehicles. The profit made from exporting to Europe is greater than exporting to New Zealand, hence the availability of vehicles in New Zealand could change.
- Currently any age of vehicle can be imported from Japan but 6 to 10 years is common.
- It is now becoming more common for New Zealand to import new rather than second-hand cars.
- All distributors offer the repair industry a discount on airbag units, normally about 20%. This is seen as justification for visiting the panel shops as a more realistic 'industry' specific price will be quoted.
- The price of an airbag module in New Zealand is the same as in other countries, the freight costs increase the pricing.
- The expectation was that airbag prices will come down in the years ahead as volume increases.
- There was conflicting information about whether the sensing systems needed to be replaced. For some vehicles (eg: Holden Commodore), it is certain that the sensing system has to be replaced. For others, there was a view that sensing systems have become so sophisticated that they can cope with multi-sensing (i.e. can be used over and over again). On that basis it was assumed that at present, 10% of sensors can be used whilst the majority need to be replaced, but in 5 years time, the balance may be closer to 50/50.
- The issue of airbag degradation might be of some relevance given that an airbag might decay beyond its useful life after ten years or so (BMW recommend airbag replacement after 15 years).
- There is a need to establish current compliance standards in New Zealand. For example, some talk that the frontal impact compliance standard was introduced in March 1999 but other standards applied before this date.
- The insurers have some say over what can and cannot be replaced. It was reported that there have been instances where the insurers have actually stipulated that the sensor should not be replaced because of cost, even if the airbag is replaced.
- The crux of the whole matter seems to be the New Zealand frontal impact rule (introduced March 1999) which stipulates that '*the repaired vehicle must be brought back to the original manufacturer's specification'* (Land Transport Rules 32006, para 2.6).

5.2 FUTURE OF REPLACEMENT AIRBAG COSTS

As noted from comments made during the visits to the various organisations, there was a high degree of expectation that replacement airbag costs will fall in New Zealand in the years ahead. The reasons for this include an increase in sales volume as more and more cars on New Zealand roads have airbags fitted as well as associated price reductions from improved airbag technology.

To estimate what these price reductions would likely be, a similar pricing exercise was conducted in Australia where there is generally a higher airbag exposure to New Zealand currently as well as higher volumes. Table 5.3 shows the findings from that additional analysis.

Table 5.3 *Airbag replacement costs in Australia, August, 2000*

Make & Model	Driver Airbag $	Sensor/ECU $	Labour $max	Total A$	Total NZ$
Holden Commodore	407	178	200	785	950
Ford Falcon	352	89	200	641	770
Honda Accord	987	812	200	1999	2400
Toyota Camry	176	812	200	1188	1425
Subaru Baleno	1305	255	200	1760	2112

On this basis, a 20% to 40% reduction in the price of replacement airbags would not be unreasonably expected in New Zealand in the coming years.

5.3 DISCUSSION

On the basis of the information presented above, it is reasonable to assume the following costs for a replacement airbag in New Zealand:

- immediate cost - NZ$1320 is not unreasonable (this is justified on the basis that if BMW and Suzuki vehicles can meet these costs, then so should most others); and

- future cost – NZ$950 or NZ$770 are a reasonable estimates, based on the difference currently between replacement costs in Australia and New Zealand. This might even fall beyond these figures in future as efficiencies and exposure increase substantially in the years ahead.

Chapter 6 Benefit-Cost-Ratio Calculation

6.1 INTRODUCTION

The objectives call for examination of the requirement to replace any driver airbag, which is inoperative at the time of importing or because of a crash in New Zealand, and determine the Benefit-Cost-Ratio (BCR) by the age of the vehicle for the replacement. Cars, which are damaged so badly that they are written off, are excluded from the requirement to replace the airbag, but if the only reason for the write-off is the airbag replacement cost- they are included.

The calculation needs to be done somewhat differently from that done in CR100, because it applies only to those cars with a replacement airbag, rather than all new cars. The total annual Harm savings for the whole crashed fleet in Chapter 4 provide the basis for calculating the average Harm saved in a crash resulting from deployment of the airbag.

6.2 BENEFITS

The first step is to follow a car throughout its life, starting when the airbag is fitted, and to calculate the probability of a crash resulting in an airbag deployment during that period. The calculation of benefits then requires a value for the driver injury cost savings ($h) in the average relevant crash when an airbag is operative, compared with when the airbag is non-operative. A relevant crash is defined as one in which a driver airbag, if present, would have been deployed, i.e. essentially frontal and at a velocity change sufficient to deploy an airbag. As the database does not contain velocity change, a relevant crash has been defined as a frontal crash in which the driver was injured.

An alternative would be a crash in which any vehicle occupant was injured. The former is a slight underestimate because it omits the relatively few cases where a driver airbag was present and there were no driver injuries after its deployment, while the latter is likely to be an overestimate because it could include cases where the driver was not injured, even without an airbag. On balance the former estimate is considered to be the more appropriate, even though it is a slight underestimate of the potential benefits.

Then, on average, the benefit for a car just fitted with an airbag, over the next n years (ignoring discounting) is determined from the following formula.

$$\text{benefit} = h(p_a + p_{a+1} + ... + p_n) = h\sum_{i=0}^{n-a} p_{a+i} \quad \textbf{(1)}$$

where: p_{a+i} = the probability of this car having a relevant crash during the calendar year when it reaches "$a+i$" years of age, that is "i" years after the airbag was replaced.

a = the age of the car at the end of the calendar year during which the airbag was replaced, ie. the age of a car is 0 during the whole of the calendar year when it was new, and the age is 1 year during the whole of the next calendar year.

i = the number of years since the airbag was replaced

n = the maximum car age for which a calculation of benefits is made

Thus:

p_a = the probability of this car (aged *a* years) having a relevant crash during the calendar year in which the airbag was replaced

Note for a new car *a*=0 and equation (1) reduces to:

$$\text{benefit} = \text{h}(\text{p}_0 + \text{p}_1 + ... + \text{p}_\text{n})$$

Then p_{a+i} is defined as $p_{a+i} = \frac{f_{a+i}}{v_{a+i}}$ where

f_{a+i} = the number of relevant crashes of cars aged $a+i$ years, expected during the calendar year which occurs in *i* years from now

v_{a+i} = the number of cars aged $a+i$ years on the register in i years from now

As neither f_{a+i} nor v_{a+i} are known they must be estimated. An acceptable approximation is to assume that the probability of a car now aged "*a*" years having a relevant crash during the calendar year *i* years from now (when it will be *a+i* years old) is the same as the probability of a car which is *a+i* years old now, having a relevant crash this year,

i.e. $P_{a+i} = \frac{F_{a+i}}{V_{a+i}}$

Then it is assumed that p_{a+i} equals P_{a+i}

where:

P_{a+i} = the probability of a car $a+i$ years old having a relevant crash this year

F_{a+i} = the number of relevant crashes this year involving a car $a+i$ years old

V_{a+i} = the number of $a+i$ year old cars on the register this year

The above formula makes no allowance for scrappage, which should be done, because a vehicle fitted with an airbag this year will not be available to provide airbag benefits in a future crash if it is scrapped in the meantime. For the purpose of this calculation "scrappage" is defined to include all vehicles in which an airbag is deployed, as well as all vehicles which are removed from the road for other reasons, such as damaged beyond repair, rusted out or exported.

It should be noted that all vehicles in which an airbag is deployed are designated as "scrapped" even if the airbag is replaced and the vehicle put back on the road, because for the purposes of calculating the airbag benefit, a vehicle must be excluded once that specific airbag is no longer available to provide future benefits. (The calculation of benefits from the replacement airbag would be a separate calculation similar to that now being done).

Hence allowing for scrappage:

$$p_{a+1} = \frac{F_{a+i}}{V_{a+i}}(1-s_{a+1})$$

$$p_{a+2} = \frac{F_{a+2}}{V_{a+2}}(1-s_{a+1})(1-s_{a+2})$$

$$p_{a+i} = \frac{F_{a+i}}{V_{a+i}}(1-s_{a+1})(1-s_{a+2})......(1-s_{a+i}) = \frac{F_{a+i}}{V_{a+i}}\prod_{j=0}^{i} 1-s_{a+j})$$

where:

s_{a+j} = the probability of a vehicle being "scrapped" in the calendar year during which it becomes $a+j$ years old, i.e. j years after the airbag was replaced.

s_a is taken to be zero.

6.3 BENEFIT-COST-RATIO (BCR)

In order to calculate Benefit-Cost-Ratio (BCR), the benefit per car in equation (1) must be discounted so that future benefits are expressed in present day terms, and then divided by the average present day cost of replacing an airbag ($c),

$$BCR = \frac{h}{c}(p_a + \frac{p_{a+1}}{(1+d)} + \frac{p_{a+2}}{(1+d)^2} + ...\frac{p_n}{(1+d)^{n-a}})$$

$$= \frac{h}{c}\sum_{i=0}^{n-a}\frac{p_{a+i}}{(1+d)^i} \qquad \textbf{(2)}$$

where:

d = discount rate $(\frac{percent}{100})$

c = average replacement cost of an airbag ($NZ) at import or after a crash, and

$$p_{a+i} = \frac{F_{a+i}}{V_{a+i}}\prod_{j=0}^{i}(1-s_{a+j})$$

This calculation of BCR can be done for whatever value of n (life of car) which is selected for the purposes of this calculation. The calculation has to be done for several values of "a" (car age when airbag was replaced), so that the value of "a" for which the BCR just exceeds 1:1 can be found. Initially the calculation will be done for values of *a* from 0 to 20, and for *n* = 30 years.

6.3.1 Discussion

The advantage of this method is that it is not necessary to know how many cars will be imported each year requiring an airbag replacement. The BCR is calculated for each car, according to the age at which the airbag replacement was made, and hence it is possible to determine the age of replacement at which the BCR becomes less than 1. Similarly it is not necessary to know what proportion of cars that crash each year will require an airbag replacement. Again the BCR is calculated for each age of car which requires a replacement airbag to determine the cut-off age, beyond which the BCR <1.

6.4 BENEFIT-COST-RATIO

Using the formula described above, it was possible to calculate the BCR for retrofit airbags by year of the vehicle as specified in objective 1. A number of different BCR values were computed for various discount rates (5% and 10%) and fitment costs (NZ$1,320, NZ$950 and NZ$770). These results are listed in Table 6.1 and shown graphically in Figures 6.1 and 6.2.

Table 6.1 *BCR for retrofitting airbags by vehicle age, discount rate and fitment cost*

Vehicle Age	5% Discount $1,320 cost	10% Discount $1,320 cost	5% Discount $950 cost	10% Discount $950 cost	5% Discount $770 cost	10% Discount $770 cost
0*	1.44	1.01	2	1.41	2.47	1.73
1	1.42	1.01	1.97	1.4	2.43	1.73
2	1.39	1.01	1.93	1.4	2.39	1.73
3	1.36	1	1.89	1.39	2.33	1.71
4	1.34	1	1.86	1.39	2.29	1.72
5	1.31	1	1.82	1.39	2.24	1.71
6	1.26	0.98	1.75	1.36	2.16	1.68
7	1.22	0.96	1.69	1.34	2.09	1.65
8	1.17	0.94	1.62	1.31	2	1.61
9	1.1	0.9	1.53	1.26	1.89	1.55
10	1.04	0.87	1.45	1.21	1.79	1.49
11	0.98	0.83	1.36	1.15	1.68	1.42
12	0.89	0.77	1.24	1.07	1.53	1.32
13	0.81	0.7	1.12	0.97	1.38	1.2
14	0.72	0.64	1	0.88	1.24	1.09
15	0.65	0.57	0.9	0.8	1.11	0.99
16	0.6	0.53	0.83	0.74	1.03	0.91
17	0.55	0.49	0.76	0.68	0.94	0.84
18	0.5	0.45	0.7	0.63	0.87	0.77
19	0.47	0.42	0.66	0.59	0.81	0.73
20	0.46	0.42	0.64	0.58	0.79	0.71
21	0.41	0.37	0.57	0.51	0.71	0.63
22	0.38	0.34	0.53	0.47	0.66	0.58
23	0.37	0.33	0.52	0.46	0.64	0.56
24	0.37	0.33	0.51	0.46	0.63	0.56
25	0.37	0.33	0.51	0.46	0.63	0.57
26	0.33	0.31	0.47	0.43	0.57	0.52
27	0.33	0.31	0.46	0.44	0.57	0.54
28	0.31	0.3	0.43	0.41	0.53	0.51
29	0.29	0.29	0.4	0.4	0.49	0.49

* *ZERO years represents cars in their first year of registration*

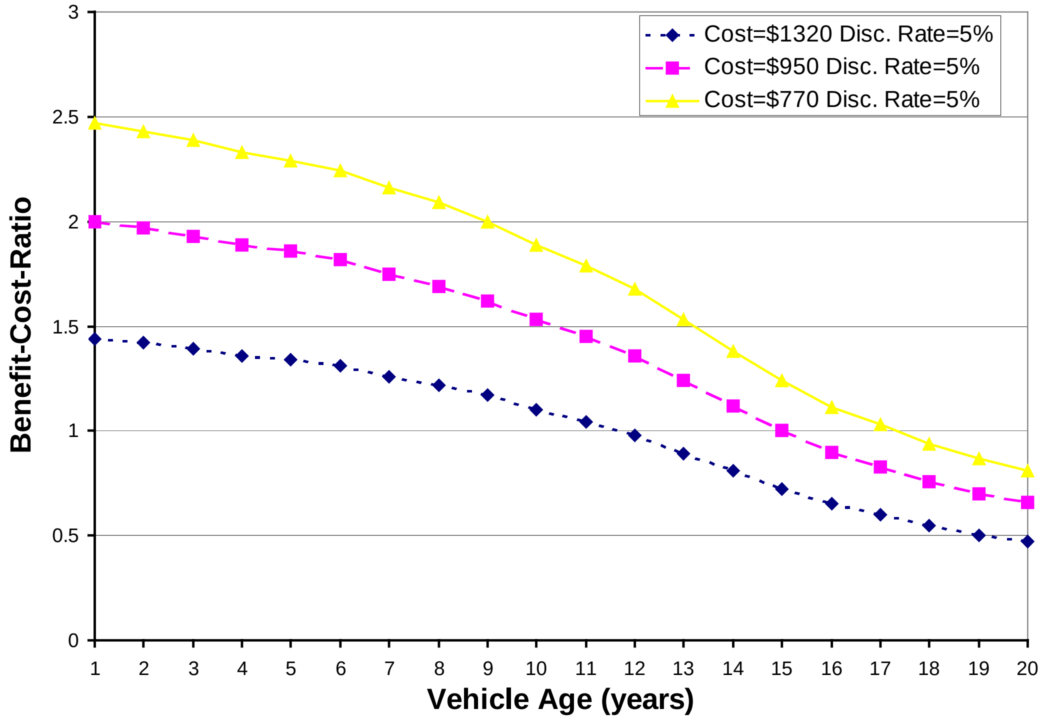

Figure 6.1 *BCR by vehicle age and various fitment cost for a 5% discount rate*

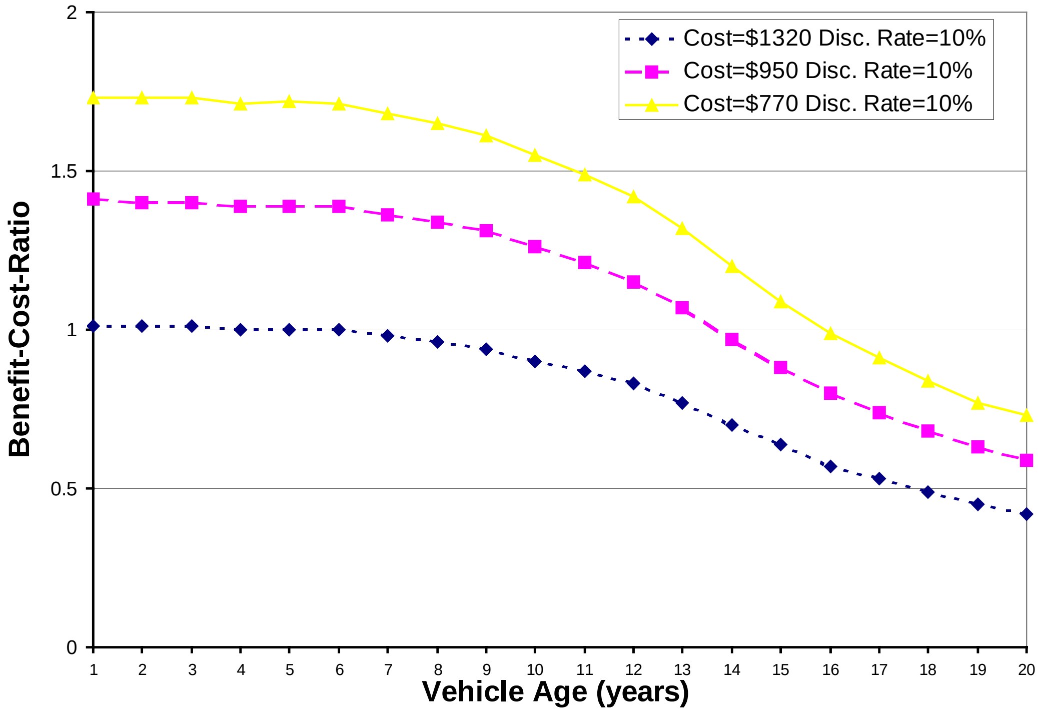

Figure 6.2 *BCR by vehicle age and various fitment cost for a 10% discount rate*

Chapter 7 Total System-Wide Airbag Benefits

It is often useful when calculating BCRs of a potential countermeasure to consider what the overall benefit of the countermeasure is across the whole system. This can provide a view of what the total extent of benefit is to society, in addition to the unit benefit cost ratio of the measure, calculated for replacement of an airbag in a vehicle of a specific age. Thus, while the marginal BCR might be close to zero, the overall BCR of a policy requiring airbags to be replaced, irrespective of age, may still be cost beneficial.

In previous chapters, the marginal BCR of replacing the airbag was calculated for each car based on its residual life, or until deployment of the airbag. In this additional analysis the overall BCR for the policy of fitting airbags to new cars and imported cars and replacing the airbag unless the car is to be scrapped, irrespective of the age of the car, is calculated for the whole system. It is based on the argument that it is inconsistent to allow any car, which had an airbag when new to be allowed to operate on NZ roads without an airbag, irrespective of the age of the car. This argument acknowledges that the marginal BCR for airbag replacement on some older cars will be less than 1, but ignores this in favour of considering the overall BCR for the whole system.

An analogy would be seatbelts where presumably these are required to be replaced if damaged, irrespective of the age of the car.

7.1 BENEFITS

The system-wide benefit is made up of two component benefits, namely those from new cars as well as from imported used cars. These are outlined separately below.

7.1.1 New Cars

The total benefit B_1, discounted to the present, for the fleet of new cars registered in one year and fitted with airbags over their life can be calculated using an equation similar to Equations (1) and (2) in the main analysis, but with *a=0* as

$$B_1 = Mh\left(p_0 + \frac{p_1}{(1+d)} + \frac{p_2}{(1+d)^2} + \ldots.. + \frac{p_n}{(1+d)^n}\right) = Mh\sum_{i=0}^{n}\frac{p_i}{(1+d)^i} \quad \textbf{(3)}$$

where,

M is number of new cars fitted with an airbag registered in one year,

$\$h$ is the injury cost saving in the average relevant crash when an airbag is operative, compared with when the airbag is non-operative,

p_i the probability of an airbag fitted car having a relevant crash during the calendar year when it reaches "*i*" years of age,

d is the discount rate $(\frac{percent}{100})$

Using the same assumptions as previously, when allowance is made for scrappage;

$$p_i = \frac{F_i}{V_i}(1-z_i)(1-z_2)...(1-z_i) = \frac{F_i}{V_i}\prod_{j=0}^{i}(1-z_j)$$

where,

F_i = the number of relevant crashes this year involving a car *i* years old

V_i = the number of *i* year old cars on the register this year

z_j = the probability of a car being scrapped in the calendar year during which it becomes *j* years old, and

z_0 is defined as zero.

In this analysis, "scrappage" is defined somewhat differently than for the previous analysis, namely it includes all those cars which are removed from the vehicle fleet, but not those cars where an airbag is deployed and replaced so that the vehicle can remain on the register. (In this calculation it is assumed that all airbags are replaced in vehicles which are otherwise able to return to the registered vehicle fleet, whereas previously, a vehicle is removed from the calculation once it has been involved in a crash involving airbag deployment)

7.1.2 Imported Used Cars

The total benefit B_2 for the group of used cars fitted with an airbag, imported in one year, over their residual life is

$$B_2 = Uh\left(p_a + \frac{p_{a+1}}{(1+d)} + ... + \frac{p_n}{(1+d)^{n-a}}\right) = Uh\sum_{i=0}^{n-a}\frac{p_{a+i}}{(1+d)^i} \qquad \textbf{(4)}$$

where,

U is the number of used cars imported with an airbag (assumes any airbags not operational would be replaced at import),

a is the average age of imported used cars fitted with an airbag

p_{a+i} is the probability of an airbag fitted car having a relevant crash during the calendar year when it reaches "a+*i*" years of age (as in (a) above), i.e. *i* years after being imported.

As in 7.1.1 above

$$p_{a+i} = \frac{F_{a+i}}{V_{a+i}}(1-z_{a+1})(1-z_{a+2})....(1-z_{a+i}) = \frac{F_{a+i}}{V_{a+i}}\prod_{j=1}^{i}(1-z_{a+j})$$

7.2 BENEFIT-COST-RATIO (BCR)

It is necessary to calculate the total costs of replacing airbags for both fleets whose benefits were calculated in Section 7.1 above, as well as the notional initial costs of the airbags.

7.2.1 New Cars

Total cost C_1, of replacing airbags after deployment over the life of these cars, discounted to present days costs is calculated using the same equation as **(3)** but with *h* being replaced by *c*.

$$C_1 = Mc\left(p_0 + \frac{p_1}{(1+d)} + \frac{p_2}{(1+d)^2} + ... + \frac{p_n}{(1+d)^n} \right) = Mc\sum_{i=0}^{n} \frac{p_i}{(1+d)^i}$$

where,

c = average replacement cost of an airbag ($NZ) after a crash

The total additional cost *X* of requiring airbags to be fitted to new cars ($NZ) must be added to obtain the total costs of the airbag program for new cars.

$X = Mx$, where *x* ($NZ) is the average additional cost of an airbag as original equipment in a new car.

Hence total costs = X+C_1 and the system-wide BCR for airbags on new cars is

$$\frac{B_1}{X + C_1} = \frac{h\sum_{i=0}^{n} \frac{p_i}{(1+d)^i}}{x + c\sum_{i=0}^{n} \frac{p_i}{(1+d)^i}}$$

Note that this is independent of *M*, as *M* is a common factor which has been cancelled out in all three terms.

7.2.2 Imported Used Cars

Total costs C_2 of replacing airbags after deployment over the residual life of imported used cars is calculated using the same equation as (4), but with *h* being replaced by *c*.

$$C_2 = Uc\left(p_a + \frac{p_{a+1}}{(1+d)} + \frac{p_{a+2}}{(1+d)^2} + ... + \frac{p_n}{(1+d)^{n-a}} \right) = Uc\sum_{i=0}^{n-a} \frac{p_{a+i}}{(1+d)^i}$$

As for new cars the additional notional costs of airbags originally fitted to imported used cars *Y($NZ)* must be added to obtain the total costs of the airbags for imported cars.

$$Y = Uy(1-g) + Ucg$$

where,

y is the average additional cost ($NZ) of an imported used car with an airbag versus one without an airbag

g is the proportion of imported used cars which had an airbag as original equipment, but where the airbag is not operational at the time of import (and must be replaced at cost $c)

Hence total costs = $Y + C_2$ and system-wide BCR for airbags on imported used cars is

$$\frac{B_2}{Y + C_2} = \frac{h\sum_{i=0}^{n-a} \frac{p_{a+i}}{(1+d)^i}}{y(1-g) + cg + c\sum_{i=0}^{n-a} \frac{p_{a+i}}{(1+d)^i}}$$

Again this is independent of U (the number of used cars imported with an airbag), as U is a common factor which has been cancelled out in all four terms.

The total system wide BCR for both airbags in new cars and in imported used cars always being replaced is:

$$\frac{(B_1 + B_2)}{(C_1 + X + C_2 + Y)}$$

If this is required then M and U must be estimated.

7.3 RESULTS

The calculation uses the same airbag benefit *h* calculated in the previous analysis and the same airbag replacement costs ($c) but requires additional data which may have to be estimated, including:

- *x*: the average additional cost of an airbag as original equipment in a new car – estimated to be $800 (NZ)
- *y:* the average additional cost of an imported used car with an airbag to one without can be estimated from $*x* (the new car additional cost) but depreciated to the average age of imported used cars, say 50% of *x* that is y=$400 (NZ)
- *g*: the proportion of imported used cars, in which the original equipment airbag is not operational and must be replaced, say 0.1

Again, the calculation was undertaken for two discount rates (5% and 10%) and for three used airbag replacement costs ($1320, $950 and $770). The resultant figures computed are listed below in Table 7.1.

Table 7.1 *System-wide benefits in NZ for airbags in new and used vehicles*

Cost of Used Airbag	**Discount Rate**	
	5%	**10%**
NZ$770	3.39	2.51
NZ$950	3.33	2.47
NZ$1,320	3.21	2.38

7.4 DISCUSSION

It is interesting to note that the BCRs calculated for the total system-wide effects are significantly greater than the marginal BCRs for replacing deployed airbags in used vehicles of any age. This is predominantly due to the significant benefits that accrue from airbags in new vehicles (they have a maximum expected life over used vehicles and their fitment cost is substantially lower than the replacement cost).

What this shows is the substantial overall safety benefit of cars in the New Zealand fleet being fitted with airbags. Allowing imported used vehicles, which had airbags as original equipment on the roads without operable airbags, would substantially dilute this benefit.

Chapter 8 General Discussion

This research set out to estimate the likely Harm benefits for New Zealand of mandating retrofitting driver's airbags to second-hand vehicles where an airbag had been supplied as original equipment but had subsequently not been replaced after a crash or was shown to be inoperative. This was especially important for New Zealand, given that they allow importation of second-hand cars and have an annual inspection program of all vehicles on their roads.

The main study objective was to estimate the benefits and costs (BCR) by vehicle age when the airbag is fitted retrospectively. This was to include different discount rates of future benefits (5% and 10% values) as well as current and future fitment costs. In addition, it was to estimate the total system-wide benefits of mandating airbag fitment in suitable vehicles. The study was to use Willingness-To-Pay (WTP) injury costs applicable in New Zealand and local fitment costs for replacement airbags.

The analysis was to use the same methodology as that used in an earlier study by the Monash University Accident Research Centre (MUARC, 1992) for the Federal Office of Road Safety in Australia, with a number of revisions to take account of the special nature of the task. There are a number of aspects of these analyses that require further discussion.

8.1 ASSUMPTIONS

As is normal in analyses such as these, it was necessary to make a number of assumptions during the course of this research as described throughout the report. The more important assumptions are listed below with the justification for their use.

8.1.1 Harm Reduction Method

The Monash University Accident Research Centre previously computed the benefits and costs of airbags in Australia in a report to the Federal Office of Road Safety (ATSB) (MUARC, 1992) using the Harm reduction method. It was agreed that this approach was suitable for use in this study also as it provided a systematic and transparent method of estimating the likely benefits of a future countermeasure. The method has widespread acceptance around the world and is applicable for the level of data available in New Zealand.

8.1.2 New Zealand Harm Distribution

It was necessary to construct a baseline Harm distribution for calculating airbag benefits using this approach. Several assumptions were made in constructing this database.

- Applicable Vehicle Fleet - airbags are gradually being fitted to vehicles other than passenger cars. However, there is less reason to expect these vehicles to have airbags as they are not currently expected to meet frontal design regulations. Thus, only benefits to drivers in passenger cars were considered here.

- Injuries to Vehicle Occupants - As there were insufficient in-depth crash data available in New Zealand, it was assumed that the Australian distribution was applicable for New Zealand, albeit for a fewer number of injuries and injured occupants (13.3% based on local crash statistics).

- WTP Costs By Injury Severity – New Zealand has detailed Willingness-To-Pay injury costs for fatalities but little WTP cost information on less severe injuries. Relativities published in the USA by Ted Miller during the mid-nineties were deemed to be applicable, adjusted to suit New Zealand fatal injury costs.
- Total Harm – The total cost of road trauma in New Zealand was listed as NZ$2.9 billion in 1999 of which 78% of that (NZ$2.27 billion) was estimated to be applicable to injured vehicle occupants.
- Seatbelt Wearing Rates – Seatbelt wearing rates of front seat occupants in New Zealand was observed to be 89% in 1999. Australian experience shows that unrestrained occupants are over-represented as injured casualties. On this basis, it was assumed that unrestrained occupant trauma was 25% of the total annual Harm in New Zealand.

8.1.3 Injury Reductions

The earlier study in Australia (MUARC, 1992) determined that driver airbags would be effective for crash severities between 16 and 64km/h delta-V. The lower limit represented the average deployment threshold while the upper limit represented the maximum severity for which the airbag was expected to provide an added restraint benefit in a crash.

The earlier study also assumed that airbag benefits for the driver would come from a number of reductions in injury severity to various body regions. These were essentially to the head, face, chest and abdomen from contacts with steering wheel, instrument panel, windscreen and A-pillar. Unrestrained drivers would also benefit from an airbag fitted to the steering wheel.

Recent evidence suggests that the injury reductions in MUARC (1992) are realistic, albeit conservative. On this basis, it was deemed suitable to use the original injury reduction assumptions for this analysis also.

8.1.4 Airbag Costs

The cost of replacing airbags in New Zealand was estimated from discussions with numerous dealers, collision repairers, and motor industry and trade organisations. A range of parts and labour costs was compiled from information supplied for vehicles sold in New Zealand. On this basis, it was assumed that the cost of $1,320 (that relevant for a BMW Series 3) was a reasonable estimate for current replacement cost in New Zealand.

The cost of airbag replacement was also expected to reduce in the years ahead as efficiencies and exposure increase and the technology improves. On the basis of current airbag replacement costs in Australia (converted to New Zealand dollars), it was estimated that future costs of NZ$950 and NZ$770 was not unreasonable.

8.1.5 BCR Calculations

Several assumptions were necessary in estimating expected benefits of mandating retrofit airbags in vehicles where they were originally fitted but not subsequently replaced.

- Relevant Crashes – these were defined as all frontal crashes where a driver was injured. This was necessary as there were no data available on impact severity. It was concluded that this would most likely be a slight underestimate of the potential benefits.
- Harm per Crash – the annual Harm saved per crash was assumed to be the total Harm saved to drivers, divided by the average number of crashes annually (the average from

1998 and 1999 statistics provided by the LTSA). The Harm benefit, then, is the annual Harm saved by the probability of crashing accumulated for up to 30 years.

- Scrappage Rates – In computing benefits, it was important to take account of the vehicles that disappear from the fleet each vehicle year. This includes scrappage from crashing, wear and tear and other reasons (export, non-registration for financial reasons, etc). The pattern of scrappage over the last 30 years provided by the LTSA was assumed to continue and thus represented future scrappage patterns for the analyses.
- Discount Rates – current policy decisions in New Zealand assume a 10% discount rate on future earnings, which is quite a severe discount rate compared with other countries (4% and 7% in Australia and 4% maximum in the USA). Thus, benefits have been calculated for both a 10% and 5% discount rate.

8.1.6 System-Wide Calculations

Calculation of the total system-wide benefits of airbags (in both new and second-hand cars) is an important adjunct to an individual BCR computation. While the marginal BCR might be close to zero, the overall BCR of a policy requiring airbags to be replaced, irrespective of age, may still be cost beneficial. This provides a view of what the total extent of benefit is to society, in addition to the unit benefit cost ratio of the measure to help in determining policy decisions. Assumptions made in determining the system-wide benefit include the following:

- Total Fleet Benefit – it was assumed that the total system-wide benefit to drivers from airbags in New Zealand would be derived from both new cars and second-hand cars.
- Airbag Fitment Costs – the cost of fitting a replacement airbag from the unit BCR calculation was again used here for calculating overall benefits. The cost of fitting an airbag to a new car was assumed to be NZ$800, based on estimates derived from Australia (New Zealand does not have an automotive manufacturing industry). Again, this is likely to be very conservative, based on anecdotal information available to the study team.
- Imported Airbag Cars – it was assumed that the average additional cost of an imported used car with an airbag to one without was assumed to be NZ$400 (i.e., 50% of the additional cost of a new car with an airbag).
- Replacement Rates – the proportion of used cars in which the original equipment airbag was not operational and needed to be replaced was 10%.

8.2 MAIN FINDINGS

The assumptions listed above were used to estimate the likely benefits to drivers and costs (BCR) by vehicle age when the airbag is fitted retrospectively. This included different discount rates of future benefits (5% and 10% values) as well as current and future fitment costs.

8.2.1 Individual Break-Even BCR Figures

The break-even vehicle year for a BCR = 1 (i.e., where the costs outweigh the benefits) are shown below in Table 8.1 for both 5% and 10% discount rates. These include both current and future replacement costs for an airbag in New Zealand.

Table 8.1 *Break-even year (BCR=1) for retro-fitting airbags by age of second-hand vehicle in New Zealand (from Table 6.1)*

Replacement Cost	5% Discount Rate	10% Discount Rate
NZ$1,320	10 years	5 years
NZ$950	14 years	12 years
NZ$770	16 years	14 years

Figures rounded to nearest whole year

8.2.2 Total System-Wide Benefits

The total system-wide benefits (BCRs) for mandating airbags in new and second-hand cars in New Zealand are again repeated in Table 8.2 below for completeness.

Table 8.2 *System-wide benefits in NZ for airbags in new and used vehicles*

Cost of Used Airbag	Discount Rate	
	5%	10%
NZ$770	3.39	2.51
NZ$950	3.33	2.47
NZ$1,320	3.21	2.38

8.3 CONCLUSIONS

On the basis of the data on the future expected cost of airbags in New Zealand, it seems reasonable to conclude that it is cost-beneficial for cars to be refitted with airbags when they are not replaced for up to the14th year of their life. It is conceivable that the estimates provided here of the future cost of airbags might be even less as efficiencies and exposure increase substantially in the years ahead.

The benefits would be higher for a less conservative future discount rate than 10%, which is the current practice in New Zealand. Other countries, however, use less conservative rates, ranging from 4% in the USA to 5% or 7% in Australia.

The total system-wide BCRs support the overall benefit of airbags as a cost-beneficial safety feature in all New Zealand passenger cars. It is expected that these benefits would also apply to other vehicles, such as 4WDs and passenger vans.

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