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Benefits of Retrofitting Seat Belt Reminder Systems to Australian Passenger Vehicles

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Title
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Abstract
The aim of this study was to determine the potential benefits of retrofitting a seat belt reminder device to passenger vehicles in the Australian fleet. The analysis was restricted to vehicles up to ten years of age at the time of retrofitting which were assumed to have at least a driver airbag fitted. While seat belt wearing rates have been observed at around 95% in the front seat, non–wearing rates in casualty crashes are as high as 33% among persons killed and 19% among seriously injured occupants. Benefits were computed for three introduction scenarios (driver–only, front seat occupants and all occupants), four levels of effectiveness from 10% to 40%, and a per seat unit cost from $25 – $65 in $10 increments. Unit benefits were computed for 4%, 5% and 7% discount rates, and for an average device life of ten years. Using the preferred 5% discount rate, the BCRs were seen to range from 3.6:1 to 0.1:1 depending on the seating positions included, the effectiveness and cost of the device. The findings suggest that retrofitting seat belt reminder systems would be worthwhile for drivers' seat–only implementation so long as the device would cost no more than $35, and would guarantee a minimum 20% improvement in belt–wearing. At 30% and 40% device effectiveness, more expensive devices could be fitted to the driver–only position while maintaining cost–beneficial outcomes. Fitment for both front occupants would be cost–beneficial for devices that would guarantee a minimum 20% improvement in belt wearing and cost no more than $25 per unit, or a 30% improvement in belt wearing and costing less than $45 per unit. In the absence of mass–produced seat belt reminder systems, it was suggested that there is sufficient evidence to suggest that retrofitting such devices would prove cost–beneficial to Australian society in the long term if one were developed.

Keywords
Retrofitting, Seat Belt, Safety, Accident, Occupant, Injury, Cost–Benefit, Economic, Harm

Notes
(1) ATSB reports are disseminated in the interest of information exchange.
(2) The views expressed are those of the author(s) and do not necessarily represent those of the Commonwealth Government.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The aim of this study was to determine the potential benefits of retrofitting a seat belt reminder device, in addition to the current five–second warning light, to existing passenger vehicles in the Australian fleet. It has been argued that the five–second warning is lost among the various warning lights that display when the ignition is activated, and that a more persistent reminder would lead to improvements in seat belt wearing in Australia. A more "aggressive" reminder system therefore would seem warranted to help further reduce road trauma in Australia.

Australia has played a leading role historically in seat belt wearing and as a result of previous government legislation, seat belt wearing rates in the front seat have been consistently around 95% for the last decade. Current non–wearing rates in casualty crashes, however, are much higher than exposure figures, with 33% of fatally injured and 19% of seriously injured occupants being unbelted. These statistics reflect the effectiveness of seat belts in preventing injuries, and possibly a tendency for unrestrained drivers to be higher risk takers.

The National Road Safety Action Plan for 2003 and 2004 identifies seat belt reminder systems in new vehicles as a priority area for road safety improvement. An earlier report by the same authors (Fildes, Fitzharris, Koppel, & Vulcan, 2002) showed that requiring compulsory seat belt reminder systems that were more "aggressive" than the current warning light required by Australian Design Rule (ADR) 69 was likely to be cost–beneficial if the reminders were fitted to new vehicles when being manufactured.

Increases in new vehicle safety can bring substantial gains in the long term, but it takes many years for these benefits to affect the bulk of the vehicle fleet. This raises the question of whether retrofitting to existing vehicles would also be a cost–effective option.

In theory, retrofitting of seat belt reminder systems could be either voluntary or mandatory, although voluntary retrofitting would be likely to have a very limited impact. Those most likely to benefit would probably be least likely to fit the device. It is unlikely that any form of mandatory retrofitting would come in until the ADRs had been changed to make more "aggressive" seat belt reminder systems compulsory in new vehicles. Within the Australian federal system, the Commonwealth is responsible for regulating standards for new vehicles, and state and territory governments normally regulate in–service vehicle standards. For example, the Western Australian Government requires the fitment of engine immobilisers upon the transfer of registration of used vehicles; and a similar scheme could potentially be used to facilitate the retrofitting of seat belt reminder devices to appropriate vehicles within each Australian state and territory.

Within the context of the earlier report by Fildes et al. (2002), an arbitrary assumption was made for the purpose of this report that manufacturers would be required to fit a more "aggressive" reminder system than the current five–second warning light at some time in the near future. This report then analyses the potential benefits of retrofitting a seat belt reminder system to passenger vehicles up to ten years of age. The ten year vehicle age limit was selected for four principal reasons: the potential HARM savings associated with belt use were calculated for vehicles fitted with at least a frontal driver airbag; vehicles older than ten years may have a useful life less than the retrofitted device itself, therefore limiting potential benefits of a retrofitting strategy; no structural alterations to the vehicle should be required in fitting the device, and this may be more achievable with a narrow vehicle cohort; and finally the device must be able to be fitted to every vehicle in the selected cohort. These requirements may act in concert to improve the feasibility and public acceptance of a retrofitting strategy.

Recently there have been significant advances in technology to remind people to ‘buckle up’. Ford has recently developed The Beltminder™ that comprises a flashing light on the dashboard and a warning tone of reasonable intensity. Variants of this include an option for the flashing rate and tone intensity to increase at higher travel speeds. The Insurance Institute of Highway Safety and Ford have reported increased wearing rates in the United States of around 17% for the Beltminder™ system. Further highlighting the interest in seat belt reminder systems, the European New Car Assessment Program (Euro–NCAP) has commenced providing added point bonuses for cars they assess for crashworthiness if vehicles are fitted with seat belt reminders, and the Australian NCAP program has followed suit. The Swedish Insurance Industry recently held a competition aimed at locating an inexpensive retrofit seat belt reminder system for the driver. The winners of the competition are currently developing the device at Autoliv Research in Gothenburg. It is timely therefore to examine the feasibility of retrofitting seat belt reminder systems in the Australian fleet.

CALCULATING BENEFITS AND DEVICE COSTS

The benefits of seat belt reminders were computed using the HARM Reduction method developed in Australia by the Monash University Accident Research Centre (MUARC) and used for previous benefit studies for the Department of Transport and Regional Services. HARM is a metric for quantifying injury costs from road trauma. It is a function of the number and type of injuries sustained, expressed in terms of community costs.

In the absence of an available mass–produced seat belt reminder device amenable to retrofitting, benefits were calculated using four levels of effectiveness from 10% to 40%, and three implementation strategies (driver–only, front occupants, all occupants). The term ‘percent effectiveness’ refers to the percent improvement in current belt wearing rates afforded by the device. It was estimated that a device that afforded a 40% effectiveness rate would increase seat belt wearing to 97% in the front seats.

Annual HARM benefits were computed for these three implementation strategies and four effectiveness rates. Using a discount rate of 5%, the benefits varied from around $12 million to $72 million annually if all vehicles in the fleet were fitted with the devices, equating to an annual HARM reduction of between 0.14% and 0.81%.

In the absence of per unit device costs, estimates of $25–$65 at $10 increments were used. Calculations were performed using costs excluding GST. Unit HARM benefits were calculated using three levels of discount factors (4%, 5% and 7%) and a device life of 10 years. In the light of a recent report by the Bureau of Transport and Regional Economics (BTRE, 2001), it was argued that a 5% discount rate was most appropriate for this analysis.

BENEFIT–COST–RATIOS

Benefit–Cost–Ratios (BCRs) were then computed for the range of device costs, device effectiveness levels, and discount rates. BCRs for a 5% discount rate for driver–only fitment and front–occupant fitment are shown in Tables 1.1A and 1.1B.

Table 1.1A – Benefit–Cost–Ratios for retrofitting seat belt reminder systems for *driver only* fitment assuming a 10 year device life and a 5% discount rate.

Unit Benefit (A$)	% HARM saved	$25 device	$35 device	$45 device	$55 device	$65 device
10% EFFECTIVENESS						
20.65	0.14	0.9	0.6	0.5	0.4	0.3
20% EFFECTIVENESS						
41.31	0.27	1.8	1.3	1.0	0.8	0.7
30% EFFECTIVENESS						
61.96	0.41	2.7	1.9	1.5	1.2	1.0
40% EFFECTIVENESS						
82.62	0.55	3.6	2.6	2.0	1.7	1.4

Table 1.1B – Benefit–Cost–Ratios for retrofitting seat belt reminder systems for *front occupants* fitment assuming a 10 year device life and a 5% discount rate.

Unit Benefit (A$)	% HARM saved	$25 device	$35 device	$45 device	$55 device	$65 device
10% EFFECTIVENESS						
26.64	0.18	0.6	0.4	0.3	0.3	0.2
20% EFFECTIVENESS						
53.29	0.35	1.2	0.8	0.7	0.5	0.5
30% EFFECTIVENESS						
79.93	0.53	1.8	1.3	1.0	0.8	0.7
40% EFFECTIVENESS						
106.57	0.71	2.3	1.7	1.3	1.1	0.9

On the basis of the BCRs obtained and the marginal increase in HARM associated with the inclusion of front occupants, it could be concluded that if a retrofitting strategy were to be undertaken, a device fitted for the driver's seating position only would seem to be the preferred option for Australia. Retrofitting to the driver–only position would only be worthwhile if either a relatively inexpensive (up to $45) device could be fitted that would guarantee a minimum 20% improvement in current seat belt wearing rates, or a more expensive device could be developed, that was very effective at improving seat belt wearing rates. The inclusion of front passengers in the retrofitting strategy would be worth consideration only if a device that guaranteed a minimum 30% increase in belt wearing and cost no more than $35 could be developed or alternatively a $25 device that would demonstrate a 20% improvement in belt wearing rates.

This report calculates potential benefits and BCRs for vehicles up to ten years of age. The interpretation of the BCRs assumes that crashworthiness ratings remain relatively consistent in that period, an assumption that is supported by recent used car safety rating surveys. It would be essential in the choice of a device that fitment would not require structural alterations to the vehicle and that the device would be suitable to be fitted to **every** passenger vehicle in Australia in the 10–year cohort. These constraints may act to limit the types of devices and also their potential level of effectiveness in increasing belt wearing.

CONCLUSIONS

The findings from this study suggest that mandating the retrofitting of seat belt reminder systems to part of the Australian passenger vehicle fleet (all vehicles up to ten years old) for the drivers' seat only would break–even in terms of costs and benefits, so long as the device cost no more than $45 and would guarantee a minimum 20% improvement in belt–wearing. At 30% and 40% device effectiveness, more expensive devices could be fitted while maintaining cost–beneficial outcomes. The annual average HARM savings associated with retrofitting for drivers was found to range from 0.14% ($12.1m) – 0.55% ($48.6m) of total annual HARM, depending on the level of effectiveness assumed. Given the higher cost of a device intended for retrofitting currently under development in Sweden, the results of this report indicate that fitment to both front occupants is unlikely to be recommended.

In summary, this report shows the potential economic benefits to Australian society of retrofitting seatbelt reminder devices under different implementation, effectiveness and cost scenarios. It suggests that mandating the retrofitting of driver-only seat belt reminder systems to vehicles up to ten years of age in Australian passenger vehicle fleet could be a worthwhile strategy, so long as the device cost less than $45 *and* would guarantee a minimum 20% improvement in belt–wearing. At 30% and 40% device effectiveness, more expensive devices could be fitted to the driver–only position, while maintaining cost–beneficial outcomes. Fitment for both front occupants would be cost–beneficial for devices that would guarantee a minimum 20% improvement in belt wearing and cost no more than $25 per unit, or a 30% improvement in belt wearing and costing less than $45 per unit. These would be difficult criteria to meet, and it should be noted that most of the benefits in this option would derive from covering the driver's position. The analysis suggests that retrofitting seat belt reminder devices for rear occupants is unlikely to prove cost–beneficial.

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND.

The benefits of compulsory seat belt wearing in Australia are well documented (Milne, 1979; Ungers, 1974; Regan, Oxley, Godley, & Tingvall, 2001). While seat belt wearing rates among front seat occupants have been consistently around 95% for the last decade, there is a large residual population of crash–involved occupants that remain unbelted (ARUP, 1995; ATSB, 2002; VicRoads, 1998; Whelan, Diamantopoulou, Senserrick, & Cameron, 2003). Consequently, the National Road Safety Action Plan for 2003 and 2004 identified seat belt reminder systems in new vehicles as a priority area for road safety improvement. Recognising the safety benefits of seat belt reminder systems, both the European and Australian New Car Assessment Programs (EuroNCAP and ANCAP) have recently commenced awarding additional points to vehicles with such devices fitted.

A recent report conducted by MUARC for the ATSB examined the likely benefits of compulsory fitment of a number of different types of seat belt reminder systems to all new passenger cars (Fildes, Fitzharris, Koppel & Vulcan, 2002). In deriving the Benefit–Cost–Ratios for the various systems, it was estimated that unrestrained occupants accounted for 21% of the total HARM resulting from passenger car crashes, equating to approximately $1883 million per annum (Fildes et al., 2002). It was estimated that 100% seat belt wearing would result in a societal cost saving of $587 million. The report indicated that compulsory seat belt reminder systems that were more "aggressive" than the current warning light required by ADR 69, such as Ford's BeltMinder™ or similar systems, were likely to be cost–beneficial if fitted to new vehicles when being manufactured. As improvements in new vehicle safety bring substantial gains in the long term but often take many years to affect the bulk of the vehicle fleet, it is appropriate to consider whether retrofitting seat belt reminder systems to existing vehicles in the fleet would be a cost–effective strategy for Australia.

1.2 PROJECT OBJECTIVES.

The principal objective of this research was to estimate the likely HARM benefits of retrofitting a seat belt reminder system to existing passenger vehicles in the Australian fleet. It is important to note that this report does not seek to develop a seat belt reminder system, but rather to assess the potential cost effectiveness of such a device. This report uses the same methods and data, with appropriate modifications, utilised in the recent MUARC report conducted for the ATSB, titled 'Benefits of Seat Belt Reminder Systems' (Fildes et al., 2002).

For the purposes of this report, it was assumed that:

- The device would need to be invisible for those who normally wear their seat belts;
- The device would be amenable to simple fitment by after–market businesses, and
- The device would not require alterations to the structural integrity of existing vehicles or replacement of existing passenger seats.

A number of specific tasks were to be addressed, namely assessing:

- The existence of seat belt reminder systems amenable to retrofitting;
- The potential cost of retro–fitting seat belt reminder systems, and
- The potential effectiveness of seat belt warning devices in the Australian context.

1.3 USE OF THE REPORT.

This report is a scientific evaluation of the potential benefits of retrofitting a seat belt reminder system to existing passenger vehicles in the Australian fleet. In calculating potential benefits, this report uses the HARM reduction method of calculating injury benefits used in a number of previous benefit–cost estimates for the ATSB, and draws heavily on the recently completed report by Fildes et al (2002). The report 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 for three different future discount rates (4%, 5%, & 7%) and an assumed 10–year average device life estimate, using crash costs specified by the Bureau of Transport and Regional Economics (BTRE, 2001) and estimates of seat belt effectiveness based on real–world crash data.

Critically, we chose to limit the calculations for retrofitting the seat belt reminder system to vehicles up to ten years of age. The ten year vehicle age limit was selected for four principal reasons: the potential HARM savings associated with belt use were calculated for vehicles fitted with at least a frontal driver airbag; vehicles older than ten years may have a useful life less than the retrofitted device itself, therefore limiting potential benefits of a retrofitting strategy; no structural alterations to the vehicle should be required in fitting the device and this may be more achievable by selecting a narrow cohort; and finally, the device must be able to be fitted to every vehicle in the selected period. These requirements may act in concert to improve the feasibility and public acceptance of a retrofitting strategy. For the purposes of this analysis we assumed that in the near future, all new passenger vehicles would be required to have a more aggressive reminder system than the existing five–second warning light. This report then analyses the potential benefits of retrofitting a seat belt reminder system to passenger vehicles up to ten years of age.

While the results and recommendations are based on the findings of the analysis, it is ultimately a policy decision of governments whether to mandate or not. This decision is beyond the scope of this technical document. However, it can be anticipated that voluntary retrofitting of seat belt reminder systems would be likely to have a very limited impact. Those most likely to benefit would probably be least likely to fit the device. Further, it is unlikely that any form of mandatory retrofitting would come in until the ADRs had been changed to make more “aggressive” seat belt reminder systems compulsory. Within the Australian federal system, the Commonwealth is responsible for regulating standards for new vehicles, and state and territory governments normally regulate in–service vehicle standards. For example in Western Australia the fitment of engine immobilisers is required upon the transfer of registration of used vehicles.

It is hoped that the approach is sufficiently transparent that the reader is 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 the flexibility 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 on the likely cost effectiveness of mandatory retrofitting of a seat belt reminder system to passenger vehicles.

This report takes the form of a Supplement to the report by Fildes et al. (2002). The reader is referred to Fildes et al. (2002) for a detailed discussion of relevant literature regarding the effectiveness of seat belt reminder systems. This report does however draw on much of the discussion on the HARM concept and the method of BCR calculation from the earlier study.

CHAPTER 2 ANNUAL BENEFIT OF SEAT BELT REMINDERS

The concept of 'HARM' was first developed in the United States and applied to the National Automotive Sampling System (NASS) database by the National Highway Traffic Safety Administration (NHTSA) as a means of determining countermeasure benefits for road safety programs (Malliaris, Hitchcock & Hedlund 1982; Malliaris, Hitchcock & Hansen 1985; Malliaris & Digges 1987; NHTSA, 2003). The Monash University Accident Research Centre (MUARC) further modified and extended the use of HARM by recalibrating the cost estimates to Australian standards and applying these estimates to evaluate occupant protection countermeasures (MUARC, 1992). Thus, the development and use of HARM in that previous study and other Australian studies represents a significant international advancement in the ability to assess injury mitigation effects of vehicle countermeasures.

2.1 HARM & INJURY MITIGATION

HARM is a metric for quantifying injury costs from road trauma. It is a function of the number and type 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 suited for use in computing likely benefits of countermeasures where there are no global estimates of the likely improvements but where there are sufficient data available to derive the annual HARM by type of injury and crash. The method allows a picture of the expected overall benefit to be pieced together from a series of individual data sets by severity of injury, type of crash, people injured, and their restraint use. A computer spreadsheet was developed for making the detailed HARM calculations by body region, similar to that used previously in MUARC (1992).

2.1.1 National Statistics & HARM Estimates

This report examines the crash history and associated HARM for passenger vehicles and light commercial vehicles. Similarly, figures for new motor vehicle registrations used in calculations of this report relate only to passenger and light commercial vehicles. The vehicle type definitions (i.e., passenger vehicles and light commercial vehicles) follow those specified by the Australian Bureau of Statistics in the *New Motor Vehicle Registrations* report series (ABS, 1976–2002). More specifically, passenger vehicles are vehicles constructed primarily for the carriage of less than ten passengers (including the driver) and include cars, station wagons, 4WD passenger vehicles, and forward control passenger vehicles (ABS, 2002). Light commercial vehicles are vehicles constructed primarily for the carriage of goods, do not exceed 3.5 tonnes GVM, and include utilities, panel vans, cab–chassis and forward control vehicles (ABS, 2002).

To determine the HARM associated with passenger and light commercial vehicles, a comprehensive Australia–wide database of injuries was constructed for this study by merging several data sources of crash information about fatalities, seriously injured occupants and those needing medical treatment. These data were available from statistics published by the Australian Transport Safety Bureau on fatal and non–fatal injuries across Australia for 1996 (ATSB, 2002). The cost of injury was derived from figures published by the Bureau of Transport and Regional Economics (BTRE, 2001). These costs comprise not only medical and treatment data but also allowance for loss of earnings, impairment and loss of quality of life; that is, they represent societal cost of injury. They were derived from 1996 cost data from a variety of Australian sources.

The proportion of crash victims by crash type was derived from crash statistics in Victoria and Queensland, using crashes in the period 1997–1998 inclusive. Using the number of persons injured at each severity level and the proportion of persons involved in each impact type for the three severity levels, it is possible to estimate the number of persons injured for each crash severity and impact type combination and hence the overall societal cost. Estimates of unrestrained HARM were derived from the proportion of fatally injured occupants in Australia that were unrestrained (ATSB, 2002) and for severe injuries, from Fildes et al (1991). An estimate of unrestrained occupants sustaining minor injuries was gained from analysis of in–depth tow–away crash data collected by MUARC. The potential savings associated with seat belt use in airbag–equipped vehicles for each impact type were derived from figures obtained from the NHTSA web site using NASS Crashworthiness Data System (CDS) 1993–2000 data. Table 2.1 shows the subsequent HARM estimates and potential savings associated with seat belt use. It is estimated that 100% seat belt use would save the Australian community approximately $587 million per annum. It is important to note that these figures relate to the entire vehicle fleet rather than a ten–year segment.

Table 2.1 – HARM to all occupants and those unrestrained in car crashes in Australia in front, side, rollovers and rear–end collisions by severity of the injury (1996 A$ millions).

SEVERITY OF INJURY	TOTAL ANNUAL INJURED[1]	PROP. CRASH TYPE[2]	TOTAL PEOPLE INJURED	TOTAL HARM[3] ($million)	UNRESTRAINED[4] Prop.	UNRESTRAINED[4] HARM ($million)	% HARM SAVED[5] Prop.	% HARM SAVED[5] Harm ($million)
Fatal–front		0.343	469	703	0.325	229	0.38	88.6
Fatal–side		0.276	377	566	0.325	184	0.22	40.4
Fatal–roll		0.118	161	242	0.325	79	0.40	31.9
Fatal–rear		0.010	14	20	0.325	7	0.34	2.2
Fatal–other		0.254	347	521	0.325	169	0.34	57.2
Total–Fatal	**1368**		**1368**	**2052**		**667**		**220.9**
Severe–front		0.424	6583	2140	0.185	396	0.38	153.5
Severe–side		0.207	3224	1048	0.185	194	0.22	42.6
Severe–roll		0.077	1201	390	0.185	72	0.40	29.3
Severe–rear		0.084	1301	423	0.185	78	0.34	26.4
Severe–other		0.208	3230	1050	0.185	194	0.34	65.64
Total–Severe	**15539**		**15539**	**5050**		**934**		**317.6**
Minor–front		0.412	62206	722	0.086	62	0.38	24.1
Minor–side		0.289	43600	506	0.086	44	0.22	9.5
Minor–roll		0.026	3997	46	0.086	4	0.40	1.6
Minor–rear		0.198	29832	346	0.086	30	0.34	10.06
Minor–other		0.074	11182	130	0.086	11	0.34	3.7
Total–Minor	**150818**		**150818**	**1751**		**150**		**49.1**
TOTAL HARM				**8853**		**1752**		**587.21**

1. From ATSB 2002; 1996 data
2. Proportion of injured by crash type derived from Victoria and Queensland casualty crashes, 1997–1998
3. Cost of injury in 1996A$ for fatal = $1,500,000, Severe = $325,000 and Minor = $11,611 (BTE, 2000)
4. Proportion unrestrained derived from ATSB fatal files, Fildes et al (1991) & MUARC analysis of tow–away crashes
5. Proportion of HARM likely saved (assuming 100% effectiveness for the reminder system) derived from NASS CDS 1993 – 2000 in–depth crash data for airbag crashes (NHTSA Web site, see Fildes et al., 2002 for details)

2.1.2 Relevance of Figures

In compiling these national statistics, a number of assumptions needed to be made and these are detailed above. It would have been preferable if injury patterns by crash type and the proportion of unrestrained occupants were recorded nationally. Unfortunately, these data were unavailable and the assumptions listed above provided the best estimates of these figures available at this time.

In determining the proportion of HARM likely to be saved by increasing seat belt wearing, it is important to use data based on airbag crashes, as airbags provide a restraint benefit in themselves (most modern cars sold in Australia are fitted with at least a driver airbag). Data available in Australia was not comprehensive enough to derive these proportions from airbag deployed crash data and so it was necessary to refer to other overseas figures. While it is recognised that U.S. airbags, given their primary restraint nature, differ from those available in Australia, NASS is a comprehensive in–depth database where seat belt wearing can be confidently determined. Thus, comparing the difference in HARM between cases with and without a seat belt being worn provided the proportions likely to be saved by increasing seat belt wearing to 100%.

2.2 INJURY REDUCTIONS

In computing the seat belt reminder system benefit in the earlier report, a number of assumptions were made using the real world and test data available at the time to gauge injury mitigation expected from these units. In addition, an international panel of research, vehicle manufacture, and government specialists was formed to assist with estimating the expected injury reduction outcome (MUARC, 1992). These are discussed more fully in Fildes et al. (2002).

2.3 IMPLEMENTATION OPTIONS

Previous evidence suggested three different implementation options would be possible for introducing seat belt reminder systems, namely driver only, front seat occupants only or all seating positions, excluding the rear centre seat. The decision to exclude the rear centre seat from the options reviewed was based on the low exposure associated with that seating position, making a seatbelt warning device very unlikely to be cost beneficial.

2.4 ANNUAL HARM SAVED BY SEATING POSITION

The annual HARM that could be saved by the use of a seat belt reminder system for all non–users, assuming 100% compliance, was estimated to be $587.21 million in Table 2.1 above. The proportion of HARM sustained by seating position was determined from Australian in–depth data collected at the Monash University Accident Research Centre over recent years.

The amount of HARM saved each year, however, will depend upon the effectiveness of the seat belt reminder device. For the purpose of this report, and in the absence of evidence of effectiveness of retrofitted devices, four levels of effectiveness ranging from 10% to 40% were used in the calculation of potential benefits. Annual HARM saved for each device assuming these levels of effectiveness are shown in Table 2.2 below.

Table 2.2 – Likely annual HARM saved by seating position in Australia.

Seating Position	Annual HARM Saved (100% effectiveness)	Effectiveness 10%	20%	30%	40%
Driver only	$397 million	$39.7m	$79.4m	$119.1m	$158.8m
Front seat passenger	$115 million	$11.5m	$23.0m	$34.5m	$46.0m
Rear occupants	$75 million	$7.5m	$15.0m	$22.5m	$30.1m
All occupants	$587 million	$58.7m	$117.4m	$176.2m	$234.9m

2.4.1 Summary

In summary, the estimated annual HARM saved with retrofit seat belt reminders ranges from $40 million to $235 million for the entire passenger vehicle and light commercial fleet, depending on the level of effectiveness of the device in improving seat belt wearing and the range of seating positions fitted.

CHAPTER 3 UNIT HARM AND COSTS

3.1 CALCULATING INDIVIDUAL VEHICLE SAVINGS

In establishing benefit–cost relationships, it is necessary to convert annual HARM saved (a community benefit) into a saving spread across the life of an individual vehicle, to compare this with the cost of having to meet this new requirement. This is achieved by estimating the average risk of a vehicle being involved in a crash for each year of its life and multiplying that risk by the annual HARM saved per crash for that time period. The average HARM savings can then be summed across the life of the vehicle. There are alternative methods for making these estimates, each with their particular strengths and weaknesses.

3.1.1 Immediate Past History

In these calculations it was assumed that the immediate past history of crash risk, crashworthiness, crash patterns and salvage rates would continue and therefore be the best predictor of future crash risk and salvage rates. This eliminates the need for tenuous subjective predictions and has credibility in that the past is often the best predictor of the future in dealing with human behaviour. It does assume of course that the crashworthiness performance of the vehicle fleet will not alter dramatically; an assumption that has some credibility based on recent evidence (Newstead, Cameron, Watson, & Delaney, 2003), if attention is confined to the last 15 years.

The method, fully detailed in Appendix B, assumes that the risk of a new car being involved in a casualty crash during, say, the third year of its life, is the same as the risk of a car which was first registered three years ago having a crash this year. To calculate this yearly risk, the number of crashes for three–year–old cars with an occupant casualty is divided by the total number of new cars sold three years ago, with an adjustment to remove the effects of year–to–year fluctuations in vehicle sales. The risk of a casualty crash across the lifetime of a car then is the sum of each year's crash experience divided by the adjusted number of new cars sold. The process of focussing on each crash year and the number of vehicle sales each year takes account of vehicles that exit from the vehicle fleet through wreckage, wear and tear, etc., as well as the lower distances travelled by older cars and the different characteristics of those who drive older cars.

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

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

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

The average HARM reduction for any one car in its third year is calculated by dividing H_3 by the number of new cars registered three years ago. The total benefit for a single car from the seat belt reminder is then obtained by adding up the HARM reductions for each year of its life and discounting these benefits back to the first year. This is explained in more detail in Appendix B.

3.1.2 Discounting Procedure & Rate

When predicting the likely benefits of a new countermeasure, it is normal to discount future benefits back to the present so that they can be compared with present day costs of the measure. The discounting procedure used in these calculations first takes the annual HARM saved for the seat belt reminder and attributes this (discounted) to one car over its expected lifetime. The selection of an appropriate discount rate is really a matter of opinion (there is no magic number). A smaller discount rate gives greater weight to future benefits and is thus less conservative.

In the past, the Australian Government used 7% as an appropriate rate. Some state governments, however, have used a range of different values (the Victorian Government, for instance, has used 4%). In its recent evaluation of the National Road Safety Black Spot Programme, the Bureau of Transport and Regional Economics (BTRE, 2001) argued that a 5% discount rate was most meaningful in that context, although their analysis included other discount rates as well. The Commonwealth Department of Finance (1991) recommended that where possible, sensitivity analysis be undertaken involving a range of different discount rates.

It is acknowledged that the choice of the discount rate has a marked effect on the calculation; not only does it influence the BCR, but also the cost of death or serious injury. In this report, seat belt reminder options were calculated at 4%, 5% and 7% to gauge their likely unit HARM benefits. It should be noted, though, that the Bureau of Transport and Regional Economics (BTRE, 2001) used a 4% discount rate when determining the cost of injury for each injury severity level used here.

3.1.3 Life Period of the Retrofitted Device

It is also necessary to decide what constitutes the life period of the device over which the benefits are to be claimed. It was assumed for the purpose of this analysis that the retrofitted device would have an effective average life of ten years. It is necessary to use a multiplier based on each year of vehicle life and then obtain the average benefit across the time period. The age of the vehicle to which the device is fitted will vary between 0 and 10 years, with no discounting in year 0 (the year in which the vehicle was registered) and year 1 being the first full year of registration. Different multipliers are required for vehicles of different ages, as the crash history and salvage rates vary with vehicle age. Due to the intensive nature of the calculations, only three multipliers were used to obtain the average benefit over the ten year device life period: a device retrofitted to a vehicle in the year it was registered (i.e., year 0), a device retrofitted five years after the initial year of registration, and a device retrofitted ten years after the initial year of registration (See Appendix B). Based on the results in Appendix B, the multipliers used for assessing the unit HARM benefits of the seat belt reminder device are given in Table 3.1.

Table 3.1 – Multipliers used for calculating Unit HARM.

	10 year Device Life		
	Device fitted in 0 – 1st year of vehicle life	Device fitted in 5th year of vehicle life	Device fitted in 10th year of vehicle life
4% discount rate	0.3836	0.3470	0.2663
5% discount rate	0.3678	0.3177	0.2337
7% discount rate	0.3393	0.2675	0.1809

3.1.4 Unit HARM Values

Unit HARM refers to the benefit of these devices across the life of the device. Table 3.2 shows the unit HARM values derived by applying the multipliers shown above to the Annual HARM values in Table 3.1 for the expected effectiveness rates and implementation strategies. Therefore these values represent the break–even points for retrofitting a device for a given device effectiveness, implementation strategy and discount rate. Figures 1 to 3 repeat these figures in graphical form.

Table 3.2 – Average Unit HARM benefits computed for the device options (A$).

Device Effectiveness	Implementation Strategy	Discount Rate (10yr device life) 4%	5%	7%
10%	Driver only	22.40	20.65	17.70
	Front seat occupants	28.89	26.64	22.83
	All occupants[1]	33.14	30.55	26.18
20%	Driver only	44.80	41.31	35.40
	Front seat occupants	57.79	53.29	45.66
	All occupants[1]	66.27	61.11	52.36
30%	Driver only	67.20	61.96	53.10
	Front seat occupants	86.68	79.93	68.49
	All occupants[1]	99.41	91.66	78.55
40%	Driver only	89.60	82.62	70.80
	Front seat occupants	115.58	106.57	91.32
	All occupants[1]	132.54	122.21	104.73

[1] All occupants refers to driver, front left passenger, rear left & rear right passenger

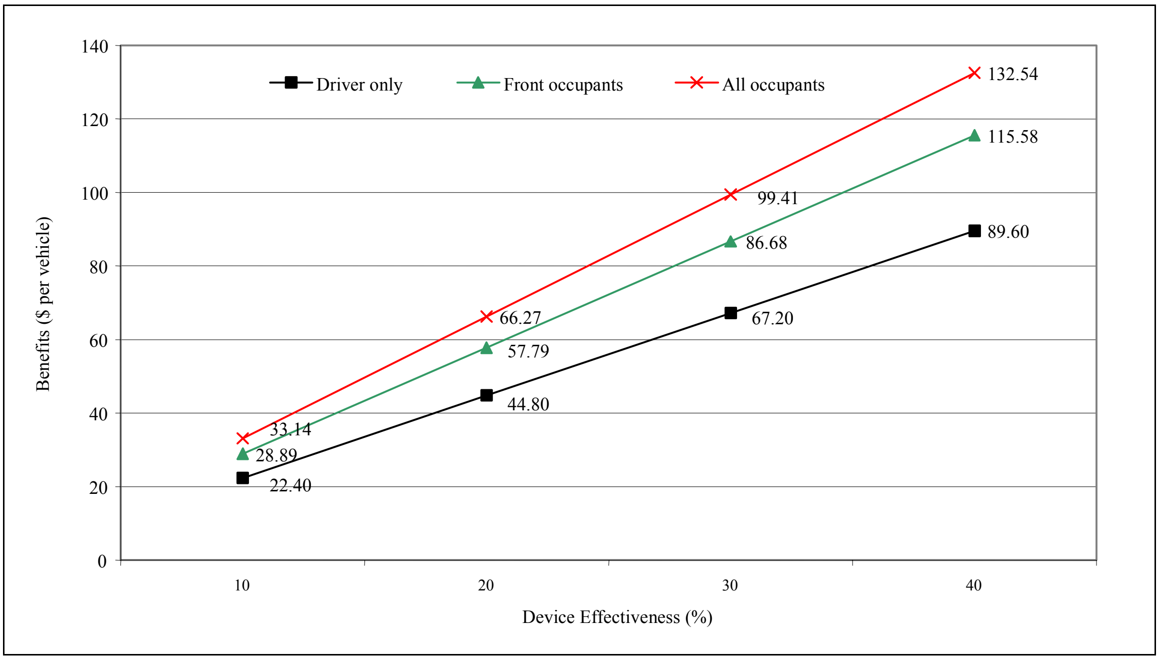

Figure 1 – Plot of benefits by percent effective of devices for driver only, front seat occupants and all occupants (4% discount rate).

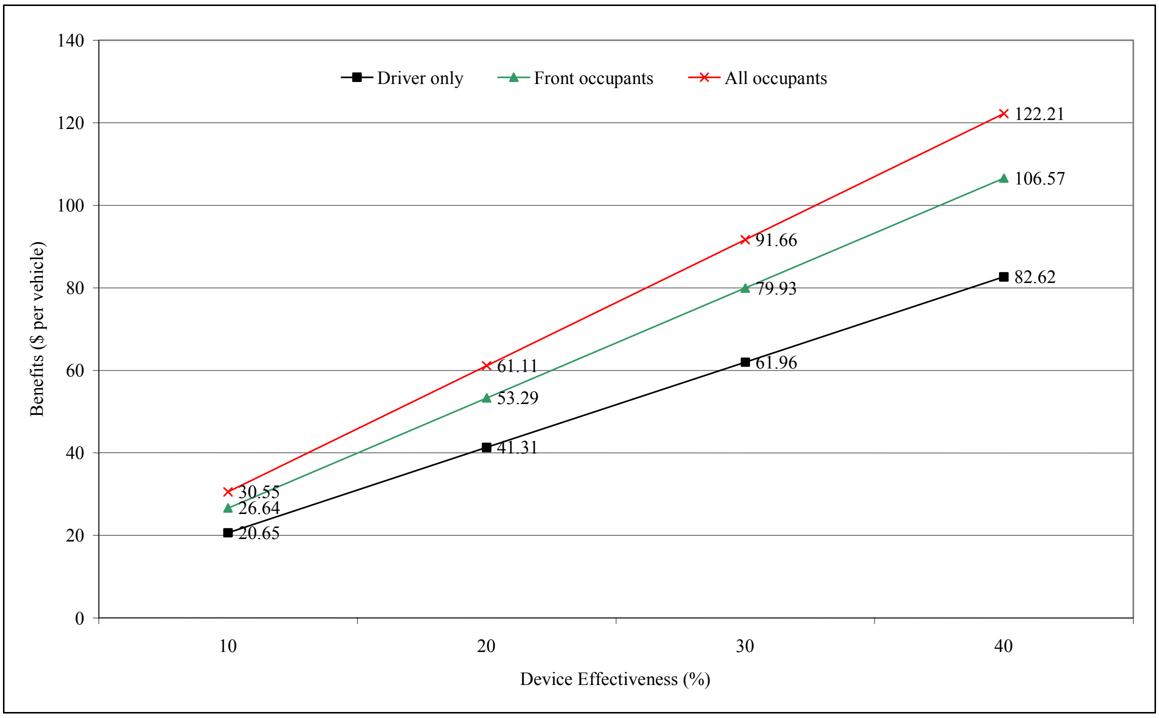

Figure 2 – Plot of benefits by percent effective for devices for driver only, front seat occupants and all occupants (5% discount rate)

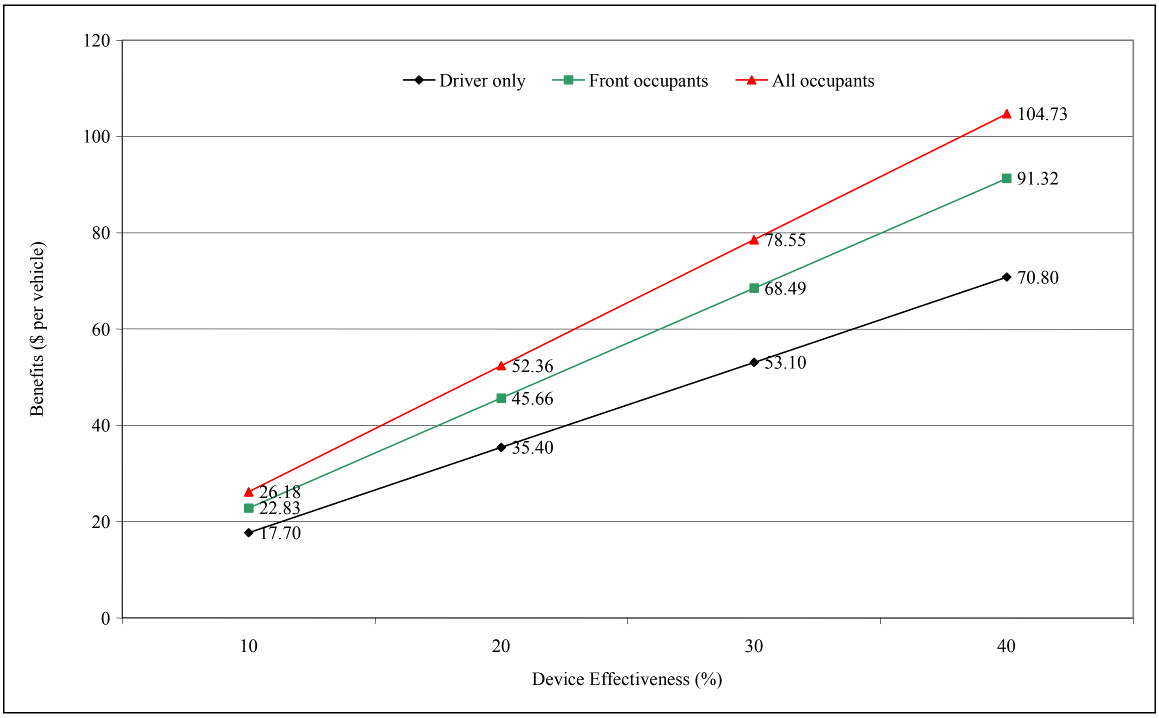

Figure 3 – Plot of benefits by percent effective for devices for drivers only, front occupants and all occupants (7% discount rate)

3.2 SEAT BELT REMINDER COSTS

As stated earlier, there is little information regarding the cost of seat belt reminder devices that might be retrofitted, due to the absence of an off–the–shelf device in the market.

The Swedish Insurance Industry recently ran a competition aimed at developing an inexpensive retrofit seat belt reminder system for the driver (Yngve Håland, personal communication, November 2002; Meijer & Roos, 2003). The winners were two students from Linköping University, Lars Meijer and Mikael Roos, who are currently engaged in graduate studies at Autoliv Research in Gothenburg. The system comprises a slim black box that is attached to the outside of the housing of the seat belt buckle using self–adhesive tape. The seat belt reminder detects both car movement from motion detectors, and whether the tongue has been put into the buckle housing. An auditory alarm sounds after 20 seconds of vehicle motion, if the occupant remains unbelted. The belt reminder is self–contained, with its own lithium batteries. The estimated life of the batteries is approximately four years if the driver needs to be reminded each time he/she starts to drive. If the occupant buckles up faster than 20 seconds, the battery life will be longer. The black box can be attached to the front seat belt buckle for a number of different cars. The students have investigated 60 different car models in Sweden, and assembly is possible in all of them.

The current estimate for the device is approximately 200 SEK (A$40). To this must be added the cost of fitting it to the vehicle, which is expected to take approximately 15 – 20 minutes. In Sweden this is likely to cost 100–150SEK (A$20–$30). A potential supplier advised that a seat belt reminder system manufactured in large quantities (several hundred thousands) will probably cost approximately 150 SEK (A$30), excluding the cost of fitment. No other prices were forthcoming during the review.

3.3 BENEFIT COST RATIOS

In the absence of an existing 'off–the–shelf' mass–produced device, Benefit–Cost–Ratios (BCRs) were calculated for a \$25 – \$65 device at \$10 increments. The Swedish system under development (discussed above) is specific to the driver position only. Whether the device is amenable to fitment to other occupant seats is yet unknown. Similarly, the cost implications of fitting such a device to seats other than the driver are also unknown. For the purpose of this exercise, the device costs have simply been multiplied by the number of seats to which they are fitted without any additional allowance for presence detectors for each seat (if required).

Table 3.3, Table 3.4, and Table 3.5 present BCRs for various device effectiveness levels and implementation strategies using a 4%, 5% and a 7% discount rate respectively.

The principal findings using a 4% discount rate (Table 3.3) are as follows:

- At 10% device effectiveness, no options result in positive BCRs, and the only option that results in a break–even BCR is a \$25 device fitted for the driver only (1.0:1).
- At 20% device effectiveness:
    - o Driver–only fitment results in a positive BCR up to a \$45 device,
    - o Fitment to front seats returns a positive BCR for a \$25 device.
- At 30% device effectiveness, fitment of a driver–only device up to \$65, and fitment to both front seat occupants up to \$45 return cost–beneficial outcomes.
- With a 40% improvement in belt wearing, a device fitted to driver–only and front occupants results in a positive BCR with a device cost up to \$65.
- If a device were to be fitted for all occupants, at 30% effectiveness, only a \$25 device results in a positive BCE. With a 40% improvement in restraint use, only a \$25 and \$35 device results in break–even (or better) BCRs.

The principal findings using a 5% discount rate (Table 3.4) are as follows:

- At 10% device effectiveness, no device from \$25 upwards results in a break–even BCR.
- At 20% device effectiveness:
    - o Driver–only fitment results in a positive BCR up to a \$35 device and a break–even BCR for a \$45device,
    - o Fitment to front seats returns a positive BCR for a \$25 device.
- At 30% device effectiveness, fitment of a driver–only device up to \$65, and fitment to both front seat occupants up to \$45 return break–even or cost–beneficial outcomes.
- With a 40% improvement in belt wearing, a device up to \$65 fitted to driver–only and up to \$55 for fitment to front occupants result in positive BCRs.
- For all occupants, with a 30% improvement in belt wearing, a \$25 device results in a break–even BCR, and at 40% effectiveness, only a \$25 and \$35 devices result in break–even (or better) BCRs.

Table 3.3– BCR calculation for a 4% discount rate and a device life of 10 years

	Benefit	$25 device	$35 device	$45 device	$55 device	$65 device
10% EFFECTIVENESS						
DRIVER ONLY	22.40	1.0	0.7	0.5	0.4	0.4
FRONT SEATS	28.89	0.6	0.5	0.4	0.3	0.2
ALL OCCUPANTS	33.14	0.4	0.3	0.2	0.2	0.1
20% EFFECTIVENESS						
DRIVER ONLY	44.80	2.0	1.4	1.1	0.9	0.8
FRONT SEATS	57.79	1.3	0.9	0.7	0.6	0.5
ALL OCCUPANTS	66.27	0.7	0.5	0.4	0.3	0.3
30% EFFECTIVENESS						
DRIVER ONLY	67.20	3.0	2.1	1.6	1.3	1.1
FRONT SEATS	86.68	1.9	1.4	1.1	0.9	0.7
ALL OCCUPANTS	99.41	1.1	0.8	0.6	0.5	0.4
40% EFFECTIVENESS						
DRIVER ONLY	89.60	3.9	2.8	2.2	1.8	1.5
FRONT SEATS	115.58	2.5	1.8	1.4	1.2	1.0
ALL OCCUPANTS	132.54	1.5	1.0	0.8	0.7	0.6

Table 3.4– BCR calculation for a 5% discount rate and a device life of 10 years

	Benefit	$25 device	$35 device	$45 device	$55 device	$65 device
10% EFFECTIVENESS						
DRIVER ONLY	20.65	0.9	0.6	0.5	0.4	0.3
FRONT SEATS	26.64	0.6	0.4	0.3	0.3	0.2
ALL OCCUPANTS	30.55	0.3	0.2	0.2	0.2	0.1
20% EFFECTIVENESS						
DRIVER ONLY	41.31	1.8	1.3	1.0	0.8	0.7
FRONT SEATS	53.29	1.2	0.8	0.7	0.5	0.5
ALL OCCUPANTS	61.11	0.7	0.5	0.4	0.3	0.3
30% EFFECTIVENESS						
DRIVER ONLY	61.96	2.7	1.9	1.5	1.2	1.0
FRONT SEATS	79.93	1.8	1.3	1.0	0.8	0.7
ALL OCCUPANTS	91.66	1.0	0.7	0.6	0.5	0.4
40% EFFECTIVENESS						
DRIVER ONLY	82.62	3.6	2.6	2.0	1.7	1.4
FRONT SEATS	106.57	2.3	1.7	1.3	1.1	0.9
ALL OCCUPANTS	122.21	1.3	1.0	0.7	0.6	0.5

The principal findings using a 7% discount rate are as follows:

- At 10% device effectiveness no device between \$25 – \$65 per unit returns a positive BCR
- At 20% device effectiveness:
  - o Driver–only fitment results in a positive BCR up to a \$35 device
  - o Fitment to front seats returns a break–even BCR for a \$25 device (1.0:1)
- At 30% device effectiveness, fitment of a driver–only device up to \$55, fitment to both front seat occupants up to \$35 return cost–beneficial outcomes
- With a 40% improvement in belt wearing, a device fitted to driver–only results in a positive BCR with a device cost up to \$65, and up to \$45 per device for front occupant fitment.
- For all occupants, only a \$25 device with a 40% improvement in restraint use results in a positive BCR.

Table 3.5 – BCR calculation for a 7% discount rate and a device life of 10 years

10% EFFECTIVENESS						
	Benefit	**\$25 device**	**\$35 device**	**\$45 device**	**\$55 device**	**\$65 device**
DRIVER ONLY	17.70	0.8	0.6	0.4	0.4	0.3
FRONT SEATS	22.83	0.5	0.4	0.3	0.2	0.2
ALL OCCUPANTS	26.18	0.3	0.2	0.2	0.1	0.1
20% EFFECTIVENESS						
DRIVER ONLY	35.40	1.6	1.1	0.9	0.7	0.6
FRONT SEATS	45.66	1.0	0.7	0.6	0.5	0.4
ALL OCCUPANTS	52.36	0.6	0.4	0.3	0.3	0.2
30% EFFECTIVENESS						
DRIVER ONLY	53.10	2.3	1.7	1.3	1.1	0.9
FRONT SEATS	68.49	1.5	1.1	0.8	0.7	0.6
ALL OCCUPANTS	78.55	0.9	0.6	0.5	0.4	0.3
40% EFFECTIVENESS						
DRIVER ONLY	70.80	3.1	2.2	1.7	1.4	1.2
FRONT SEATS	91.32	2.0	1.4	1.1	0.9	0.8
ALL OCCUPANTS	104.73	1.2	0.8	0.6	0.5	0.4

The annual HARM benefit and percentage of total Australian annual HARM are presented in Table 3.6. Any implementation strategy would ideally aim to maximise the annual HARM benefit while maintaining strong BCRs. As illustrated in Table 3.6, the highest HARM savings are associated with higher device effectiveness levels combined with a greater number of seats to which the device is fitted. Acceptance of an implementation strategy that results in lower BCRs but where annual HARM savings are greatest may be a preferred option in order to maximise public acceptance of any retrofitting strategy.

Table 3.6 – Annual HARM benefits associated with retrofitting a seat belt reminder device for each implementation strategy, device effectiveness and discount rates.

IMPLEMENTATION STRATEGY	4% DISCOUNT RATE		5% DISCOUNT RATE		7% DISCOUNT RATE	
	Annual HARM Benefit	% Annual HARM Reduction	Annual HARM Benefit	% Annual HARM Reduction	Annual HARM Benefit	% Annual HARM Reduction
10% EFFECTIVENESS						
DRIVER ONLY	$13.2m	0.15	$12.1m	0.14	$10.4m	0.12
FRONT SEATS	$17.0m	0.19	$15.6m	0.18	$13.4m	0.15
ALL OCCUPANTS	$19.5m	0.22	$17.9m	0.20	$15.4m	0.17
20% EFFECTIVENESS						
DRIVER ONLY	$26.4m	0.30	$24.3m	0.27	$20.8m	0.24
FRONT SEATS	$34.0m	0.38	$31.4m	0.35	$26.8m	0.30
ALL OCCUPANTS	$39.0m	0.44	$35.9m	0.41	$30.8m	0.35
30% EFFECTIVENESS						
DRIVER ONLY	$39.5m	0.45	$36.5m	0.41	$31.2m	0.35
FRONT SEATS	$51.0m	0.58	$47.0m	0.53	$40.3m	0.46
ALL OCCUPANTS	$58.5m	0.66	$53.9m	0.61	$46.2m	0.52
40% EFFECTIVENESS						
DRIVER ONLY	$52.7m	0.60	$48.6m	0.55	$41.7m	0.47
FRONT SEATS	$68.0m	0.77	$62.7m	0.71	$53.7m	0.61
ALL OCCUPANTS	$78.0m	0.88	$71.9m	0.81	$61.6m	0.70

3.4 SUMMARY

The analysis described above shows that the unit HARM savings for a retrofitted seat belt reminder device vary from $17.70 to $132.54 per vehicle depending on which seats have the device fitted, the effectiveness of the device, and the discount rate chosen (Table 3.2, p.9). These benefits apply to vehicles up to ten years of age within the current fleet, and assume that the device will be effective for an average 10–year period.

It is unclear at this time what the cost and specifications of a suitable device would be. The only figures available on likely cost come from a Swedish device under development at Autoliv AB that resulted from a national competition. It was suggested that the likely cost for this device would be somewhere between A$30 and A$40, depending on its level of sophistication and sales volume. At this price plus the cost of fitment, the analysis shows that in the Australian context it would only be likely to be cost–beneficial if it also has a high level of effectiveness.

Using device costs ranging from $25 to $65, the calculated BCRs were highly variable and ranged from 3.9:1 to 0.1:1 depending on the seating positions included, the effectiveness and of the device, and the discount rate for future benefits (See Tables 3.3, 3.4, 3.5, pp.13–14). Using the most appropriate discount rate, 5% (choice of discount rate was discussed in further detail in Fildes et al, 2002), the best BCR was estimated as being 3.6:1 for a device of 40% effectiveness at a cost of $25 fitted for the driver only. For driver–only implementation, break–even BCRs (1.0:1) were achieved for a device of 30% effectiveness at a cost of $65 including fitment or for a device of 20% effectiveness at a cost of $45. For a device to be cost–beneficial for front seat occupants, the device would have to guarantee a 20% increase in restraint use, and importantly this only is true for a device of up to $25 per unit. At 30% effectiveness break–even BCRs are returned for devices costing up to $45 per unit if considering fitment for front seat occupants (30%; 1.0:1) and up to $55 for a 40% effective device (1.1:1).

CHAPTER 4 GENERAL DISCUSSION

The aim of this study was to determine the potential benefits of retrofitting a seat belt reminder device, in addition to the current five–second warning light, to passenger vehicles in the Australian fleet. It has been argued that the five–second warning required by ADR 69 is lost among the various warning lights that display when the ignition is activated, and that a more persistent reminder would lead to improvements in seat belt wearing in Australia. A more "aggressive" reminder system therefore would seem warranted to help further reduce road trauma in Australia.

In the context of an earlier report by the same authors (Fildes et al., 2002), an arbitrary assumption was made that for the purpose of this report that manufacturers would be required to fit a more "aggressive" reminder system than the current five–second warning light at some time in the near future. The report then analyses the potential benefits retrofitting seat belt reminder systems to passenger vehicles up to ten years of age.

4.1 POTENTIAL SAVINGS AND BENEFIT–COST RATIO ESTIMATES

The total HARM associated with motor vehicle crashes in Australia was estimated to be approximately $8.9 billion per annum, with unrestrained occupants accounting for 21% of the total HARM (approx. $1.9 billion). The benefit associated with wearing a seatbelt in airbag fitted vehicles for frontal, side impact, rear impact and rollover crashes was determined using information from the American NASS database. Assuming full compliance with restraint use, it was determined that the potential saving in the Australian context was $587 million per annum, with drivers accounting for approximately two–thirds of potential savings (approximately $397 million), front seat passengers accounting for approximately 20% ($115 million), and rear occupants the balance. These savings apply to the entire passenger car and light commercial vehicle fleet.

In the absence of an available 'off–the–shelf' mass produced device amenable to being retrofitted to passenger vehicles, BCR calculations were performed for four levels of effectiveness in improving belt use (10%, 20%, 30% & 40%), three fitment configurations (driver–only, front seat occupants, & all occupants), and three discount rates (4%, 5%, & 7%). The device life was assumed to be an average of 10 years. As the likely cost of a device was unknown, Benefit–Cost–Ratios were calculated for a range of costs from $25 to $65 at $10 increments. The BCRS calculated for the various implementation options and discount rates are given in Tables 3.3 to 3.5. The calculated BCRs were highly variable and ranged from 3.9:1 to 0.1:1 depending on the seating positions included, the effectiveness of the device, and the discount rate for future benefits.

Using the preferred 5% discount rate (choice of discount rate was discussed in further detail in Fildes et al., 2002), the best BCR was estimated as being 3.6:1 for a device of 40% effectiveness at a cost of $25, fitted for the driver only. For driver–only implementation, break–even BCRs (1.0:1) were achieved for a device of 20% effectiveness at a cost of $45 including fitment, and a 30% effective device costing up to $65 per unit. The next lowest BCRs were 1.2:1 for a 30% effective device costing up to $55 and 1.4:1 for a 40% effective device costing up to $65 per unit.

For a device to be cost–beneficial for front seat occupants, the device would have to guarantee a 20% increase in restraint use, and importantly this is only true for a device of up to $25 per seat, or for devices that would guarantee a minimum 30% improvement in belt wearing and cost less than $45 per unit. At higher levels of effectiveness (i.e., 30% & 40%), positive BCRs are returned for devices costing up to $65 per seat if considering driver–only fitment (30%; 1.0:1). For front seat occupants, retrofitting a 30% effective device to front seat occupants returns a break–even BCR for a device up to $45 and up to $55 for a device offering 40% effectiveness. It is evident that retrofitting a device to all occupant positions would not be cost beneficial unless a device under $35 that would guarantee 40% effectiveness could be developed.

The amount of HARM saved associated with devices of various levels of effectiveness is an additional consideration in deciding whether to mandate retrofitting seat belt reminder systems to existing passenger vehicles. Using a 5% discount rate, a device offering 10% effectiveness fitted for the driver only yields a 0.14% ($12.1 million) HARM saving, while a device affording 40% improvement in belt wearing yields a HARM saving of 0.55% ($48.6 million). The inclusion of front left passengers results in a marginal 29% increase in HARM savings, however BCRs that are already borderline break–even decrease by approximately 33%. The BCRs remain sufficiently high despite this marginal increase in HARM saved and reduction in BCRs when front passengers are included in the retrofitting strategy, but only at the higher levels of device effectiveness and only for relatively inexpensive devices. While expanding the seat belt reminder to all seating positions results in a higher proportion of total HARM saved, the BCRs are only better than break–even for a device under $35 that would guarantee 40% effectiveness.

On the basis of the BCRs obtained and the marginal increase in HARM associated with the inclusion of front occupants, it could be concluded that a device fitted for the driver's seating position only would seem to be a preferred option for Australia. As a minimum requirement, a driver–only option would only be worthwhile if a relatively inexpensive device capable of a minimum 20% improvement in seat belt wearing could be fitted. Of course, as device effectiveness increases, device cost may also increase while at the same time maintaining positive BCRs. The inclusion of front occupants in the retrofitting strategy would be worth consideration only if a device that guarantees a minimum 30% improvement in belt wearing were to be developed, unless a very inexpensive device (which at this point appears unlikely) were to be developed.

4.2 EFFECTIVENESS AND COST OF RETROFITTED DEVICES

Both the level of device effectiveness in increasing belt use and device cost are critical determinants in deciding whether retrofitting a seat belt reminder device is cost–beneficial. As noted above, a device fitted to the driver's position that is relatively inexpensive and/or offers a high level of effectiveness would seem to represent the preferred option for Australia. Device effectiveness and device cost are considered in turn.

4.2.1 Device effectiveness

The BCR calculations are influenced heavily by the effectiveness of the seat belt reminder in generating greater compliance. The BCRs obtained indicate that the device would have to guarantee a minimum 20% increase in restraint use for a driver–only fitment, or at least 30% for fitment to both front occupants. Several overseas studies have specifically investigated the effect of reminder systems on seat belt wearing rates. It is important to note that these devices were not retrofitted to the vehicles, however in the absence of evidence of the effectiveness of retrofitted devices these studies represent the best evidence available.

In a Swedish study of belt wearing rates among injured drivers, Bylund and Björnstig (2001) investigated the effectiveness of different seat belt reminder systems. Using ambulance personnel to document restraint use and vehicle type, the authors reported a close to 50% improvement in restraint use where the device comprised both an auditory and visual signal (12% unbelted) compared to no reminder (23% unbelted). The presence of a visual signal (a light) alone compared to no reminder was seen to have only a negligible effect on belt wearing rates. In 2002, Ford and Insurance Institute for Highway Safety (IIHS) researchers reported that the new BeltMinder™ seat belt reminder system installed in late model Ford passenger vehicles had increased the drivers' seat belt wearing rate over a two month period (Williams, 2002). The BeltMinder™ uses both an auditory and visual alarm. Seat belt wearing rates were significantly higher for drivers of vehicles with the BeltMinder™ system (76%) than for drivers with vehicles without the BeltMinder™ (71%), representing a 17% improvement.

On the basis of these two studies, it can be suggested that a seat belt reminder consisting of both auditory and visual signals results in a 17% – 50% improvement in belt wearing rates. However these studies were unable to determine the proportion of the improvement in belt wearing that was due to the auditory warning and to the visual warning separately. Bylund and Björnstig (2001) did suggest that much of the improvement was due to the auditory aspect of the reminder system.

In a recent report by Fildes et al. (2002) that examined the benefits of mandating fitting seat belt reminder systems to all new passenger vehicles, it was estimated that only a 10% improvement in belt wearing rates would be achieved in Australia with a simple flashing light and tone of 65dB along the lines of that specified by Euro–NCAP. It was assumed that higher levels of device effectiveness would only be achieved with additional features. A system with both auditory and visual signals that increased in intensity with increasing speed was assumed to have 20% effectiveness, and one with a more sophisticated belt–wearing sensor system, and an external stimulus designed to embarrass the occupant into wearing a seat belt also added to the device was assumed to achieve either 30% or 40% (BCRs were calculated at both rates).

The Swedish device being developed for retrofitting, as described above, relies only on an auditory tone, unlike the BeltMinder™ that has an auditory tone plus a visual display. In calculating BCRs for devices fitted at manufacture, Fildes et al. (2002) were more conservative than the 17% improvement reported by Williams (2002) in that they suggested a device using an auditory tone and visual signal would achieve only a 10% improvement in belt–wearing rates in the Australian context, due to already high belt wearing rates. This suggests that any device that relies solely on an auditory tone may not achieve greater than 10% effectiveness in improving belt wearing in Australia. Alternatively, the effectiveness values utilised by Fildes et al. (2002) may prove by way of experimental design to have been conservative.

Given the BCRs obtained for the driver–only retrofitting in this study, a device in the price range of A$50 – A$70 including fitment would have to guarantee at least a 30% – 40% increase in belt use in order to ensure retrofitting is worthwhile for Australia. In the context of high levels of compliance of belt wearing in Australia among drivers in particular, and the 17% increase in belt wearing attributed to the BeltMinder™, it appears on face value that a 40% improvement is unlikely for a device that relies solely on an auditory warning, and that for such gains to be made additional higher level interventions would be required. It is clear that prior to any decision being made on whether to retrofit seat belt reminder devices to the Australian fleet, evidence is required as to the likely effectiveness of any such device.

Importantly, the desire and the potential for drivers to circumvent a retrofitted seat belt reminder device are unknown factors. Certainly, it would appear important at the outset to ensure that difficulty in circumventing any such system would be a feature guiding device choice. It is likely though, as indicated by Harrison, Senserrick, and Tingvall (2000), that the number of non–belt wearers that can be classified as 'hard–core' non–wearers is small, with most simply being forgetful, therefore unlikely to disconnect a reminder, and to whom such a device is directed. Importantly, this element was a factor in arriving at the potential benefits attributable to reminder systems.

4.2.2 Device costs, expected device life, and vehicle cohort

As noted above, there were no mass produced reminder systems available at the time of writing this report. The cost of the device under development by Autoliv Research is expected to range from A$50 – A$70 including fitment. A further issue is that the battery life is expected to be of four years duration, although it would be longer if the occupant generally 'buckles up' less than 20 seconds after starting driving. The BCR calculations presented in this report assume that the device would have an average life of ten years. For this to be achieved it appears that the system would have to be 'hard–wired' to the vehicle's power source, therefore increasing the likely cost of the device.

The device under development at Autoliv Research in Gothenburg was used in this report for illustrative purposes only. This device allowed for a sensible cost estimate to be made with existing technology, and further, demonstrates that the development and fitting of devices is practical in the first instance. The authors recommend that any seat belt reminder device designed to be retrofitted to vehicles include both a visual and an auditory signal. This approach would serve two purposes; firstly to allow consistency with the EuroNCAP standard, and secondly to increase the difficulty of disconnection or circumvention of the system by the occupant. Furthermore, consistency with an existing standard would assist with public acceptance of a retrofitting strategy and would ensure a consistent design approach across potential developers of such devices.

The earlier report by Fildes et al. (2002) suggested that a device fitted to new vehicles offering 10% improvement in belt wearing rates would cost $10, a 20% effective device would cost $40, and a device offering 30% and 40% improvement would cost $45 per seat. With the burden of retrofitting these devices, the cost per seat would be expected to increase significantly, particularly devices requiring connection to the speedometer, vehicle power source and so on. Labour costs would also increase the cost of the device.

The BCRs calculated suggest that a device resulting in a 20% improvement in restraint use remains marginally cost–beneficial up to $35 for driver–only fitment. Clearly, more expensive devices would only beneficial at higher levels of effectiveness, which in the Australian context might be difficult to achieve. It may be the case, as suggested by Fildes et al. (2002), that more expensive devices, such as those 'hard–wired' to the radio or hazard lights to act as a higher level of intervention in the case of non–compliance, may be required to achieve higher levels of effectiveness.

This report calculates potential benefits and BCRs for vehicles up to ten years of age. It would be essential in the choice of a device that fitment would not require structural alterations to the vehicle and that the device would be suitable to be fitted to **every** passenger vehicle in Australia. These constraints may act to limit the types of devices and also their potential level of effectiveness in increasing belt wearing.

A limitation of the analysis is that it was not possible to account for the potential difference in seat–belt wearing rates across vehicle models; rather the results represent average expected potential benefits across the entire vehicle fleet. Further, it was not possible in this report to accurately predict the penetration of vehicles fitted with audible and visual seat–belt warning displays into the Australian market, and hence it is not possible to quantify the effect on the expected benefits calculated. Given the relatively low penetration of vehicles meeting the recent EuroNCAP seat belt reminder system standard, it is likely that the difference in potential benefits would be marginal.

4.3 CONCLUSION

This report shows the potential economic benefits to Australian society of retrofitting seatbelt reminder devices under different implementation, effectiveness and cost scenarios. These scenarios can be used to inform the development and choice of device that maximises benefits to the community. On the basis of this study, it can be suggested that mandating the retrofitting of seat belt reminder systems to a vehicles up to 10 years of age in Australian passenger vehicle fleet would be worthwhile for a driver–only strategy, so long as the device would cost less than $45 *and* would guarantee a minimum 20% improvement in belt–wearing. At 30% and 40% device effectiveness, more expensive devices could be fitted while maintaining cost–beneficial outcomes. The annual HARM savings associated with retrofitting were found to range from 0.14% ($12.1m) – 0.81% ($71.9m) of total HARM depending on level of effectiveness assumed. Given the cost of a device currently under development that is amenable to retrofitting, the results of this report indicate that fitment to both front occupants could not be recommended.

It would, however, appear unlikely that a seat belt reminder device amenable to retrofitting without 'hard–wiring' to the vehicle could achieve a higher than 20% improvement in belt wearing in the context of very high levels of seat belt wearing in Australia. While the current regulation for a five–second reminder light is perceived to be inadequate in reminding motorists to buckle up, no mass produced device amenable to retrofitting currently exists that can guarantee a minimum 20% improvement in belt wearing for a reasonable cost. If a relatively inexpensive device capable of a minimum 20% improvement in belt wearing among Australian drivers was developed, there is sufficient evidence to suggest that retrofitting such devices would prove cost–beneficial to Australian society in the long term.

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APPENDIX A: NASS CRASHWORTHINESS DATA SYSTEM, 1993–2000: ESTIMATION OF EFFECT OF SEAT–BELT EFFECTIVENESS IN INJURY MITIGATION

Table A.1 – Mean HARM (A$000) for belted and unbelted occupants by crash type.

IMPACT	Seat Belt	N	Minimum A$000	Maximum A$000	Mean A$000	Std. Deviation A$000
Frontal	Unbelted	849	$0	$382.33	14.35	25.48
	Belted	3038	$0	$555.00	8.05	15.25
Side impact	Unbelted	109	$0	$153.15	23.71	32.14
	Belted	409	$0	$375.67	17.15	36.17
Rear	Unbelted	16	$3.00	$106.00	26.19	34.58
	Belted	75	$2.75	$188.00	8.85	25.13
Rollover	Unbelted	59	$0	$208.50	21.32	42.60
	Belted	134	$0	$104.42	12.65	18.92

Table A.2 – Mean delta–V (km/h) for belted and unbelted occupants by crash type.

IMPACT	Seat belt	N	Mean (km/h)	Std. Deviation	Std. Error Mean	p–value
Frontal	Unbelted	849	33.03	16.10	.55	t(3885)=9.3,p<.05
	Belted	3038	28.05	13.04	.23	
Side impact	Unbelted	109	30.24	13.51	1.29	t(516)=2.48,p<.05
	Belted	409	26.73	12.99	.64	
Rear	Unbelted	16	35.56	18.08	4.52	t(89)=1,95,p>.05
	Belted	75	28.00	13.09	1.51	
Rollover	Unbelted	59	32.20	14.39	1.87	t(191)=1.07,pp>.05
	Belted	134	29.85	13.85	1.19	

Due to the statistically significant difference in the mean delta–V of the belted and unbelted occupants (drivers and front seat passenger) for both frontal and side impact crashes, it was necessary to match the samples on delta–v distribution. This was done by using the percentage distribution of delta–V (5km/h categories). Twice the number of belted occupants were used, and were selected using the RANDOM SELECT CASES function in SPSS. The mean delta–V and mean HARM for frontal crashes and side impact crashes are presented below. These figures relate to cases where the delta–V was known, an air–bag deployed and involved driver and front seat passengers.

FRONTAL CRASHES – NASS CRASHWORTHINESS DATA SYSTEM 1993 – 2000

Table A.3 – Mean HARM for belted and unbelted occupants in frontal crashes.

	N	Minimum A$000	Maximum A$000	Mean HARM A$000	Std. Deviation A$000
Unbelted	849	.00	$382.33	$14.35	$25.48
Belted	1652	.00	$177.57	$8.78	$12.32

Table A.4 – Mean delta–V for belted and unbelted occupants in frontal crashes.

	N	Minimum (km/h)	Maximum (km/h)	Mean (km/h)	Std. Deviation
Unbelted	849	10.00	112.00	33.03	16.10
Belted	1652	9.00	100.00	31.66	14.32

The difference in mean delta–V for belted and unbelted occupants was not statistically significant. The difference in HARM was seen to be 39%. Hence, 39% is the saving in injury due to wearing a seatbelt for a frontal crash, where an airbag has deployed.

SIDE IMPACT

The delta–V of side impact cases was capped at 72 km/h due to differences in the upper end of the belted and unbelted delta–V distributions.

Table A.5 – Mean HARM for belted and unbelted occupants in side impact crashes.

IMPACT	N	N	Minimum A$000	Maximum A$000	Mean A$000
Unbelted	109	.00	153.15	23.71	32.14
Belted	214	.00	375.67	18.49	40.62

Table A.6
Mean delta–V for belted and unbelted occupants in side impact crashes.

IMPACT	N	Mean (km/h)	Std. Deviation (km/h)
Unbelted	109	30.24	13.51
Belted	214	29.36	12.95

The difference in mean delta–V for belted and unbelted occupants was not statistically significant. The difference in HARM was seen to be 21%. Hence, 21% is the saving in injury due to wearing a seatbelt for a side impact crash, where an airbag has deployed.

ROLLOVER

The mean HARM and mean delta–V for rollover crashes is presented in Tables A.1 and A.2 above. As there was no statistically significant difference in the mean delta–V, it was not necessary to match the samples. The difference in HARM was 41%.

REAR & OTHER

For these crash types, the weighted mean of savings was used.

APPENDIX B: CALCULATION OF UNIT BENEFITS

When considering the benefits of new safety features, it is useful to compute the unit benefits per passenger car so that Benefit–Cost–Ratios (BCRs) can be determined. The most commonly used method of calculating unit benefits in Australia involves the Discount Present Value method where the likely benefits per car are estimated for the life of the vehicle but discounted back to present day values. The method set out below was adopted for use in previous projects (eg: CR100, Monash University Accident Research Centre, 1992; CR154, Fildes, Digges, Carr, Dyte & Vulcan 1995) and has been used again in this project. It was adopted in consultation with Professor Parish, Monash University Department of Economics, and the Bureau of Transport and Communications Economics (now Bureau of Transport and Regional Economics).

DISCOUNT PRESENT VALUE METHOD

The method assumes that the risk of a new car being involved in a casualty crash during any one year (say the third year of its life) is the same as the risk of a car which was first registered three years ago having a crash this year. To calculate this yearly risk, the frequency of crashes for three–year–old cars is divided by the total number of cars sold three years ago (with an adjustment to remove the effects of year–to–year fluctuations in vehicle sales). The risk of a casualty crash across the lifetime of a car then is the sum of each year's crash experience, divided by the adjusted number of new cars sold. The process of focussing on each crash year and the number of car sales in the year when the car was new takes account of vehicles that exit from the vehicle fleet through wreckage, wear and tear, etc., as well as the lower distances travelled by older cars and the different characteristics of those who drive older cars.

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

$$\frac{H_3}{H} = \frac{F_3}{F} \qquad \text{or} \qquad H_3 = \frac{F_3}{F} \times H \qquad \text{Eq. (1)}$$

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

The average HARM reduction for any one car in its third year is calculated by dividing H_3 by the number of new cars registered three years ago. The total benefit for a single car from the new safety feature is then obtained by adding up the HARM reductions for each year of its life and discounting these benefits back to the first year (no discount is applied to the first year [year 0] because both the costs and benefits accrue progressively during that year).

The total benefit per car over its life is then:

$$B = \frac{H_0}{V_0} + \frac{H_1}{V_1[1+d]} + \frac{H_2}{V_2[1+d]^2} + \cdots\cdots\cdot \frac{H_n}{V_n[1+d]^n} \qquad \text{Eq. (2)}$$

Where

H_n = reduction in HARM by the measure for vehicle n year old
V_n = number of new vehicles registered n years ago
d = discount rate
n = the age of the vehicle; note: a vehicle is considered 0 years old during the calendar year in which it was registered

Then, if the economic cost of the measure is $C per device, the Benefit–Cost Ratio is:

$$BCR = 1/C * \left[\frac{H_0}{V_0} + \frac{H_1}{V_1[1+d]} + \frac{H_2}{V_2[1+d]^2} + \cdots\cdots\cdot \frac{H_n}{V_n[1+d]^n} \right] \qquad \text{Eq. (3)}$$

With Equation 3 being simplified to:

$$BCR = H/C \text{ x } V * \left[\frac{f_0}{v_0} + \frac{f_1}{v_1[1+d]} + \frac{f_2}{v_2[1+d]^2} + \cdots\cdots\cdot \frac{f_n}{v_n[1+d]^n} \right] \qquad \text{Eq. (4)}$$

Where:

f_n	=	F_n / F; number of cars involved in crashes with an occupant casualty in their nth year expressed as a proportion the total number of cars involved in crashes with an occupant casualty in one year
v_n	=	V_n / V; correction factor for cars registered n years ago
V	=	Average number of new vehicles registered per annum over the past 15 years
d	=	Discount rate applied
C	=	Economic cost, excluding GST

For all BCR calculations in this report, Equation 4 was used. Tables B.1–B.3 show the number of cars with occupant casualties by vehicle age in Victoria, NSW and Queensland for vehicles aged 10 years, 5 years, and in their first year of life (year 0) respectively. These numbers are also expressed in column 3 as the percentage of the total number of cars with occupant casualties (40,397) as well as the cumulative percentage (column 4). The crash data used to establish the proportion of vehicles involved in crashes by vehicle age for the year 2000 was reported casualty crash data for Victoria, NSW, and Queensland (Newstead, Cameron, Watson, & Delaney, 2003). While the ideal would be to examine all crashes in

Australia by year of vehicle manufacture, crash data from other States and Territories was not readily available. The assumption, therefore, is that crash involvement by vehicle age and fleet age distribution in Victoria, NSW and Queensland is indicative for Australia as a whole. It is critical to note that the use of the crash data was limited to establishing the proportional crash involvement of vehicles by year of manufacture rather than the actual numbers of vehicle involved. The number of new cars registered in each year from 1975 to 2000 is also shown in column 5. The final column shows the cumulative sum of the terms $[(F_0 / FV_0) + (F_1 / FV_1 \{1+d\}) + \cdots F_n / FV_n \{1+d\}^n)]$ from equation (4) above, using a 4% discount rate. This is the multiplier for converting total annual HARM saved H (expressed in millions of dollars) to unit HARM savings over the life of the vehicle (expressed in dollars). Tables B.4–B.6 and B.7–B.9 show similar tables for 5% and 7% discount rates. These figures were used for calculating the multipliers used for the 10–year device life in the body of the Table, namely:

	10 year Device Life		
	Device fitted in 0 – 1st year of vehicle life	**Device fitted in 5th year of vehicle life**	**Device fitted in 10th year of vehicle life**
4% discount rate	0.3836	0.3470	0.2663
5% discount rate	0.3678	0.3177	0.2337
7% discount rate	0.3393	0.2675	0.1809

It should be noted that the choice of the discount rate has a marked effect on the calculation. Not only does it influence the BCR, but also the cost of injury [BTRE, 2001 used a 4% discount rate in determining the cost of injury for each injury severity level].

In recent times, the BTRE (2002) argued that a 5% discount rate was "most meaningful" for undertaking benefit–cost analyses, although they still recommend calculations at a range of rates should be undertaken as a sensitivity analysis.

Table B.1
Numbers & Percentages of Cars with Occupant Casualties with a 4% discount rate for a 10–year device life fitted to 10–year–old vehicles.

DF = 1.04	Cars with killed or injured occupants				
Car Age	**Total number vehicles involved (F_n)**	**Proportion of total (f_n)**	**Cumulative Proportion**	**Number of new cars registered in Australia**	**Multiplier (cumulative sum of terms)**
19	1082	0.0267842	0.90	555753	0.2663
18	1330	0.0329232	0.88	580654	0.2528
17	1297	0.0321063	0.84	524515	0.2363
16	1827	0.0452261	0.81	579925	0.2178
15	2176	0.0538654	0.77	625061	0.1933
14	1636	0.0404981	0.71	478197	0.1651
13	1510	0.037379	0.67	414467	0.1363
12	1790	0.0443102	0.64	477461	0.1045
11	2008	0.0497067	0.59	544296	0.0703
10	2038	0.0504493	0.54	567202	0.0354
9	1591	0.0393841	0.49	482099	
8	1635	0.0404733	0.45	526303	
7	1637	0.0405228	0.41	530947	
6	1990	0.0492611	0.37	588550	
5	2142	0.0530237	0.32	613261	
4	2194	0.054311	0.27	630869	
3	2412	0.0597074	0.21	698916	
2	2572	0.0636681	0.15	778997	
1	2556	0.063272	0.09	740998	
0	1087	0.0269079	0.03	760523	
Total	40397	1		11698994	
Average New Registrations p.a. (last 15 years)				**588872.4**	

Table B.2
Numbers & Percentages of Cars with Occupant Casualties with a 4% discount rate for a 10–year device life fitted to 5–year–old vehicles.

DF = 1.04	Cars with killed or injured occupants				
Car Age	Total number vehicles involved (F_n)	Proportion of total (f_n)	Cumulative Proportion	Number of new cars registered in Australia	Multiplier (cumulative sum of terms)
14	1636	0.0404981	0.71	478197	0.3470
13	1510	0.037379	0.67	414467	0.3182
12	1790	0.0443102	0.64	477461	0.2863
11	2008	0.0497067	0.59	544296	0.2522
10	2038	0.0504493	0.54	567202	0.2172
9	1591	0.0393841	0.49	482099	0.1818
8	1635	0.0404733	0.45	526303	0.1480
7	1637	0.0405228	0.41	530947	0.1150
6	1990	0.0492611	0.37	588550	0.0808
5	2142	0.0530237	0.32	613261	0.0418
4	2194	0.054311	0.27	630869	
3	2412	0.0597074	0.21	698916	
2	2572	0.0636681	0.15	778997	
1	2556	0.063272	0.09	740998	
0	1087	0.0269079	0.03	760523	
Total	40397	1			
Average New Registrations p.a. (last 15 years)				**588872.4**	

Table B.3
Numbers & Percentages of Cars with Occupant Casualties with a 4% discount rate for a 10–year device life fitted to 0–year–old vehicles.

DF = 1.04	Cars with killed or injured occupants				
Car Age	**Total number vehicles involved (F_n)**	**Proportion of total (f_n)**	**Cumulative Proportion**	**Number of new cars registered in Australia**	**Multiplier (cumulative sum of terms)**
9	1591	0.0393841	0.49	482099	0.3836
8	1635	0.0404733	0.45	526303	0.3498
7	1637	0.0405228	0.41	530947	0.3167
6	1990	0.0492611	0.37	588550	0.2825
5	2142	0.0530237	0.32	613261	0.2436
4	2194	0.054311	0.27	630869	0.2017
3	2412	0.0597074	0.21	698916	0.1584
2	2572	0.0636681	0.15	778997	0.1137
1	2556	0.063272	0.09	740998	0.0692
0	1087	0.0269079	0.03	760523	0.0208
Total	40397	1			
Average New Registrations p.a. (last 15 years)				**588872.4**	

Table B.4
Numbers & Percentages of Cars with Occupant Casualties with a 5% discount rate for a 10–year device life fitted to 10–year–old vehicles.

DF = 1.05	Cars with killed or injured occupants			Number of new cars registered in Australia	Multiplier (cumulative sum of terms)
Car Age	Total number vehicles involved (F_n)	Proportion of total (f_n)	Cumulative Proportion		
19	1082	0.026784	0.90	555753	0.2337
18	1330	0.032923	0.88	580654	0.2224
17	1297	0.032106	0.84	524515	0.2086
16	1827	0.045226	0.81	579925	0.1928
15	2176	0.053865	0.77	625061	0.1718
14	1636	0.040498	0.71	478197	0.1474
13	1510	0.037379	0.67	414467	0.1222
12	1790	0.04431	0.64	477461	0.0940
11	2008	0.049707	0.59	544296	0.0636
10	2038	0.050449	0.54	567202	0.0322
9	1591	0.039384	0.49	482099	
8	1635	0.040473	0.45	526303	
7	1637	0.040523	0.41	530947	
6	1990	0.049261	0.37	588550	
5	2142	0.053024	0.32	613261	
4	2194	0.054311	0.27	630869	
3	2412	0.059707	0.21	698916	
2	2572	0.063668	0.15	778997	
1	2556	0.063272	0.09	740998	
0	1087	0.026908	0.03	760523	
Total	40397	1		11698994	
Average New Registrations p.a. (last 15 years)				**588872.4**	

Table B.5
Numbers & Percentages of Cars with Occupant Casualties with a 5% discount rate for a 10–year device life fitted to 5–year–old vehicles.

DF = 1.05	Cars with killed or injured occupants			Number of new cars registered in Australia	Multiplier (cumulative sum of terms)
Car Age	Total number vehicles involved (F_n)	Proportion of total (f_n)	Cumulative Proportion		
14	1636	0.0404981	0.71	478197	0.3177
13	1510	0.037379	0.67	414467	0.2925
12	1790	0.0443102	0.64	477461	0.2643
11	2008	0.0497067	0.59	544296	0.2339
10	2038	0.0504493	0.54	567202	0.2024
9	1591	0.0393841	0.49	482099	0.1703
8	1635	0.0404733	0.45	526303	0.1393
7	1637	0.0405228	0.41	530947	0.1086
6	1990	0.0492611	0.37	588550	0.0767
5	2142	0.0530237	0.32	613261	0.0399
4	2194	0.054311	0.27	630869	
3	2412	0.0597074	0.21	698916	
2	2572	0.0636681	0.15	778997	
1	2556	0.063272	0.09	740998	
0	1087	0.0269079	0.03	760523	
Total	40397	1			
Average New Registrations p.a. (last 15 years)				**588872.4**	

Table B.6
Numbers & Percentages of Cars with Occupant Casualties with a 5% discount rate for a 10–year device life fitted to 0–year–old vehicles.

DF = 1.05	Cars with killed or injured occupants				
Car Age	**Total number vehicles involved (F_n)**	**Proportion of total (f_n)**	**Cumulative Proportion**	**Number of new cars registered in Australia**	**Multiplier (cumulative sum of terms)**
9	1591	0.0393841	0.49	482099	0.3678
8	1635	0.0404733	0.45	526303	0.3368
7	1637	0.0405228	0.41	530947	0.3062
6	1990	0.0492611	0.37	588550	0.2742
5	2142	0.0530237	0.32	613261	0.2374
4	2194	0.054311	0.27	630869	0.1975
3	2412	0.0597074	0.21	698916	0.1558
2	2572	0.0636681	0.15	778997	0.1124
1	2556	0.063272	0.09	740998	0.0687
0	1087	0.0269079	0.03	760523	0.0208
Total	40397	1			
Average New Registrations p.a. (last 15 years)				**588872.4**	

Table B.7
Numbers & Percentages of Cars with Occupant Casualties with a 7% discount rate for a 10–year device life fitted to 10–year–old vehicles.

DF = 1.07	Cars with killed or injured occupants			Number of new cars registered in Australia	Multiplier (cumulative sum of terms)
Car Age	Total number vehicles involved (F_n)	Proportion of total (f_n)	Cumulative Proportion		
19	1082	0.0267842	0.90	555753	0.1809
18	1330	0.0329232	0.88	580654	0.1731
17	1297	0.0321063	0.84	524515	0.1632
16	1827	0.0452261	0.81	579925	0.1518
15	2176	0.0538654	0.77	625061	0.1362
14	1636	0.0404981	0.71	478197	0.1178
13	1510	0.037379	0.67	414467	0.0985
12	1790	0.0443102	0.64	477461	0.0764
11	2008	0.0497067	0.59	544296	0.0522
10	2038	0.0504493	0.54	567202	0.0266
9	1591	0.0393841	0.49	482099	
8	1635	0.0404733	0.45	526303	
7	1637	0.0405228	0.41	530947	
6	1990	0.0492611	0.37	588550	
5	2142	0.0530237	0.32	613261	
4	2194	0.054311	0.27	630869	
3	2412	0.0597074	0.21	698916	
2	2572	0.0636681	0.15	778997	
1	2556	0.063272	0.09	740998	
0	1087	0.0269079	0.03	760523	
	40397	1			
Average New Registrations p.a. (last 15 years)				**588872.4**	

Table B.8
Numbers & Percentages of Cars with Occupant Casualties with a 7% discount rate for a 10–year device life fitted to 5–year–old vehicles.

DF = 1.07	Cars with killed or injured occupants				
Car Age	Total number vehicles involved (F_n)	Proportion of total (f_n)	Cumulative Proportion	Number of new cars registered in Australia	Multiplier (cumulative sum of terms)
14	1636	0.0404981	0.71	478197	0.2675
13	1510	0.037379	0.67	414467	0.2481
12	1790	0.0443102	0.64	477461	0.2261
11	2008	0.0497067	0.59	544296	0.2018
10	2038	0.0504493	0.54	567202	0.1763
9	1591	0.0393841	0.49	482099	0.1497
8	1635	0.0404733	0.45	526303	0.1235
7	1637	0.0405228	0.41	530947	0.0971
6	1990	0.0492611	0.37	588550	0.0691
5	2142	0.0530237	0.32	613261	0.0363
4	2194	0.054311	0.27	630869	
3	2412	0.0597074	0.21	698916	
2	2572	0.0636681	0.15	778997	
1	2556	0.063272	0.09	740998	
0	1087	0.0269079	0.03	760523	
	40397	1			
Average New Registrations p.a. (last 15 years)				**588872.4**	

Table B.9
Numbers & Percentages of Cars with Occupant Casualties with a 7% discount rate for a 10–year device life fitted to 0–year–old vehicles.

DF = 1.07	Cars with killed or injured occupants			Number of new cars registered in Australia	Multiplier (cumulative sum of terms)
Car Age	Total number vehicles involved (F_n)	Proportion of total (f_n)	Cumulative Proportion		
9	1591	0.0393841	0.49	482099	0.3393
8	1635	0.0404733	0.45	526303	0.3131
7	1637	0.0405228	0.41	530947	0.2867
6	1990	0.0492611	0.37	588550	0.2588
5	2142	0.0530237	0.32	613261	0.2259
4	2194	0.054311	0.27	630869	0.1896
3	2412	0.0597074	0.21	698916	0.1509
2	2572	0.0636681	0.15	778997	0.1099
1	2556	0.063272	0.09	740998	0.0678
0	1087	0.0269079	0.03	760523	0.0208
	40397	1			
Average New Registrations p.a. (last 15 years)				**588872.4**	