Centre for
Automotive Safety Research

Analysis of crash data to estimate the benefits of emerging vehicle technology

RWG Anderson, TP Hutchinson, B Linke, G Ponte

CASR REPORT SERIES
CASR094
April 2011

THE UNIVERSITY
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Report documentation

REPORT NO.	DATE	PAGES	ISBN	ISSN
CASR094	April 2011*	85	978 1 921645 31 0	1449-2237

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ABSTRACT

The purpose of this report is to estimate the potential benefits of some of the safety technologies emerging for passenger vehicles, trucks and motorcycles. The focus is overwhelmingly on systems that actively prevent crashes, but a few passive safety features are also included. Intelligent speed adaptation is excluded from this report as it is being considered separately in an accompanying report. Direct short-range communication technologies were also outside the scope of the present report. The largest potential for reducing the number of serious and fatal crashes in coming years is likely to come from forward collision detection and avoidance technologies. These technologies currently include emergency brake assist, 'city-safe' low speed obstacle detection with automatic braking, and adaptive cruise control with automatic braking (operating sometimes only above, for example, 60 km/h). In the next five years, it is expected that the technologies will continue to develop such that there will be complete convergence in the operable range of systems, and a complete integration of the sensing and intervention technologies. It is from such future systems that the largest road safety gains are likely to be made. However, BCR values for forward collision detection and avoidance in passenger vehicles appear marginal given the present stage of development of the relevant technologies (where such systems might only be used to effect in higher speed limit areas); better estimates of future costs of the relevant technology will be critical to any justification for wide-scale installation. Nevertheless, BCR values support wide-scale installation of forward collision avoidance technologies in trucks. Mechanisms are suggested for accelerating the deployment of cost-effective safety technology into to the Australian passenger fleet.

KEYWORDS

Active vehicle safety, Passive vehicle safety, Passenger vehicles, Trucks, Motorcycles, Emerging technology, Cost-benefit analysis, Crash data

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* Report accepted as final and complete in June 2010

Executive Summary

New vehicle safety technology is in the midst of a revolution. For the past 25 years, major advances have been made in the area of vehicle crashworthiness with high levels of secondary safety expected in new vehicles. But much more recently, technologies have been developed that tackle primary safety by focusing on crash causations and mechanisms. New primary safety technologies are still emerging and the vehicle of the future will have ever-tighter integration of primary and secondary safety features. But while primary safety features appear to offer much, their potential to reduce crashes remains, for many, uncertain.

The purpose of this report is to estimate the potential benefits of some of the safety technologies emerging for passenger vehicles, trucks and motorcycles. The focus is overwhelmingly on systems that actively prevent crashes, but a few passive safety features are also included. Intelligent speed adaptation is excluded from this report as it is being considered separately in an accompanying report. Direct short-range communication technologies were also outside the scope of the present report.

A review of the literature revealed that only a few technologies had been evaluated using data on actual crashes. As some of these technologies are so new, and the market penetration is so shallow, it is unsurprising that proper evaluations have not yet been done for many technologies. Nevertheless, in most cases, some form of evaluation has been conducted.

Methodology overview

The approach taken in this report was to estimate potential benefits of each technology by examining historical crash data in New South Wales. Crashes that would have been likely to be affected by the introduction of each technology were identified by according to attributes of the crashes. Where possible, published effectiveness estimates were then applied to the crash data; but in the majority of cases, benefits were estimated by assuming a high effectiveness in a specific and narrow range of crash types, and a lower effectiveness in a broader range on non-specific but relevant crash types.

Costs of fleet deployment of each technology were combined with estimated benefits in order to calculate benefit-cost ratios (BCRs).

Results

The results of the analysis are given in Table E1. Results have been sorted according to estimated benefits in terms of monetised crash reductions. Note that overall benefits are, to a large extent, driven by potential reductions in passenger vehicle crashes. Benefits specific to each vehicle type are contained in the body of the report.

Because of uncertainties in costs and crash reductions, BCR values should be seen as approximations. Some technologies with moderately low BCR values should not yet be rejected where potential road-safety benefits are large, as currently quoted prices for relevant technologies are likely to fall with time, if historical precedence is a guide. Given the uncertainty in costs, some BCR estimates might approximately double with better information on future costs.

The largest potential for reducing the number of serious and fatal crashes in coming years is likely to come from forward collision detection and avoidance technologies. These technologies currently include emergency brake assist, ‘city-safe’ low speed obstacle detection with automatic braking, and adaptive cruise control with automatic braking (operating sometimes only above, for example, 60 km/h). In the next five years, it is expected that the technologies will continue to develop such that there will be complete convergence in the operable range of systems, and a complete integration of the sensing and intervention technologies. It is from such future systems that the largest road safety gains are likely to be made. However, BCR values for forward collision detection and avoidance in passenger vehicles appear marginal given the present stage of development of the relevant technologies (where such systems might only be used to effect in higher speed limit areas); better estimates of future costs of the relevant technology will be critical to any justification for wide-scale installation. Nevertheless, BCR values support wide-scale installation of forward collision avoidance technologies in trucks.

Table E1
Summary of potential crash reductions, monetised crash savings and benefit cost ratios of technologies examined in this report

Technology	Estimated annual crash reductions in Australia[1]		Monetised crash savings[2] (2006 dollars, millions)	Estimated benefit cost ratios		
	Fatality (percentage of all fatals)	Non-fatal injury[1]		Pass.	Truck	M/cycle
Forward collision avoidance, all speeds	227 (16%)	54305	4,143	1.3	1.8	-
Alcohol interlocks	217 (15%)	9301	1,007	0.5	2.5	2.0
Fatigue management systems	150 (10%)	9233	992	0.5	2.9	-
Forward collision avoidance in 80 km/h and greater speed areas	127 (9%)	8204	873	0.2	1.1	-
Motorcycle ABS	88 (6%)	8618	795	-	-	27
Dedicated pedestrian detection - Daylight	43 (3%)	6711	415*	0.2	0.3	-
Lane departure warnings	100 (7%)	4177	539	0.3	2.2	-
Lane change warnings	14 (1%)	5031	365	0.2	0.7	-
Seatbelt interlocks	88 (6%)	726	268*	1.6	3.3	-
Dedicate pedestrian detection – Darkness	54 (4%)	2007	233*	0.0	0.1	-
Seatbelt reminder	71 (5%)	580	214*	1.3	2.7	-
Truck stability	20 (1%)	1130	126	-	1.5	-
Motorcycle traction control	10 (1%)	1091	98	-	-	1.7
Rear seatbelt improvements (pretensioners)	4 (0%)	10617	43*	0.1	-	-
Motorcycle airbags	2 (0.1%)	51	8*			0.03

[1] Based on BITRE estimates of the numbers of crashes in Australia, 2006 (Percentage also needed for relevance?)

[2] PDO costs imputed from injury costs except where indicated (next note)

* Property damage costs excluded from estimate

Other systems with large potential are fatigue management systems and alcohol interlock systems. Alcohol interlocks are designed to prevent the operation of a vehicle while intoxicated, while fatigue management systems detect driver impairment through one of several means: for example, systems that monitor steering wheel and vehicle movements, or eye movements. An effective fatigue system (one that reliable detects and prevents fatigued driving) is likely to be very beneficial, but there is great uncertainty regarding effectiveness.

Most technologies considered in this report offer crash reductions in the order of 1-10%. But some may be cost prohibitive at this time (noting comments below on costs). But for trucks and motorcycles, most emerging technologies appear to promise positive net returns in terms of monetised crash reductions. They include:

- Stability control/rollover prevention, higher speed adaptive cruise control with braking, lane departure and lane change warnings for trucks
- Motorcycle anti-lock braking systems and cornering traction control.

How the crash data were analysed

The methodology used to estimate the potential benefits of the technologies was to analyse police reported crash data in New South Wales (1999-2008), identifying the proportion of crashes where it was likely that the technology would have prevented the crash. Benefit estimates were then applied to all crashes in Australia at an aggregate level, using crash numbers estimated by the Bureau of Infrastructure, Transport and Regional Economics (BITRE).

The Definitions for Coding Accidents (DCA) in the crash data were used to categorise crashes. By identifying the DCA codes that were likely to be sensitive to certain technologies (that is, the technology would be likely to reduce the incidence or severity of such crashes), the number and proportion of crashes likely to be affected by each technology could be estimated.

For some technology types, DCA codes are unsuitable to identify crash types affected by a particular safety technology. In these cases, other crash variables were used (illegal blood alcohol concentration, fatigue etc.).

Calculation of costs and benefits

Benefit cost calculations assumed a steady state: that is a constant number of registered vehicles and a constant number of crashes over time. While police reported crashes in New South Wales were the basis for estimating possible crash reductions, it was recognised that this would give an incomplete picture of crashes: many non-fatal crashes are probably missing or miscoded in police reported data, and calculations in this report take this into account. Estimates of the number and costs of crashes have been made consistent with estimates published by the Bureau of Infrastructure, Transport and Regional Economics (2009).

There are difficulties with precisely estimating crash reductions. The level of information contained in police reported data is certainly useful but also provide a fairly blunt guide to those crashes likely to be positively affected by each technology. The efficacy of the technology is also uncertain. The approach taken was to assume that technologies would be very effective in a narrow range of scenarios closely related to the function of the technology, and somewhat effective in a broader range of scenarios where the technology is still likely to function, but with less effect.

Estimated fatal and injury crash reductions were monetised using the costs of crashes in Australia (BITRE, 2009). Additional benefits arising from reduced property damage crashes were included where appropriate by noting that BITRE have estimated that for every dollar in non-fatal injury costs, there is an additional $0.44 in costs associated with property damage only (non-injury) crashes.

On the cost side of the equation, calculations used the costs of technology as quoted by industry sources. However, some consideration is given to how such costs tend to fall over time. For example, the price of optional anti-lock brakes has fallen about 30% per five years over the last decade or so. Furthermore, while many safety technologies have become commonplace, where they were novel 20 years ago, there has been no real price increase in vehicles. Hence there is reason to be optimistic about the price of technology in general.

Cost benefit calculations used a discount rate of 5.5% and a benefit period that reflects an empirical average present value of crashes over a vehicle's service life. The period used in the calculation for each type of vehicle (truck, passenger car or motorcycle) was determined from the ages of vehicles in injury and fatal crashes in New South Wales. Periods were calculated so that, with a constant rate of crashing and for a discount rate of 5.5%, the present value of future crashes matched the empirical present values for each vehicle type. These periods were 16 years for passenger vehicles, 13 years for trucks and 11 years for motorcycles. Costs of fleet deployment were determined by estimated unit costs and Australian Bureau of Statistics figures of the numbers of vehicles in New South Wales, separately for passenger vehicles, trucks and motorcycles.

Encouraging the take-up of technology

Because of the service life of passenger vehicles in Australia it can take more than a decade before many of the passenger vehicles that are typically operated by drivers subjected to crash exposures will benefit from the technology. Where the rate of market penetration is slow, the situation can be exacerbated. Mechanisms to encourage efficient take up are therefore very important, and need to be considered with as much attention as given to the assessments of the technologies.

There are several mechanisms available to encourage the take-up of technology. In summary they include:

- Mandating where a positive benefit-cost case exists
- Promotion through the inclusion of active technologies in non-regulatory schemes such as the Australasian New Car Assessment Program
- Promotion through targeted take up by government and non-government fleets
- Promotion of technologies to the general public
- Promotion through government incentives

A large proportion (up to 50%) of the stock of vehicles in the registered fleet is determined by the purchases of government and non-government fleets. Purchasing polices that include requirements for effective safety technologies are likely to be cost-beneficial for the fleet purchaser as well as improve the efficiency of technology take-up in the entire fleet as ex-fleet vehicles continue their service life in the second hand vehicle market. Such policies are also more likely to lead to lower unit costs for manufacturers and purchasers alike, further encouraging take-up by all buyers.

For the foreseeable future, the Australasian New Car Assessment Program is likely to have an important role in providing advice to the passenger car market. It is common to see ANCAP ratings as part of 'safe' vehicle purchasing policies, sometimes with the addition of, for example, electronic stability control. As a greater variety of technologies become available, it will be important that those technologies that are most effective are given prominence, with the objective of efficient take up throughout the fleet.

Contents

1 Introduction

New vehicle safety technology is in the midst of a revolution. For the past 25 years, major advances have been made in the area of vehicle crashworthiness with high levels of secondary safety expected in new vehicles. But much more recently, technologies have been developed that tackle primary safety by focusing on crash causations and mechanisms. New primary safety technologies are still emerging and the vehicle of the future will have ever-tighter integration of primary and secondary safety features. But while primary safety features appear to offer much, their potential to reduce crashes remains, for many, uncertain.

There have been recent successes: electronic stability control (ESC) is consistently associated with substantial reductions in single vehicle crashes in particular where loss of control is a common precursor to a crash. But ESC was predated by a range of other active safety systems, the benefits of which are much more difficult to detect. For example, anti-lock braking systems (ABS) may not result in a net savings of crashes. A recent study was unable to associate any reduction in injury crashes with the fitment of ABS (Cummings and Grossman, 2007). Other evidence suggests that ABS may be useful for only sub-groups of drivers and crashes (Nishida, 2009).

Future developments in vehicle safety systems will include integration of active and passive safety systems. Active systems typically rely on an array of sensors to detect vehicle dynamics and current environment. Data from these sensors can be used to optimise passive safety features by pre-emptively preparing airbags and restraint systems before a crash. TRW Automotive predicts that these systems are likely in production vehicles in 2013 or 2014 (SAE, 2010).

In theory, active safety systems improve aspects of a vehicle or driver’s behaviour in what would otherwise be an emergency situation. In theory, ABS and ESC both offer this potential, but only ESC is associated with apparently clear crash reductions. There are many possible reasons any particular technology may not live up to expectations: advantages conferred in one driving situation may be offset by unintended disadvantages in other driving situations, improved vehicle handling may be used by drivers to increase vehicle speed, or system performance may fall short due to technical limitations or cost constraints.

Some of the newest technologies make the most of sensing systems that can inform vehicle control systems of potentially dangerous situations more efficiently (it is hoped) than the driver. Vehicle systems can then be primed or engaged to maximise the chance of a crash being avoided.

Because these systems are designed to work in specific ways, information contained within crash data provides an opportunity to examine the potential scope of new technologies to effect crash reductions. With the use of an estimate of each technology’s effectiveness, it is then possible to estimate potential crash reductions.

1.1 Motivation for this report

In February 2008, Australian Transport Council (ATC) Ministers received a briefing from the National Transport Commission (NTC) on the development of a National Transport Policy Framework. Queensland agreed to take responsibility for developing the Safety and Security aspects of the framework. This action resulted in the establishment of the Safety Standing Sub Committee (SSSC).

As part of the SSSC work program, Queensland agreed to lead the development of technology based solutions that facilitate safety outcomes. To progress elements of this work the In-Vehicle and At-

Roadside Technologies (IVART) project was established to manage, develop and regulate the evolving information and communication technology transport safety and security applications to facilitate appropriate adoption in Australia within a planned framework and business and system architecture.

The IVART project has five core project components; one of these components includes the identification of high priority technology based safety solutions and the subsequent research and analysis of these technologies. Consequently, Queensland Transport and Main Roads commissioned the present report on the potential benefits of emerging vehicle technologies.

1.2 Methodology

By definition, emerging technologies are difficult to evaluate in a way that can inform us of real-world benefits. Only once a technology has been widely deployed will there be an opportunity to examine crash data to examine whether vehicles are under-represented in serious crashes because of the inclusion of the technology. The results of trials and studies predicting benefits will usually be published prior to wide-scale deployment. These studies use methodologies such as driving simulators, closed-course driving on test tracks, reconstruction of crashes investigated in sufficient depth to allow “what-if” scenarios to be constructed, disaggregation of crash data to identify that proportion of crashes likely to be affected by a given technology, or maybe even simply “expert judgement”.

The present study has taken the approach of examining routinely reported crashes in Australia to identify the proportions of crashes that are likely to be affected by the wide-scale deployment of each technology that was within the scope of the project. The dataset used is crashes that occurred over 10 years to the end of 2008 in New South Wales as reported in the state’s CrashLink system. These crashes represent a proportion of all crashes in NSW; the shortfall is a result of under-reporting or a miscoding of severity. For this project, estimates of the true number of crashes were obtained from the Bureau of Infrastructure, Transport and Regional Economics (BITRE), and crash numbers obtained from CrashLink data were adjusted to provide annualised estimates of the number of injury and fatal crashes in New South Wales.

Benefits were monetised according to the costs of crashes published by BITRE (2009). BITRE estimates were also used to impute further savings in property damage only crashes where appropriate.

Cost calculations were based on the costs of individual technologies as obtained for this report, and number of vehicles in New South Wales counted by the Australian Bureau of Statistics (ABS, 2007).

Benefit-cost calculations used the estimate in monetised crash reductions, discounted according to BCR conventions, and the costs of fitment to the NSW vehicle fleet. Finally, benefits were extrapolated to the rest of Australia using BITRE estimates of the numbers of crashes occurring annually in Australia.

Note that the BCR values presented in this report are based mostly on information about the costs of the technology to consumers, and do not take into account components sometimes considered in, for example, regulation impact statements. Similarly, the starting point has been that the technologies are virtually un-implemented in the fleet and prospective benefits are being estimated assuming that crashes in the historical dataset represent the population of crashes likely to be affected by new technology in the future. Therefore BCR values estimated in the future, for example when considering any justification for regulation, might be quite different to those presented here.

1.3 How this report is organised

This report considers technologies that may be considered “emerging” in that they are not part of any Australian regulatory process and that are not widely deployed in new vehicles. The approach has been to try and predict likely benefits from these technologies through a process of reviewing currently available literature (Section 2) and through analysis of Australian crash data (Sections 4 and 6). Details of the methodology used in the analysis are given in Section 3. The analysis of crash types and data recorded by transport authorities in crash databases allows crash types likely to be sensitive to any given technology to be identified.

Some commentary is provided in Section 5 on ways in which the take up of safety technology might be encouraged.

2 A brief review of the technologies considered in this report

2.1 Previous reports

Probably because of the interest in new vehicle technology generated by the apparent success of ESC, and the theoretical benefits of active safety systems, there have been several reports that have had the same objective as the present study: that is to summarise technologies, their purported or actual benefits, costs and the potential crash reductions that might result from widespread deployment. Some of these reports are described below. A common problem with many reports (but not necessarily those described below) is the strength of the evidence in much of the source material. Only one report we examined (Paine et al., 2008 – unavailable publicly) gives any systematic indication of the level of evidence for the claims made about individual technologies. Unfortunately, many reports rely too heavily on untested claims or thin evidence in an attempt to distill some estimate of a benefit or a crash reduction; sometimes cited benefits may have been given credentials that are undeserved. It may be that the tendency is to provide whatever scant information exists rather than to provide no estimate of benefit at all.

The reader's attention is brought to the following reports that may be of particular utility:

- COWI (2006) conducted a review of vehicle safety technologies for the European Commission Directorate General Energy and Transport. They reviewed 17 technologies. Their review included the calculation of cost-benefit ratios for most technologies and break-even costs for those technologies that they were unable to cost. Most technologies were found to be cost effective.
- Linder et al. (2007) reviewed 20 areas of intelligent transport systems (ITS) vehicle technology. They also draw on the experience of other industries (pharmaceutical, defence, food, security etc.) in how the process of introduction and evaluation of novel systems or products is handled. At the time of the review, in the area of emerging vehicle technologies, only established technologies (ABS, ESC) had been comprehensively evaluated. For the remainder, there have been studies on behavioural response and at best some evaluation on the effects on crashes "by proxy".
- Paine et al. (2008) considered a list of 32 intelligent vehicle technologies. They gave each a score out of 20 for "returns for government effort", in their informed opinion. The score was derived from assessments of trauma reduction, technology readiness, the need for new regulations, the need for new infrastructure or data, the likely influence of government support on uptake of the technology, the likely costs of the technology, and the acceptability to users of the technology. Of these different dimensions, at the present stage of our project, we are only interested in trauma reduction. The trauma reductions that were estimated or guesstimated by Paine et al. can easily be worked out: the percentage trauma reduction is 6 multiplied by the "trauma score" in column 2 of Table 10 of Paine et al. (2008).
- Page et al. (2009) point out that several systems (e.g., night vision enhancement, adaptive cruise control, lane departure warning) are at present restricted to luxury cars only, with very low penetration into the general car market, and that there cannot be any convincing analysis of their effects because of the low relevant crash counts.
- Austroads recently released a report on the benefits of ITS technology in Australia (Cairney et al., 2010) and that report covers similar ground to the present report.

Cairney et al. were pessimistic about most in-vehicle technologies, estimating that when their costs are subtract from the benefits (monetised crash reductions), the results are negative.

- Farmer (2008) considered five technologies, and found that the one with the greatest potential was forward collision warning and mitigation, relevant to 38 per cent of crashes in the United States. Farmer concluded that vehicle-based crash avoidance systems have great potential effectiveness, with technologies for forward collision warning and mitigation coming top of the list.

Additionally, two repositories of information about studies on vehicle safety aspects of ITS may be found on the Internet:

- The eSafety Effects Database (http://www.esafety-effects-database.org/index.html) is a clearinghouse for research on the effects of “eSafety systems” including:
    - Adaptive headlights
    - Alcohol (inter)lock
    - Blind spot monitoring
    - eCall
    - Lane departure warning
    - Obstacle & collision warning (including ACC)
    - Seat belt reminder

- The US Research and Innovative Technology Administration operates an ITS Benefits Database (http://www.itsbenefits.its.dot.gov/) including summaries of studies examining the costs and/or benefits of relevant safety technologies .

The evidence in these reviews may broadly be categorised as one of two types:

- Direct evidence, comparing vehicles with and without the technology. This comes from jurisdictions or types of vehicle that have adopted the technology early.
- Indirect methods – for example, identifying which types of crash are intended to be prevented by the technology, determining what proportion of the total number of crashes these relevant types constitute, and estimating or guesstimating what proportion of the relevant types actually would be prevented. Performance in driving simulators is another form of indirect evidence.

The reviews make clear that (a) for many of these technologies, there is no direct evidence, as the technology has not been used in enough (or in some cases any) vehicles, and (b) there is no indirect method that gives a clear and convincing prediction of real-world effect.

An objective in the present review was to focus on studies reporting actual crash reductions while acknowledging other methods used to estimate benefits. However, we do not wish to overstate the level of review we have given to any study in particular. In general we have taken conclusions based on clearly described methodologies, made in reputable forums, at face-value. In summing up, some attention is given, where possible, to benefits suggested by previous analyses and those that are indicated by the analysis of crash data.

2.2 Forward collision avoidance

2.2.1 Emergency brake assist (EBA)

APPLICABLE VEHICLE TYPES:

Passenger vehicles; Heavy vehicles

PURPOSE:

To reduce the stopping distance of a vehicle in an emergency braking situation.

MECHANISM:

A sensor attached to the braking system detects pedal pressure beyond a preset threshold and determines that the vehicle is undergoing emergency braking. In collaboration with ABS and ESC, the system then applies maximum braking force to the vehicle for the current situation. As a result, stopping distance is minimized, either reducing or avoiding potential impact.

An extension of this technology uses throttle position monitoring to detect rapid lift-off of the accelerator pedal, a typical sign that emergency braking may soon follow. The braking system is subsequently pre-primed (by way of reducing the gap between brake pad and disc rotor) to minimise brake application time in the event that they should be required.

In heavy vehicles, EBA is often part of an emergency braking system that might include forward collision warning with braking (Grover et al., 2008). If the driver does not respond to an alert by braking (at which point the EBA would assist), then automated braking might ensue.

POTENTIAL EFECTIVENESS:

Only a few studies have been conducted on the effectiveness of EBA. A brief review by Bayly et al. (2007) summarises the abstracts of eight reports on the benefits of brake assist, but many of these eight turn out to be secondary sources. Primary studies are few in number.

Because the technology is very new and the number of relevant vehicles and crashes is small, crash studies are difficult to undertake. One study, Page et al. (2005), examines the apparent effectiveness of the brake assist in two vehicle models in France.

Several studies have estimated potential benefits by examining in-depth crash data and, given reduced lag in brake application, improved brake responsiveness and the reduced risk of being injured or killed as impact speed declines (Page et al., 2005; Hannawald and Kauer, 2004; Lawrence et al., 2006).

Studies that calculate potential benefits do so by reconstructing the sequences of crashes that have been the subject of in-depth investigation. The timing of brake initiation and brake force are assumed from typical values and then the reconstruction is “replayed” with adjusted values for brake timing and brake force based on the performance of brake assist systems. Hypothetical impact speeds are estimated from these pseudo-reconstructions, and injury risk curves are used to estimate the reduction in injury risk. (A similar approach is taken in Anderson et al., 1995, to estimate reduction in fatalities for reduced vehicle travel speeds.)

Based on this method, Page et al. (2005) estimated that occupant fatalities in France might be reduced by 6.5-9 percent when vehicles are equipped with brake assist, and pedestrian fatalities by

10-12 percent. Note though only crashes involving non-ABS vehicles were used in the analysis (due to the need to use skid mark analysis), and these crashes were drawn from a database of fatal crashes pre-dating 1991.

Brake assist systems received particular attention in Europe in relation to pedestrian safety. Phase II of the European Directive on Pedestrian Protection includes the specification of emergency brake assist and has been specified to reduce impact speeds in an effort to offset easing in pedestrian passive safety requirements.

Lawrence et al. (2006) critically reviewed the effectiveness of brake assist as reported by Page et al. and Hannawald and Kaur (the latter report is apparently available only as a slide-based presentation). Lawrence et al. reconciled differences in their own estimates with that of Hannewald and Kaur and arrive at estimate of effectiveness of between 0 and 12 percent for fatal pedestrian and bicycle crashes. For the purposes of their own cost-benefit study of pedestrian protection, they arrive the following crash reductions for brake assist systems:

- 7.7 percent reduction in fatal pedestrian crashes and 4.2 percent reduction in fatal pedal cycle accidents
- 10.1 percent reduction in serious pedestrian crashes and 5.7 percent reduction in serious pedal cycle accidents
- 15.7 percent reduction in slight pedestrian crashes and 7.3 percent reduction in slight pedal cycle accidents

More recently, Page et al. (2009) used routine crash data from France to estimate the benefit of various safety configurations of cars. They found that, given that the car has four stars in the Eupropean New Car Assessment Program (EuroNCAP) rating system, brake assist in addition led to a 15 percent reduction in severe injuries and fatalities for vehicle occupants.

Paine et al. (2008) judged that this technology might lead to a trauma reduction of 5 percent.

Farmer (2008) considered five technologies, and found that the one with the greatest potential was forward collision warning and mitigation, relevant to 38 per cent of crashes in the United States, though he noted that Gottselig et al (2008) had arrived at a lower figure, 10 per cent. Farmer was careful to refer to potential. He did not adduce the argument we have made that even a small reduction in impact speed will be worthwhile.

COST:

Emergency brake assist is common on the majority of new cars, with 14 of the top 20 cars (by sales volume) having this technology fitted as standard and another two as optional. This could be due to the fact that it is closely related to electronic brake force distribution, which is also used by stability control systems; every vehicle sold with EBA is also fitted with EBD. In an example where EBA is not standard fitment (the base model Hyundai Getz), it is available as part of a safety pack comprising of both EBA and EBD, costing $1000. It is also available as an $1300 option on the Ford Focus as part of a safety package.

For trucks, Mercedes offer EBA as a $2250 option on the Actros prime mover. It is offered as a standard feature on Volvo and Scania trucks in the heavy rigid and multi combination categories.

2.2.2 Following distance warning/forward collision warning

APPLICABLE VEHICLE TYPES:

Passenger vehicles; trucks

PURPOSE:

To monitor the forward path of a vehicle and warn the driver should an object/vehicle present a potential collision risk. With the advent of similar systems that intervene to apply braking (heavy braking if required), this forward obstacle detection that only provides a warning is likely to be superseded.

MECHANISM:

A laser/radar or camera system is attached to the front of the equipped vehicle and is used to monitor both distance and relative speed to other objects/road users in the forward travel path. The driver will then receive an alert should the distance or approach speed to the object/road user be outside a predetermined safety margin. Some devices utilise a graduated warning system, employing a range of audible, visual or tactile responses, which vary according to proximity and the likelihood of a collision.

POTENTIAL EFECTIVENESS:

The eSafety Effects Database (www.esafety-effects-database.org) uses a heading “Obstacle and collision warning”, that includes what we term adaptive cruise control, following distance warning, and forward collision avoidance with braking. It finds that “no reliable safety estimates yet exist”.

Paine et al. (2008) judged that this technology might lead to a trauma reduction of 2 percent.

For heavy vehicles, Murray et al. (2009a) estimated benefits of following distance warnings coupled with adaptive cruise control in heavy vehicles in the United States. They thought credible industry estimates of effectiveness of between 21 percent and 44 percent for heavy vehicles striking other vehicles in rear end crashes. The estimate of 21 percent came from a field trial of Volvo forward collision warning systems. Notable in this trial was that this benefit was not appreciably changed by the bundling of forward collision warning with adaptive cruise control and advanced braking systems.

COST:

Following distance/forward collision warning is not currently available in any of the top selling vehicles category, but is standard fitment to both the Audi A8 and Mercedes S Class.

2.2.3 Active forward collision detection and intervention

APPLICABLE VEHICLE TYPES:

Passenger vehicles; Heavy vehicles.

PURPOSE:

These technologies include those referred to as adaptive cruise control with braking, and ‘city-safe’ systems that assist the driver to avoid rear-end crashes. The systems aid the driver in maintaining a safe following distance from the vehicle ahead in a highway environment through active control of vehicle acceleration and braking systems. In essence, this system is an advance on following distance warnings, using similar sensing functionality, but with the addition of active intervention.

MECHANISM:

Radar/laser sensors or a front mounted camera are used to detect other road users in the path of travel. This, combined with information from the vehicle speed sensor, can be used to determine approach speed to the car ahead. The system then decides if it is safe to continue travelling at the preset cruise speed or whether brake application is required (the system can utilise up to around one third of braking capability) to maintain a safe following distance. The system will continue to monitor the situation until the path is clear, at which time the vehicle is automatically accelerated to its preset cruise speed (Marsden et al. 2001).

Some current adaptive cruise control systems will operate only between speeds of 60 km/h and 180km/h. The newest adaptive cruise control can be activated at speeds as low as 30km/h. According to manufacturers, such systems are not effective with stationary objects or for collision prevention with an oncoming vehicle, because the speed difference at any given speed is much higher than it is in the case of one vehicle following another.

Lower speed systems use analysis of images from video camera systems and/or LASER/RADAR ranging systems. Braking is engaged approximately 0.5 seconds prior to calculated impact in an attempt to avoid or mitigate associated damage/injury. For some companies this technology is only active below a certain speed (30km/h for Volvo) although there appears to be no such limitation in most cases. The image analysis may include recognition of pedestrians and cyclists.

POTENTIAL EFECTIVENESS:

Much of the literature on adaptive cruise control is oriented to traffic flow rather than safety. Little attention has been given to quantifying any accident savings from adaptive cruise control. Linder et al. (2007, p. 38) refer to this as a convenience system, though they do note when integrated with systems such as obstacle detection, there is potential to reduce crashes.

The eSafety Effects Database (www.esafety-effects-database.org) uses a heading “Obstacle and collision warning”, that includes what we term adaptive cruise control, following distance warning, and forward collision avoidance with braking. It finds that “no reliable safety estimates yet exist”.

It seems reasonable to assume that this technology would prevent a high proportion of the crashes to which it is relevant --- rear-end crashes in a cruising environment (which would exclude many of those in urban areas).

Paine et al. (2008) judged that ACC might lead to a trauma reduction of 1.5 percent.

It is reasonable to assume that there will be a convergence in the operating conditions of the systems such that within a few years, full time systems that activate braking when needed will operate across intermediate and higher vehicle speeds. Thus this collection of discrete technologies might be considered collectively when assessing benefits.

Forward collision mitigation technology came top of the list of five considered by Farmer (2008) using crash data from the U.S.A. The criterion used was the number of crashes potentially prevented. Farmer considered that this technology is potentially relevant to 38 percent of crashes. Gottselig et al. (2008) came up with a lower figure, 10 percent, and considered that in practice the trauma reduction would be much less than this figure. There have been a number of relevant driving simulator studies. Linder et al. (2007, p. 49) discussed them, and summed up by saying that “Preliminary research results indicate a significant benefit in terms of decreased number of collisions”. The eSafety Effects Database (www.esafety-effects-database.org) uses a heading “Obstacle and collision warning”, that includes what we term adaptive cruise control, following distance warning, and forward collision avoidance with braking. It finds that “no reliable safety estimates yet exist”. Paine et al. (2008) judged that this technology might lead to a trauma reduction of 3 percent.

With figures in the previous paragraph being between 3 and 38 per cent, there cannot be said to be any consensus in the literature, although with the rapid development of the technology, authors may be referring to different levels of functionality in assessing benefits. Our view is that the potential benefits from this technology are great, as in the great majority of crashes, at least one vehicle has a frontal impact. Although it is intended that some crashes be prevented, it is important to note that a crash does not need to be entirely prevented in order for much of the benefit of a technology to be realised --- a reduction in the speed of the impact may be sufficient. Rather than the less optimistic figures suggested by Gottselig et al. and Paine et al., we would prefer to take Farmer’s figure of 38 per cent, and (because it is unreasonable to expect 100 per cent effectiveness) multiply it by some factor to account for effectiveness.

With regard to heavy vehicles, Paine (2003) reviewed the benefits of forward (and side) detection of obstacles. Paine refers to studies by Sweatman et al (1990; 1995) who examined crashes in New South Wales and who concluded that forward collision avoidance with automatic braking might have influenced 7 percent of crashes on highways. Paine also mentions later research in NSW that found that half of all fatal and serious crashes occurred in urban areas, where forward collision warning would be of limited benefit. In conclusion, Paine is reserved about the benefits of forward collision avoidance in Australia. A trial in North America in which 100 trucks were monitored for between 2 and 3.5 years found that vehicles that spent an extended time at highway speeds (> 90 km/h) were less exposed to potential conflict situations when forward collision avoidance technology was installed (Carnell and McMillan, 2007). Through reconstructions of actual accidents, Grover et al. (2008) examined the crash reductions likely from the installation of automated emergency brake assist (a system that includes forward collision warning and automated braking). They had most information for heavy vehicle crashes. For heavy vehicles, they estimated that between 25 percent and 75 percent (depending on the type of braking system) of all rear-shunt fatalities and serious injuries would be avoided where the bullet vehicle was a heavy vehicle.

COST:

Following distance/forward collision warning is not available separately within the vehicle group being examined, instead being included within the adaptive cruise control/forward collision avoidance systems as a precursor to automatic braking. Even the differences between adaptive cruise control and forward collision avoidance are minimal, the systems often utilised very similar hardware and, in the case of the Audi A4, were sold within the same option package at a cost of $2754. Therefore this cost represents the culmination of all three technologies in the one package, highlighting that, once the base hardware is installed for one of the technologies in this group, additional cost to expand functionality is effectively zero. Volvo offer a pack of three active technologies for $5,000. A cost of $2,700 will be utilised for the purposes of benefit cost calculations,.

2.3 Other crash avoidance, speed and traffic behaviour

2.3.1 Stability control and rollover warnings for heavy vehicles

APPLICABLE VEHICLE TYPES:

Heavy vehicles

PURPOSE:

To reduce the incidence of heavy vehicle loss-of-control and rollover crashes.

MECHANISM:

There are two main technologies available to help achieve this goal: driver alert and vehicle stability systems.

The driver alert system utilises a number of vehicle based sensors to monitor road wheel speed, yaw angle, lateral acceleration, roll angle and driver inputs. It then compares these results to an inbuilt vehicle dynamic model to determine rollover potential. Should this potential be above a predetermined threshold, a visual/auditory alert will be issued to the driver, allowing them to take corrective action before the situation develops.

Rollover stability systems are an extension of the above technology, utilising a largely similar sensor network. One technology uses active roll control via hydraulic actuators, linking the suspension anti roll bars to the chassis frame. Based on the sensor network output, a controller determines how much fluid to pump to the actuators to achieve the desired roll angle. The aim of this system is to provide a roll moment to counteract cornering forces, shifting the vehicle centre of mass towards the inside of the turn radius, improving tyre contact. This improves vehicle cornering performance, reducing the chance of a rollover.

Anti rollover technology can also be included in existing electronic stability programs. By monitoring the above sensors, the program can detect a potential rollover and apply a combination of individual wheel braking and engine power reduction to help stabilise the vehicle and prevent the rollover from occurring.

POTENTIAL EFECTIVENESS:

Murray et al. (2009) used effectiveness rates of between 37 percent and 53 percent for heavy vehicle crashes occurring on curves. These figures were arrived at through simulation and through consultation with motor carriers, but the estimation method is not fully explained.

A study from the US National Highway Traffic Safety Administration (NHTSA, 2009) indicated a reduction in injury and fatality within the prime mover/semi trailer vehicle class of 31% and 42% respectively for Roll Stability Control, and 42 and 49% for ESC. The study was based on 2005 US road transport data, with effectiveness calculated from expert analysis of a selection of crashes chosen to represent the entire population.

COST:

Scania offer free trailer ESP with their prime movers, as the ESP module is factory-fitted. Iveco offer ESP as standard on their light and heavy rigid trucks, and Kenworth on their heavy and multi combination trucks. It is available as a $2000 option for Volvo (and is also part of their safety pack).

2.3.2 Lane departure warning

APPLICABLE VEHICLE TYPES:

Passenger vehicles; Heavy vehicles

PURPOSE:

To detect a vehicle unintentionally leaving its driving lane and alert the driver to take corrective action if required.

MECHANISM:

Through the use of a forward viewing camera and image processing technology, a central computer can determine the intended travelling lane of the vehicle to which it is fitted. By identifying reflective lane markings, an indication of vehicle lane positioning can be established. Combined with information including steering wheel angle and indicator use, the system can determine if the driver is unintentionally leaving the intended driving path. Should this be the case, the driver will be alerted via audible, visual and/or tactile responses so that they may take corrective action before the lane is departed. Advanced systems may also attempt to correct the situation by nudging the steering wheel in a direction to maintain vehicle lane position, both alerting the driver and indicating the method of corrective action necessary.

POTENTIAL EFECTIVENESS:

Several reports have suggested how effective this technology might be.

- A crash reduction of about 10 percent, according to the eSafety Effects Database (www.esafety-effects-database.org).
- Farmer (2008) considered that this technology is potentially relevant to 8 percent of crashes in the U.S.A.
- Gottselig et al. (2008) found that this technology might be relevant in 4 percent of cases, and that in practice the trauma reduction would be much less than this figure.
- A trauma reduction of 2 percent, in the judgment of Paine et al. (2008).

Our opinion is that the link between an event of leaving the driving lane and subsequently having a crash is quite a tenuous one, and that the lowest of these figures, the 2 percent of Paine et al., is the most plausible. Cases most relevant are those that do not involve loss of control, and crash data appear to suggest that the proportion of serious crashes represented by these types of crash is marginal.

COST:

This technology is also available within the top selling vehicle segment, with Audi, Mercedes and Volvo being the only manufacturers offering lane departure warning. It is included as standard fitment in high end Mercedes and Audi models, optional in their vehicles of a lower specification, as well as optional in BMW and Volvo. Cost varies from $1400 (Audi/BMW) to $2075 (Volvo).

A figure of $1400 will be used in the benefit-cost calculations in Section 4 below.

For trucks, it is available as an option in Mercedes, Volvo, and Scania, at costs ranging from $650 to $3000. It is part of Mercedes and Volvo safety packages. A cost of $650 will be used to calculate the benefit-cost ratio for this technology in heavy vehicles.

2.3.3 Side blind spot/ lane change warning

APPLICABLE VEHICLE TYPES:

Passenger vehicles; Heavy vehicles

PURPOSE:

To detect other road users in an area that would cause a potential hazard during a lane change manoeuvre and alert the driver of their presence.

MECHANISM:

Through the use of either RADAR, SONAR or video cameras and image processing technology, the system is able to detect the presence of other road users alongside a vehicle. Combined with information from a number of sensors (lateral acceleration, steering wheel angle, indicator usage etc.), it can determine whether or not the driver is intentionally changing lanes or merging into traffic. If another road user is detected in the path of this manoeuvre, the driver is alerted of their presence via an audible/visual response, allowing enough time for corrective action to be taken.

POTENTIAL EFFECTIVENESS:

According the eSafety Effects Database (www.esafety-effects-database.org), there are no reliable safety effect estimates yet.

Paine et al. (2008) judged that this technology might lead to a trauma reduction of 0.5 percent.

Gottselig et al. (2008) found that this technology might be relevant in 1 percent of cases. However, they were discussing crashes (in which blind spot detection was relevant) that occurred at quite high speeds (at least 60 km/h), and it is not clear why they omitted consideration of pedestrians and pedal cyclists.

As a result, the actual effectiveness of this technology would be much less than 1 percent, so their findings are consistent with the 0.5 percent from Paine et al. Crash data presented later are consistent with this.

COST:

Again, this technology is only available in the luxury car segment, being offered as standard or optional by Audi and Mercedes, and optional (for $1275-$1550) by Volvo.

For trucks, Volvo offer Lane Change Warning for $3000, or as part of their safety package.

A figure of $1400 for both passenger vehicles and trucks will be used in the benefit-cost calculations in Chapter 4.

2.3.4 Traction control for motorcycles

APPLICABLE VEHICLE TYPES:

Motorcycles

PURPOSE:

To assist a rider in maintaining control of their motorcycle through computer controlled modulation of the engine and accelerator inputs in an attempt to prevent traction levels from being exceeded.

MECHANISM:

By monitoring signals from the rear wheel speed sensor (part of the anti-lock braking system), it can detect wheel spin by measuring the relative difference in rotational speed compared to the front wheel. Should slip be detected, a combination of throttle input reduction and/or a momentary engine power cut can be employed to reduce this and restore rear wheel traction, preventing a possible loss of motorcycle control.

Whilst the use of a wheel speed sensor is common for this technology, it is also possible to use a combination of tachometer (measures engine RPM), gear selection and throttle position sensors to achieve the same goal, as has been demonstrated in at least one aftermarket system (Brissette, 2008).

One limitation is that some current production systems are only functional when the motorcycle is accelerating in a straight line (bike upright). The functionality for traction control whilst cornering comes about through the addition of a bank angle sensor, as motorcycle lean is an important factor in determining maximum traction levels through a turn. This technology is currently employed on a number of motorcycles, including the 2010 BMW S1000RR.

Similar technology could also be combined with motorcycle ABS and Electronic Brake-force Distribution (EBD) to prevent wheel lockup under braking in the same situation.

Future evolution would involve the combination of these technologies to form a complete electronic stability control system, although this would require the inclusion of steering assistance, which is yet to be developed.

POTENTIAL EFECTIVENESS:

Analysis of German motorcycle crashes showed that only 4 to 8 percent of fatal crashes would be preventable through additional stability technology (Seiniger et al., 2008). The remainder might have been affected by the use of ABS or TCS or not at all (because the rider was unable to react to the imminent collision).

COST:

Both BMW and Ducati offer traction control on their current motorcycles, in both standard and optional fitment level depending on the bike chosen. BMW offer it as an option as part of a safety package comprising of ABS and traction control at a cost of $2200; it is $1000 more than ABS alone. Ducati have much the same arrangement, with traction control being included with ABS and other extras as part of a $6000 package.

2.3.5 ABS for motorcycles

APPLICABLE VEHICLE TYPES:

Motorcycles

PURPOSE:

To prevent motorcycle wheel lock up and facilitate maximum deceleration during braking conditions.

MECHANISM:

Wheel speed sensors are fitted to both front and rear of the motorcycle, relaying information to a control computer. If under brake application it is sensed that a wheel is about to stop rotating, brake line pressure will be reduced to avoid wheel lock up. The ABS system will then maintain the highest brake pressure achievable within the traction limits of the tyre, resulting in maximum vehicle deceleration and a shorter stopping distance.

POTENTIAL EFECTIVENESS:

Antilock braking systems have had several evaluations. Teoh (2010) evaluated the effect of antilock braking systems on fatal crash rates per registrations of motorcycles with and without ABS. Fatal crash rates were calculated across 2003-2008, and most motorcycles with ABS were Honda Goldwings. Motorcycles with ABS had a fatal crash involvement rate 37 percent lower than that for their non-ABS versions during the study years.

Rizzi et al. (2009) examined a series of in-depth crash investigations of crashes involving motorcycles in Sweden. The authors examined the potential of ABS to reduce crashes and injuries in the sample. It was noted that head on crashes were hardly affected by the presence of ABS, and hence head on crashes were used as an induced exposure measure in a larger set of crashes consisting of police reported crashes matched to hospital records. Assuming that ABS does not effect the incidence of serious frontal collisions, the authors estimated that ABS was associated with a reduction of 38 percent of all crashes with injuries (minimum 11 percent) and 48 percent on all severe and fatal crashes (minimum 17 percent). They also provide estimates of benefit for sub-categories of crash.

COST:

Anti-lock brakes are offered on a wide variety of the bikes being examined. It is featured as standard on certain BMW, Ducati, Harley Davidson, Kawasaki and Yamaha models, with it being offered as an option on a number of BMW, Honda, Ducati, Suzuki and Triumph motorcycles at a cost of between $500 (Suzuki) and $2000 (Ducati).

2.4 Passive safety

2.4.1 Crash analysis – rear seat pre-tensioners, force limiting belts and inflatable seat belts

APPLICABLE VEHICLE TYPES:

Passenger vehicles

PURPOSE:

To reduce rear seat occupant deceleration levels in an impact and minimize the chance of potential injury.

MECHANISM:

Certain technologies are designed to improve the performance of seatbelts in crashes. The benefits to rear-seat occupants of pre-tensioners and force limiting seat belts are described by Zellmer et al (1998).

In general, the ability of an occupant to ride the crash down with the vehicle is impeded if there is any slack in the system – the slack may cause an increase in forces on the body of the occupant. Pre-tensioners are systems designed to eliminate any slack in the belt system at the onset of a crash. Systems may vary in the means that they employ to perform this function, but often a pyrotechnic charge is used to drive a piston in such a way as to pull the belt tight around the occupant.

While eliminating slack improves the efficiency of the belt system, large forces on the occupant may still arise in more severe crashes. Force limiters allow the belt system to give when restraint forces approach injurious levels. Often these systems allow the belt to spool out in a controlled manner so that in a frontal crash, the free space between the occupant and the vehicle interior can be utilized to absorb energy at force levels below the tolerance of the occupant to injury.

Recently, Ford introduced an inflatable seat belt for rear seat occupants. Essentially, these perform a similar function to pre-tensioners (by immediately taking up the inevitable slack between the belt and the occupants body in a crash). Additionally these devices spread load to reduce pressure on the torso of the occupant.

POTENTIAL EFECTIVENESS:

Occupants in almost all crash types benefit from being restrained by a seatbelt. Unbelted drivers are apparently over-represented in Australian fatality statistics. The non-wearing rate in South Australian fatal crashes was 40% in 2008 and 25% in 2007 (Wundersitz et al., 2010).

Recently there has been some concern that the specifications of restraint systems in rear seating positions are inferior to those in the front (Beck et al., 2009; Kent et al., 2007; Tylko and Dalmotas, 2005. Almost no vehicles in the Australian registered fleet sample have either pre-tensioners or force limiting belts in rear seating positions. In South Australia, rear seat occupants accounted for 8.7 percent of serious and fatal car occupant casualties in 2007, with the great majority of those being adults and the majority wearing their restraint at the time of the crash (South Australian Traffic Accident Reporting System).

No study exists that estimates potential benefits from implementing this technology in rear seating positions. A study in the United Kingdom by Cuerden et al. (2001) estimated that adaptive restraints (airbag plus optimised belt) could prevent about 25 percent of injuries sustained by drivers in frontal collisions (over older-style retractor belts alone), where the injury was classified as serious or higher on the Abbreviated Injury Scale (AIS). It is unlikely that the same net benefit might be realised in the rear in frontal impacts as there is significantly less injury potential in rear seating positions in frontal impacts.

Pre-tensioning may also assist in retaining occupants in roll-over crashes (McCoy and Chou, 2007).

COST:

Of the technologies listed in this category, it is only rear seat pre-tensioners that are currently available within the same vehicle segment. They are fitted to Volkswagen Passat, Volvo S40 and S80 as standard, although in the case of the Passat and S40, only fitted to the outside seats.

Inflatable seatbelts, whilst not available on any vehicle within the sample group, are currently fitted as standard to the Ford Explorer series of SUVs, with the intention for the technology to filter down to other models, according to a Ford representative.

An approximate price is $140 per seat fitted.

2.4.2 Seatbelt interlock/reminder systems (those not covered by existing ADR requirements)

APPLICABLE VEHICLE TYPES:

Passenger vehicles; Heavy vehicles

PURPOSE:

To promote seatbelt usage amongst motor vehicle occupants through notification and/or an ignition interlock system.

MECHANISM:

Seatbelt usage is monitored via sensors in both the seatbelt buckle and the seat itself. Should an occupant be detected and the seatbelt remain unbuckled above a certain vehicle speed, the system will display visual and/or auditory warnings until the seatbelt is fastened. Additionally, an ignition system interlock can prevent vehicle operation until all detected occupants are wearing seatbelts.

Whilst the ignition interlock system is effective at increasing seatbelt use, lack of public acceptance of enforced behaviour has caused vehicle manufacturers to adopt a less intrusive reminders (Regan et al. 2006; Williams et al., 2002).

POTENTIAL EFECTIVENESS:

Seat belt reminders have been found to increase seat belt use even in cities where the usage rate is above 90 percent (Lie et al., 2008). As there is very good evidence that safety belts are an effective safety feature, it is very likely there is a corresponding safety increase. In the U.S.A., Farmer and Wells (2009) compared deaths in cars with seat belt reminders and the same models of cars without these, and found a 2 percent reduction (which they found credible, though it was not statistically significant).

Seat belt wearing rates in Australia are very high, which if considered on its own, suggests this technology could not have much benefit. On the other hand, it is often said that failure to wear a seat belt is as high as 30 percent among vehicle occupants who are killed. (The figure that currently appears on the website of the South Australia Police is 18 percent, for 2009.) If that statistic is correct, there is indeed potential for this technology to have benefit. However, there is an unresolved inconsistency between this number, the rate of wearing seen in survey data, and the accepted reduction in fatality risk. This inconsistency is likely to mean that either survey data fail to capture those drivers/occupant most at risk of being killed in crashes without a seat belt, or that the rate of non-wearing in fatal crashes is not as high as is often concluded. Effectiveness estimates for Australia may rest on resolving this inconsistency.

We conclude that a major uncertainty in estimating the effectiveness of this technology in Australia (i.e. in circumstances where seat belt use is very high) lies in determining what proportion of car occupants who are killed were not wearing a seat belt --- and this is difficult to determine.

Paine et al. (2008) judged that this technology might lead to a trauma reduction of 5.5 percent.

COST:

It is reasonable to assume that the cost of interlock technology is no different to that required for audible and continuous seat belt warnings, the only difference being some interface with the vehicles electronic control unit. ETSC (2003) worked on the basis that audible warning devices were 60 Euro (Year 2000 costs). Inflating for CPI and converting to Australian dollars suggests a cost of about $130.

2.4.3 Airbags for motorcycles

APPLICABLE VEHICLE TYPES:

Motorcycles

PURPOSE:

To reduce the deceleration experienced by a motorcycle rider during a crash and hence decrease the resultant chance of serious injury.

MECHANISM:

Whilst the general principle of this technology is similar to that used in a car, the specific application to motorcycles has not proven straightforward. As a result, their use today is still not commonplace.

One method is to install a front airbag to the motorcycle, which, when triggered by the deployment sensor will help slow the rider and stop them from impacting the front of the bike. It can also help prevent the rider from flying over the handlebars, potentially into the path of other hazards.

The airbag system can also be integrated as part of the rider’s suit. Once triggered by the detachment of a ripcord, a high pressure carbon dioxide canister is released, inflating a number of internal chambers to form a protective cushion around the rider.

POTENTIAL EFECTIVENESS:

Airbags for motorcycles are designed to prevent injury in frontal crashes. Although they have been in development for some time, no crash studies were identified that estimated reductions in injuries arising from their use.

Berg and Rücker (2007) citing Dreher (1998) describe a retrospective file review of 97 motorcycle crashes that were investigated at the scene in Germany. An assessment was attempted to determine if a frontal airbag for a motorcycle would have changed the outcome of the crash. The conclusion was that an airbag would have deployed in 58 percent of cases, and reduced the injury severity in 11 percent of cases, had no influence in 76 percent of cases and its possible influence was undetermined in 13 percent of cases.

Because it is not known how representative the sample of crashes is of Australian motorcycle crashes, it is not known how applicable the estimate of 11 percent injury reduction is, nor by how much injury would be reduced.

It may however be possible to estimate the proportion of crashes that might be affected. The airbag is designed to protect mainly in the case of a right angle crash between a motorcycle and a car (with the motorcycle striking). It may therefore be possible to identify crashes between motorcycles and another vehicle at intersections in crash data, and to determine the proportion of all serious injury motorcycle crashes this crash type represents.

COST:

Honda is the only manufacturer offering an airbag within their fleet, being fitted to the GL1800 Goldwing Tourer. The airbag is fitted as part of a premium package, at a cost of $6000 more than the base model.

2.5 Vision/Detection by other road users

2.5.1 Active pedestrian detection system

APPLICABLE VEHICLE TYPES:

Passenger vehicles

PURPOSE:

To detect the presence of pedestrians in the forward path of a vehicle and apply emergency braking in the event of an imminent collision.

MECHANISM:

Through the use of a front mounted camera and/or radar system and image processing technology, the system can detect the presence of a pedestrian in the travel path of a vehicle. Should it determine that a collision is imminent, it will apply the braking system to avoid or reduce the speed of a potential impact.

POTENTIAL EFECTIVENESS:

Description of the technology implies that it would save some proportion of pedestrian deaths and injuries. However, the technology seems to be so immature that the central question is how effective it will be. Gerónimo et al. (2009) reviewed the image processing aspects of this topic. Their view is that technical problems are not yet solved. In their Conclusion, they say “Major progress has been made in pedestrian classification, mainly due to synergy with generic object detection and applications such as face detection and surveillance. However, there is still work to do before a useful performance level is achieved and protection systems can be installed in a serial car.”

This technology could have quite a broad potential as pedestrian collisions with passenger vehicles form a large group in the category of fatal crashes.

COST:

Pedestrian detection technology is available on both the Mercedes S Class and Audi A8 as standard fitment. It is also available in BMW vehicles for $4500. However, it is offered by Volvo as part of a safety pack that cost $5,000 but include three active safety technologies.

Apportioning the cost of such a pack between the three technologies would suggest a price estimate of around $1500; this figure will be used in the benefit-cost calculations in Section 4.

2.5.2 Night vision enhancement

APPLICABLE VEHICLE TYPES:

Passenger vehicles; Heavy vehicles

PURPOSE:

To increase driver visibility in low light conditions, to provide early detection of potential hazards.

MECHANISM:

A forward facing infra-red sensor is attached to the vehicle. Either a passive or active sensor is used depending on system requirements. The passive sensor detects ambient infra red levels and has a potentially longer detection range whilst the active sensor, designed to pick up reflected infra red from a vehicle based transmitter, produces a higher quality image but over a shorter distance.

Information is presented via either a secondary monitor or projected onto the windscreen as a heads up display (HUD). More advanced systems use image processing technology to detect potential hazards and alert the driver of their proximity/location on the road.

POTENTIAL EFECTIVENESS:

Rösler et al. (2006) obtained the opinions of eight experts while they used various systems under real traffic conditions at night. The experts, while regarding night vision enhancement as a promising technology, identified a number of problems. These will presumably be overcome in the near future. There have been demonstrations that such a system does lead to earlier detection of hazards in test conditions (Mahlke et al., 2007).

As we have said elsewhere, methods of improving visibility are very evident to the driver, and there is the potential for the driver to react by driving at a higher speed, with a consequent reduction of safety.

Paine et al. (2008) judged that this technology might lead to a trauma reduction of 0.4 percent.

We do not disagree with this assessment. But we also note the potential for the use of night vision enhancement in pedestrian detection, as many of these crashes occur during hours of darkness, quite possibly increasing the potential benefit of this technology.

COST:

This technology is only offered in the luxury vehicle segment, as standard fitment on the Mercedes S Class and as a $4000 option on the Audi A8. It is also optional on the BMW 7 Series.

A figure of $4000 will be used in the benefit-cost calculations in Section 4.

2.6 Impairment/distraction

2.6.1 Fatigue warning system

APPLICABLE VEHICLE TYPES:

Passenger vehicles; Heavy vehicles

PURPOSE:

To detect excessive fatigue levels and alert the driver so that a crash does not occur as a result.

MECHANISM:

Whilst fatigue itself is hard to measure, one method is to monitor eyelid movements of the driver, particularly the length of time over which they are closed, a longer period generally indicating higher fatigue levels. The combination of an infra red camera and image processing technology are used to monitor the duration of retina visibility over a given time period. This information is used to calculate an approximate level of fatigue, which is initially communicated to the driver on a visual basis (generally a series of lights mounted on the dashboard). Once observed retina coverage reaches a certain level, an audible warning is triggered, alerting the driver and prompting them to stop for rest.

Other systems monitor steering wheel movements on basis that such movements tend to become erratic when the driver is fatigued. If the vehicle is also fitted with video-based lane departure detection, the two systems may interact to warn the driver of his/her fatigued state.

POTENTIAL EFECTIVENESS:

No publication comparing crash numbers with and without a fatigue warning system has been found.

Results of a closed-track overnight driving experiment by Vincent et al. (1998) give no cause for optimism: they found no effect of a fatigue warning system on objective or subjective driver fatigue.

The report by COWI (2006) considered the effect might be a 10 percent reduction in crashes (but based on what we consider flimsy reasoning).

The following considerations suggest it will be difficult to narrow down the types of crash that might be affected, and hence put limits on the number of crashes that might be prevented. May and Baldwin (2009) distinguish between sleep-related forms of fatigue (SR) and task-related forms (TR). SR includes forms arising from the circadian rhythm and forms arising from sleep deprivation. TR includes forms caused by mental under-load and those caused by mental overload. One might start by asking what proportion of night time crashes might be prevented. It is known that a large proportion of night time crashes are associated with alcohol, so one then asks what proportion of night time alcohol crashes might be prevented, and what proportion of night time non-alcohol crashes might be prevented. But it seems unlikely that credible data will be found on sleepiness in alcohol-related crashes. Then one needs to consider daytime crashes, too, as TR fatigue crashes cannot be neglected, and it is far from clear how to identify crashes that are fatigue-related.

Paine et al. (2008) judged that this technology might lead to a trauma reduction of 2 percent.

With regard to heavy vehicles, fatigue has been consistently identified as an important factor in crashes. In a review of 511 crash reports of all severity that occurred in New Zealand, Gander et al (2006) identified fatigue as a factor in 5.1 percent of crashes. Fatigue was reportedly a significant contributor (20 percent) to major incidents in 2007 involving heavy vehicles managed by National Transport Insurance (NTI) in Australia (Driscoll, 2009). Consistent with these figures, Friswell et al. (2006) estimated fatigue involvement in 7.5 percent of light truck crashes and 9.14 percent of heavy truck crashes in NSW (1996-2000). For fatal crashes, the rate was much higher - 25.3 percent. Similar figures are estimated for Australian crashes by Dobbie (2002) - 30 percent of fatal articulated truck crashes - but the author noted that of the 250 fatigue related crashes, the driver of the articulated truck was fatigued in only about a third. Curnow (2002) examined both the NTI database and the Australian Truck Crash Database and found that about 10 percent of articulated truck drivers involved in serious injury crashes were fatigued at the time of the crash, consistent with the findings of Dobbie (2002).

We consider that it is exceptionally difficult to forecast the effectiveness of this technology, and that it would be premature to do so. Thus we are reluctant to accept the 2 percent of Paine et al. or even the

10 percent of COWI. At this stage, it is only possible to identify that proportion of crashes recorded by police as “fatigue involved”, and this is used with an assumed effectiveness in Section 4.

COST:

Fatigue warning is only available on the Mercedes S Class as standard fitment, so penetration into even the luxury car market is quite limited.

For trucks, Volvo offer their Driver Alert Support system as a $1500 option. It is also part of their safety package.

A figure of $1500 will be used in the benefit-cost calculations in Section 4 below.

2.6.2 Alcohol interlock

APPLICABLE VEHICLE TYPES:

Passenger vehicles; Heavy vehicles; Motorcycles

PURPOSE:

To prevent the operation of a motor vehicle by a person under the influence of drugs or alcohol.

MECHANISM:

A compact breath testing unit is connected to the engine control unit (ECU), requiring a satisfactory test result to allow vehicle operation, achieved through control of the ignition system. Should the test sample detect the presence of drugs or a blood alcohol content (BAC) over the legally prescribed threshold, the ignition system will be disabled, preventing the vehicle from starting for a predetermined period of time.

Some systems also require repeated re-tests to ensure sobriety of the driver during vehicle use and to discourage another person to submit a test on behalf of the intended driver. Should a re-test prove positive, the vehicle will not be stopped (for safety reasons) but the lights and horn will be activated until the driver ceases operation of the vehicle.

The Swedish Roads Administration has been particularly active in deploying alcohol interlocks in commercial vehicles, but has retracted on an earlier commitment to legislate the mandatory use of interlocks (originally slated for 2010) (Eksler and Janitzek, 2010).

POTENTIAL EFECTIVENESS:

Regan et al. (2002) were optimistic about the potential of alcohol interlocks if these were fitted in all vehicles: they assumed that an interlock would be 96 percent effective in preventing all crashes where BAC exceeds 0.05. A presentation by Coxon (2005b) was also optimistic about the benefits from having all vehicles fitted with interlocks. Requiring an alcohol interlock for all vehicles has sometimes been considered seriously by governments (see Coxon, 2005b). In Australia, Recommendation 20 of the Inquiry into National Road Safety by the House of Representatives Standing Committee on Transport and Regional Services (2004) was that an Australian Design Rule be introduced requiring interlocks on all new vehicles. Sweden was at one stage planning to require interlocks in heavy vehicles by 2010 and all new vehicles by 2012 (Bjerver, 2006), but has since pulled back from this position (Eksler and Janitzek, 2010). If interlocks were to be required on all new vehicles, presumably some action would be needed in respect of vehicles already registered, but we are unaware of what is envisaged.

Paine et al. (2008) judged that this technology might lead to a trauma reduction of 5 percent.

COST:

Alcohol interlock systems are not currently available as either an option or standard fitment in the passenger vehicle segment. They are however available for retrofitment due to use by vehicle fleet operators and in mandatory drink driving intervention programs, the purchase cost typically around $1500-$2100 (see http://www.breathalysers.com.au), depending on the model chosen.

For trucks, Scania offer an alcohol interlock for $200 to $300 ($1300 to $1400 if retrofitted).

A figure of $1500 will be used in the benefit-cost calculations in Section 4. (The information from Scania suggests this figure could fall considerably in the future.)

2.6.3 Workload manager

APPLICABLE VEHICLE TYPES:

Passenger vehicles; Heavy vehicles

PURPOSE:

To regulate the flow of vehicle information to the driver based on the evaluated complexity of current driving conditions.

MECHANISM:

The system monitors both vehicle behaviour (i.e. lateral and longitudinal acceleration/velocities) and driver inputs (steering wheel angle, windshield wiper/indicator usage etc) to gauge the complexity of the current driving environment. Flow of information is then regulated based on these conditions to minimise risk of driver distraction.

According to Green (2004), this could involve diverting an incoming phone call whilst the driver is changing lanes or choosing not to display a vehicle service notification during adverse weather conditions. An analysis of data from two naturalistic driving studies in heavy vehicles would seem to indicate that the highest risk tasks that might potentially be managed by a commercial driver workload manager include: interaction with dispatching devices, interaction with mobile phones and navigation aids. The total removal of distraction due to these devices (which might not be possible to realise) would have reduced the incidence of “safety-critical events” by about 6 percent (Olson et al., 2009).

POTENTIAL EFECTIVENESS:

Workload management in part looks toward a time when many technologies may overload drivers. Current generation management systems focus on streamlining navigation, phone and vehicle status information sensitive to vehicle manoeuvres. The crash reduction effectiveness of such devices is completely unknown, but would affect those crashes where internal distraction contributed to the crash.

COST:

Volvo is the only company offering this technology in their fleet, it is standard fitment on both the S40 and S80 series.

This technology is not available in the popular makes of truck.

This technology is even further in the future than others in this report. As already said, its effectiveness in preventing crashes is completely unknown, and it will not be considered in Section 4.

2.7 Post crash

2.7.1 Automatic crash notification

APPLICABLE VEHICLE TYPES:

Passenger vehicles; Heavy vehicles; Motorcycles

PURPOSE:

To reduce the response time of emergency services to a crash scene, as well as providing personnel with important information prior to their arrival.

MECHANISM:

The mechanism by which this feature is activated is through a telematics module that monitors various vehicle ‘events’. In the particular ‘event’ of a significant crash where an airbag is deployed, a Short Message Service (SMS) text is sent to a call centre by the telematics module via Global System for Mobile (GSM) communications with the details of the crash event and Global Positioning System (GPS) coordinates of the location of the event. A SMS is sent to the call centre every 20-30 seconds until an operator acknowledges the message.

Once an SMS is received and acknowledged by a call centre operator, voice communication is attempted by the call centre operator with the driver of the crashed vehicle through the vehicle telematics module speaker phone. Once communication is established with the driver (or if there is no response) emergency services can be notified (if required) by the call centre with the relevant location and details of the crash.

In Australia, crash notification systems have been incorporated into telematic modules manufactured by Australian Arrow Pty. Ltd. (AAPL). The basic module is the “Telematics T2”, which uses GSM and GPS technologies to allow communication between the driver of a vehicle with the telematics module and a secondary service provider, Intelematics Australia Pty. Ltd.

Only two vehicle manufacturers utilise this Crash Notification technology in Australia, Holden and Toyota. Holden use a system called “Holden Assist Telematics”. Previously this technology was available as a standard feature on the Holden Caprice and as optional extra on base model Omega (approx $2000-$2500 extra). As of early 2010, Holden no longer offer this technology in vehicles. Toyota use a system called “Toyota Link”. Previously this technology was available on the Camry V6 Azura and Grande 2004-2006, and currently it is only available as a standard feature on the Toyota Aurion Presara. However as of early 2011, it will no longer be available on Toyota vehicles in Australia.

The telematics system in the above mentioned vehicles is initially required to be activated for use by the driver or owner of such a vehicle, ie it must be registered and set up after vehicle purchase to be functional. From a personal discussion with a representative from AAPL it was believed that based on a survey of the consumers who bought vehicles with the above technology only about 20% of owners actually physically activated the system for use.

The technology is available as a retro-fit costing around $640 as a spare part, or $1500 installed. According to figures from AAPL only 100 units have been sold in the last 3 years in this form. Further, on-going yearly monitoring service is required, currently $300 p.a. once the initial vehicle manufacturer service arrangement ends.

This technology was initially forecast by the manufacturers of the technology to have an increasing demand, however consumer demand in Australia has declined to the point where the telematics module will soon no longer be manufactured in Australia. In addition, operating on the Telstra GSM network, there are limitations to the coverage of the system.

CRASH TYPE AFFECTED:

None, this technology is focused on casualty minimization once the crash has occurred.

CRASH PHASE TARGETED:

Post crash

POTENTIAL EFECTIVENESS:

A study in Finland, based on the time delay between accident occurrence and notification of the emergency response centre, concluded that some 4 - 8 percent of road fatalities might be prevented (Sihvola et al., 2009).

The eSafety Effects Database (www.esafety-effects-database.org), on the basis of several studies, estimates a reduction of road fatalities of between 2 and 15 percent, and of seriously injured casualties by between 3 and 15 percent.

Paine et al. (2008) judged that this technology might lead to a trauma reduction of 5 percent.

Lahausse et al. (2008), estimated that an Automatic Crash Notification system installed and activated in all registered Australian vehicles had the potential to reduce crash notification times to emergency medical services (EMS) to one minute in both urban and rural areas. Potentially, according to Lahausse et al. (2008) this could reduce passenger vehicle occupant fatalities by 10.8% or 104 road fatalities. However, this study considered estimated crash-to-EMS notification times from U.S. data (Champion et al. 1999) as well as the U.S. based ACN systems by OnStar©. Also Lahausse et al. assumed that the ACN system would be “95% accurate in notifying a call centre that serious crash had occurred and in identifying its location”.

As the currently available Australian ACN system is based on airbag deployment; rollover crashes, rear-end crashes and other crashes that may be potentially fatal and yet do not deploy an airbag would not be detected. Also due to limitations in the GSM coverage in Australia there may be severe crashes that would trigger notification through the ACN system but would simply not be received by the call centre.

Lahausse et al. calculated that to achieve a BCR of 1.5:1, such an ACN system would need to cost $120 or $140 per car, based on 15 year or 25 year vehicle lifespan. Further, they noted that “the system would only be a cost-effective option for was mandatory installation in all Australian passenger cars if substantial government subsidization was involved."

One further benefit on the telematics system that incorporates the ACN are the remote engine immobilisation features the system offers. This system, especially if fitted across 100% of registered Australian vehicles (and if 100% tamper proof) offers the potential for reducing vehicle theft, immediate vehicle location if a vehicle is stolen and significant reduction in high speed police pursuits of stolen vehicles or vehicles being used illegally.

COST:

$1500 is the cost of a retrofitted device. Given the work of Lahausse, and difficulties in identifying specific crashes that might benefit from ACN, no further consideration is given to this technology in Section 4.

3 Methods for estimating costs and benefits of vehicle safety technology

This section describes the basis for the methodology of calculating costs and benefits of a given technology. Described are methods to

- identify crashes where it was likely that they would have been affected by the presence of a particular technology,
- estimate the benefits that are represented by those crashes,
- estimate appropriate discount periods for each vehicle type, and
- identify appropriate costs associated with each technology.

Finally some commentary is given in relation to the difficulty in identifying technology costs.

3.1 Identifying crashes potentially affected by each technology

Initial analyses were made using crash data from the CrashLink database in New South Wales. The results of this are given in Section 4. Analyses were then extrapolated to the remainder of the Australia at an aggregate level. This is detailed in Section 5. Data from New South Wales was selected because of the state’s relative size, and its consistent use of DCA codes to describe crashes.

3.1.1 New South Wales crash data

Crash data from 1999-2008 were examined through provision of CrashLink data from the Roads and Transport Authority of New South Wales. Crashes not causing injury or death were excluded from explicit consideration; however, benefits arising from reduced non-injury crashes are included by imputation (see later). The general characteristics of the sample are as shown in Table 3.1.

The data indicate the relative average severity of different crash types. Loss of control, opposite direction, pedestrian and overtaking crashes have higher than average fatality rates (per casualty crash) whereas intersection, manoeuvring, and same-direction crashes have much lower fatality rates, indicating the lower speed environment that these crashes tend to occur in; rear end crashes cause vehicle damage and slight injury with high frequency.

It is immediately clear that countermeasures to loss of control, opposite direction crashes and pedestrian crashes will have the greatest pay-off in terms of fatal crash reductions. Similarly, a focus on passenger vehicles will also affect the largest group of vehicles, as indicated by the frequencies of the types of vehicles in the crash data. But note too the relatively high fatality rate in crashes in which trucks and motorcycles are involved.

Table 3.2 is a cross tabulation of crash configuration and vehicle type in fatal single vehicle crashes in New South Wales (1999-2008). The data highlight the importance of preventing loss-of-control crashes in passenger vehicles, accounting for 66 percent of such crashes. A further 16 percent of involve the loss of control of a truck and are the major cause of fatal single vehicle truck crashes.

Table 3.1
General characteristics of crashes in New South Wales (1999-2008)

	Fatal	Injury	Percentage fatal
Total crashes	4643	204887	2.2%
Number of units			
1	1829	52110	3.4%
2	2335	128517	1.8%
3	347	18800	1.8%
4	87	4172	2.0%
>4	45	1288	3.4%
Crash configuration			
Opposite direction	1076	27411	3.8%
Off path bend	1048	24428	4.1%
Off path straight	854	30308	2.7%
Pedestrian	834	23148	3.5%
Intersection	266	27959	0.9%
Same direction	255	55380	0.5%
Overtaking	114	1570	6.8%
On path	79	5146	1.5%
Manoeuvering	70	8275	0.8%
Other	47	1262	3.6%
Traffic unit types involved (many crashes have multiple units per crash)			
Total units	8198	389336	2.1%
Passenger	5327	303466	1.7%
Truck	907	11205	7.5%
Pedestrian	924	24914	3.6%
Motorcycle	650	20919	3.0%
Other	157	4027	3.8%
Pedal cycle	126	11939	1.0%
Unknown	107	12866	0.8%

Table 3.2
Vehicle type and crash type in single vehicle fatal crashes in New South Wales (1999-2008)

Vehicle type	Crash configuration						
	LOC on bend	LOC straight section	Other	Parked vehicle/ stationary object in path	Overtaking	U-turn, parking, reversing, emerging	Total
Passenger	704	656	18	14	24	9	1425
Motorcycle	177	57		12	5		251
Truck	72	34	5	1			112
Other	4	5	6				15
Pedal cycle	5	5		3		1	14
Unknown	6	3	3				12
Total	968	760	32	30	29	10	1829

Table 3.3 is a cross tabulation of vehicle types in fatal two-unit crashes in New South Wales (1999-2008). The most common combinations (numbers highlighted in red) are passenger vehicle-to-passenger vehicle and passenger vehicle-to-pedestrian. Less common (highlighted in green) are truck-to-passenger vehicle, motorcycle-to-passenger vehicle and motorcycle-to-truck. Less common again are truck-to-truck and truck-to-motorcycle crashes, truck-to-pedestrian and motorcycle-to-motorcycle crashes.

Table 3.3
First two unit combinations in multi-unit (more than one unit) fatal crashes in New South Wales (1999-2008)

Unit 1	Unit 2						
	Pedestrian	Pedal cycle	Passenger	Truck	Motorcycle	Other	Unknown
Passenger	662	68	930				
Truck	93	18	460	40			
Motorcycle	8	3	249	47	25		
Other	43	9	59	4	15	1	
Unknown	2	1	25	9	6	3	2

It may be assumed that electronic stability control will make substantial inroads into those crashes currently classified as loss-of-control crashes. Current estimates of the effectiveness of ESC on preventing loss-of-control are consistently high, and systems are associated with single vehicle injury crash reductions of 32 and 68 percent for cars and SUVs (Scully and Newstead, 2008).

3.1.2 Crashes sensitive to individual technologies or technology types

For the present purpose, and with reference to high-frequency crash configurations in Table 3.1, 3.2 and 3.3, the technologies described in Section 2 were grouped into broad categories for analysis. Presently, active systems relying on detection remain largely separate systems. For example Volvo can include active systems separately for pedestrian detection and low speed rear-end crash avoidance and for high-speed adaptive cruise control. It is probable that commercial systems will see further integration between systems with improved levels of performance in coming years (Autoliv, 2010). For the present purpose, crashes will be grouped separately according to whether they may be sensitive to forward collision detection, lane change, lane departure, heavy vehicle stability, alcohol interlocks, fatigue management, pedestrian detection, motorcycle braking and loss of control, and seat belt enhancements. These groups are used to examine the number and proportion of all crashes that are likely to be affected by each group of technologies. Consideration is given too, to whether or not crashes fall into a narrow set of selected crash types likely to be highly sensitive to the technology, or a broader group that also includes crashes for which the technology may be only partially effective.

Crashes likely to be sensitive to each technology may, in many instances, be identified through information on their configuration. The 'Definitions for Coding Accidents' (DCA) provide a means of filtering crashes to make such an identification.

For this analysis, each DCA code was evaluated for the potential effectiveness of each technology or group of technologies. The potential relevance of each DCA to each technology was categorised according to whether the crash would be narrowly sensitive to the technology (a crash for which the technology is specifically designed to prevent), broadly sensitive where the technology might provide more limited benefits, or not sensitive at all.

Table 3.4 identifies which DCA descriptions apply to crashes that will be assumed to be affected by each technology. Loss of control is also identified as this is a relevant consideration with respect to some of the technologies.

Note too that, sometimes, additional crash variables were used in conjunction with the following table. For instance, with respect to pedestrian crash interventions, crashes were considered only where the crash itself was clearly a pedestrian crash (typically Unit 2 being a pedestrian). This approach is taken as often pedestrian crashes are assigned DCA codes outside those obviously grouped as a pedestrian DCA code. For some technologies, DCA codes were not a suitable means for identifying relevant crashes, and in these cases, other crash factors were used. For technologies that tackle impaired driving, DCA codes are not useful. Instead, indications of fatigue, and drivers who had illegal blood alcohol concentrations are used to identify crashes likely to be sensitive to such technologies. Details specific to each technology are given in Section 4.

Table 3.4
DCA grouping to identify crash types sensitive to individual technologies

	DCA description	Technology grouping (black indicates narrow selection of crash types likely to be more sensitive to the technology, grey indicates crashes to be included in a broader selection of crash types but are likely to less sensitive to the technology)				
		Pedestrian /cyclist Detection	Forward collision	Lane change warning	Lane keeping	Loss of control
Pedestrian	Other	▒	▒			
	Near side	▒	▒			
	Emerging	▒	▒			
	Far side	▒	▒			
	Playing, working, lying, standing on carriageway	■	▒			
	Walking with traffic	■	▒			
	Facing traffic	■	▒			
	Driveway	▒				
	On footway/median	▒				
	Struck while boarding or alighting	▒	▒			
Intersection	Other	▒	▒			
	Cross traffic	▒	▒			
	Right-through from left	▒	▒			
	Left-through from left	▒	▒			
	Right-through from right	▒	▒			
	Two right turning	▒	▒			
	Right-left from right	▒	▒			
	Left-through from left	▒	▒			
	Right-left from left	▒	▒			
	Two left turning	▒	▒			
opposite direction	Other	■	▒			
	Head on (not overtaking)	■	▒		▒	
	Right-through	■	▒			
	Right-left	■	▒			
	Right-right	■	▒			
	Left-through	■	▒			

	DCA description	Technology grouping (black indicates narrow selection of crash types likely to be more sensitive to the technology, grey indicates crashes to be included in a broader selection of crash types but are likely to less sensitive to the technology)				
		Pedestrian /cyclist Detection	Forward collision	Lane change warning	Lane keeping	Loss of control
	Left- left	■	▒			
	U-turn	■	▒			
Same direction	Other	■				
	Rear end	■	■			
	Rear left	■	■			
	Rear right	■	■			
	U-turn	■	▒			
	Lane side swipe	■		■		
	Lane change right	■		■		
	Lane change left	■		■		
	Right turn side swipe	■		■		
	Left turn side swipe	■		■		
	Pulling out		▒	■		
Manoeuvering	Other					
	Leaving parking		▒	▒		
	Entering parking		▒	▒		
	Parking-parked vehicles only					
	Reverse in traffic		■			
	Reversing into fixed objects					
	Emerging from driveway					
	From footway		▒			
	From footway		▒			
	U-turn into fixed object		▒			
Overtaking	Other					
	Head on (includes side swipe)		▒			
	Out of control					
	Pulling out		▒			
	Cutting in		▒			
	Pulling out rear end		▒			
	Overtaking right turn		▒			
On path	Other					
	Parked		■			
	Double parked		■			
	Accident or broken down		■			
	Vehicle door					
	Struck permanent obstruction on carriageway		■			
	Struck temporary roadworks on carriageway		■			
	Struck object on carriageway		■			
	Accident or broken down		■			
	Struck animal (not ridden)		▒			
	Load or missile struck vehicle		▒			

	DCA description	Technology grouping (black indicates narrow selection of crash types likely to be more sensitive to the technology, grey indicates crashes to be included in a broader selection of crash types but are likely to less sensitive to the technology) Pedestrian /cyclist Detection	Forward collision	Lane change warning	Lane keeping	Loss of control
Off path straight (LOC)	Other				▒	■
	Off carriageway to left				▒	■
	Off carriageway to right				▒	■
	Left off carriageway into object				▒	■
	Right off carriageway into object				▒	■
	Out of control on carriageway					
	Left turn					■
	Right turn					■
	Mounts traffic island					■
	Off end of road or T intersection		■			
Off path bend (LOC)	Other				▒	■
	Off carriageway right bend				▒	■
	Off carriageway left bend				▒	■
	Off carriageway on right bend in to object				▒	■
	Off carriageway on left bend in to object				▒	■
	Out of control on carriageway					■
	Mounts traffic island					■
Other	Other					
	Fell in/from vehicle					
	Struck while boarding or alighting	▒	▒			
	Struck train/aeroplane		▒			
	Parked vehicle ran away					
	Vehicle movements not known					

3.1.3 Effects in narrow and broad crash types

Narrowly selected crash types are those that are likely to be more sensitive to each technology group than the broadly selected crash types. So, for example, two percent of all fatal crashes might be highly sensitive to forward collision warning avoidance, but 21 percent might be somewhat sensitive, but to a lesser extent than the first group. However, if a forward collision avoidance technology were 100 percent effective in the narrowly defined set crashes and 30 percent effective in the broadly defined crash category, we might expect an overall effectiveness of 100% x 2% + 30% x 21% = 8%, demonstrating that the broad but smaller benefits should not be discounted when estimating benefits. However, this does imply that the overall estimate of benefit can become sensitive to the assumed effectiveness of the technology in the broadly selected crash types.

3.2 Estimating crash reductions

For the present purpose, calculations need to account for under-reporting and the non-processing of non-fatal crash reports. A comprehensive treatment of this issue is given by BITRE, (2009). To estimate the true number of crashes in Australia, BITRE used data from multiple sources, and examined crash ratios across jurisdictions to impute the numbers of crashes not appearing in official statistics at each level of severity. In summary, they found that there is effectively no under-reporting of fatal crashes, but at each subsequent level of severity, a greater proportion of crashes tend to be "missing" from crash databases maintained by state transport authorities.

The approach that was adopted in the present analysis to account for missing crashes was to:

- First, estimate reductions in police reported crashes,
- Second, express this reduction as a percentage, and
- Third, apply this percentage to the costs of crashes of the relevant severity published by BITRE (2009).

As mentioned above, in the absence of effectiveness estimates in many cases, the approach was to assume a rather high effectiveness in those crashes narrowly sensitive to each technology – 75% – and a lower effectiveness in the balance of those crashes in the broader category – 25%.

To estimate the total costs of crashes in Australia, the BITRE adopted a "bottom-up" approach where details of costs associated with individual crashes were totalled. The total costs were then averaged to give the average cost of a crash at each level of severity.

Fatal crash costs in NSW were $1,196.8m in 2006. Injury crash costs (all severities) were $3,140.7m and PDO crash costs were $1,398.5m (BITRE, 2009). This indicates that for every dollar of injury (but not fatal) crashes, there was an additional $0.44 related to property damage only (PDO) crashes. As reductions in PDO crashes are not explicitly examined in this report, it will be assumed that reductions in PDO crashes arising for active safety systems will be proportional to savings in injury crashes, and hence a factor of 1.44 is applied to monetised injury crash reductions to account for potential reductions in PDO crashes. The applicability of this factor to specific crash types is an assumption, rather than an empirical fact. However, the factor varies less than +/- 5% between NSW metropolitan and rural crashes (based on BITRE, 2009 T7.3), and is almost identical across the rest of the country, providing some confidence that it may apply fairly constantly across crash types.

In Section 5, benefits of the technologies examined in the present Section are used to estimate likely crash reductions across Australia.

3.3 Discounting future benefit

To estimate monetised benefits in line with principles of benefit cost analysis, consideration is given to the time elapsed between the installation of the technology in a new vehicle and the realisation of the benefit. Clearly, if a technology prevents a crash, there is a period between the purchase of the vehicle/technology and the event in which the crash is prevented. The standard practice is to assume that the rate of crashing is constant, and to assume that this continues for a period of 10 or 20 years to reflect the useful life of the technology/vehicle. The benefit of crash reductions in each year is discounted by a set rate. This rate is often set to 4%, 7% or 10% to reflect typical market rates of return on investment. In this report an intermediate value of 5.5% is used to calculate the present value of crash reductions from each technology.

The number of registered vehicles in NSW in 2006 is used to calculate total costs of a technology (unit cost multiplied by the number of vehicles) and the annualised reductions in crashes that occur over the discount period are used to define the benefit.

While the above procedure assumes a constant rate of crashing, it is possible to be more precise about the true situation. The period between the installation of the technology and the crash that is to be prevented has an empirical distribution of values that can be estimated by examining crash data: the distribution can be estimated by examining the age of vehicles in crashes. This can be worked out for all crashes, or by severity, and/or by crash/vehicle type.

As mentioned above, when a crash event is separated by any finite period from the purchase of the vehicle, it is normal practice to discount that benefit. In this way, the technology can be compared to a theoretical “ideal” technology or intervention that acts with zero lag on all vehicle crashes.

For example, consider all passenger vehicle crashes (fatal plus injury) that occurred in New South Wales between 1999 and 2008. The cumulative distribution of the ages of vehicles at the time of the crash is given by the black line in Figure 3.1 (the meaning of the discounted line is explained later). It is immediately apparent that the median age of passenger vehicles in fatal crashes is about nine years, but vehicles continue to be involved in crashes for up to 20-25 years of age. The distribution is also that of the un-discounted cost of fatal crashes amongst vehicles of different ages.

According to benefit-cost accounting principles, those crashes that are avoided, that would otherwise have occurred sooner after the purchase, are valued more highly than those occurring later. The question then arises, if all crashes in the distribution could be prevented, what is the present value of those crashes?

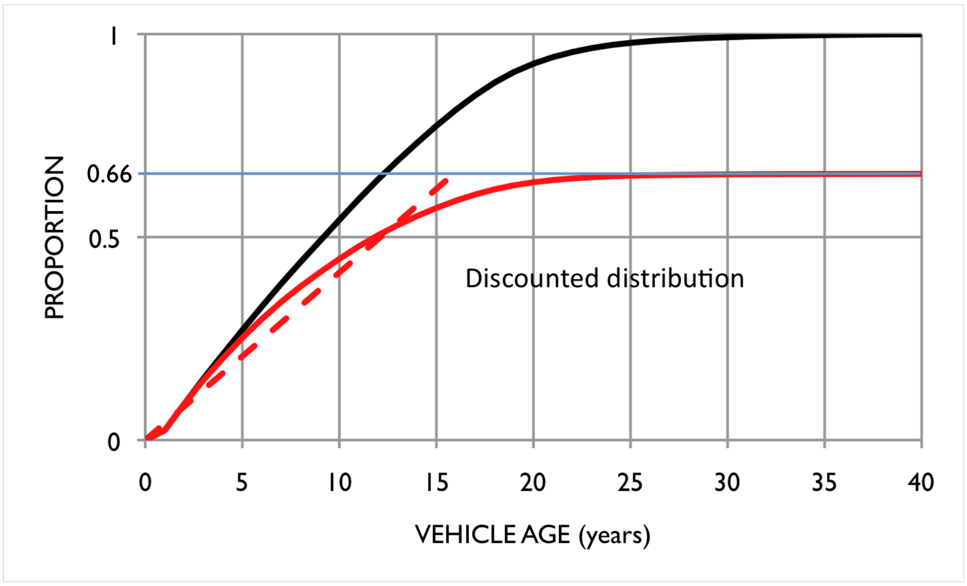

Figure 3.1
Cumulative distribution of crash costs by vehicle age in fatal and injury passenger vehicle crashes in New South Wales (1999-2008). The black line is the undiscounted costs. The red solid line is a “discounted” distribution where future crash costs are discounted by 5.5% per annum. The red dashed line is the linearised approximation of the discounted distribution, which implies an effective passenger vehicle life of 16 years.

For the present purpose, consider the cumulative distribution (black line) in Figure 3.1 as representing the undiscounted cost of fatal and injury crashes; one can apply a discount to reflect the age of the vehicle at the time of the crash. The discount reflects the lag between the “investment” and the “return”. When a discount rate of 5.5% per annum is applied to the distribution, the distribution flattens at about 0.66. The resulting distribution of discounted crash costs is shown in Figure 3.1 with a solid red line. Therefore, the present value (cost) of fatal and injury crashes involving new vehicles is 0.66 times the undiscounted cost of fatal crashes that new vehicles will experience over their effective life.

It turns out that the proportion is consistent between passenger vehicle crash types and severities in the New South Wales data.

Next, we can ask: if we assume a constant rate of crashing and constant vehicle numbers in the benefit cost calculations, what is an appropriate period to use, that will reflect the present value of crashes in Australia? This is equivalent to linearising the discounted distribution in Figure 3.1. The period can be determined by finding the discount period, applied to a constant rate of crashing, with a rate of 5.5%, that produces a present value of 0.66 times the undiscounted cost of those crashes. This period turns out to be 16 years for passenger vehicle crashes. The linearised distribution of crashes is shown with a dashed line in Figure 3.1. An important feature of determining a period in this way is that all crashes, including those occurring much later in a vehicle's life are used, as the present value of all crashes is used to determine the appropriate benefit period in the calculation.

Equivalent calculations for trucks and motorcycles show that appropriate discount periods are 13 years and 11 years respectively, given a discount rate of 5.5%.

Note that because New South Wales has one of the younger registered vehicle fleets in Australia, the benefit period is slightly conservative. Slightly greater benefits might be estimated for States with older average vehicle ages.

The benefit-cost calculation itself uses a steady state assumption: that is a constant number of vehicles and a constant rate of crashing. Technology costs are estimated by taking the per-vehicle cost estimates given in Section 2 and multiplying these by the total number of relevant vehicles in the New South Wales registered fleet (passenger vehicles, light trucks or motorcycles). The number of registered passenger vehicles, trucks and motorcycles is given in Table 3.5.

The benefit-cost ratio (BCR) of each technology is present value of the monetised crash reductions estimated for the technology (per registered vehicle of the appropriate type) divided by the per-vehicle cost of the technology.

Table 3.5
Number of registered passenger vehicles, trucks and motorcycles in New South Wales, 2006 (ABS, 2006)

Vehicle type	Number (thousands)
Passenger (inc. light truck)	3982.8
Trucks	130.3
Motorcycles	122.2

3.4 The costs of technology

For the purposes of this report, it has been assumed that the cost of each technology being considered is the cost provided to us, either as an optional cost by manufacturers/dealerships, or reported by some other means. However, this is not to say that these costs reflect the costs incurred were the technology to become widely deployed or standard. In the following subsections, some consideration is given to costs associated with advancing technologies in the past few years. Readers who would prefer to move straight to the results of the estimation of benefit-cost figures may move directly to Section 4.

3.4.1 Car vehicle prices in recent years

Cars have much more advanced technology and many more features than they used to. This includes safety technology and safety features. Despite this, there has not been an increase in price.

Figure 3.2 shows the sales-volume-weighted average of the recommended retail price (RRP) of motor vehicles according to vehicle segment. These figures have been generated from a sample of the currently registered passenger vehicle fleet in New South Wales (2010), disaggregating according to year of first sale and according to vehicle segment. The weighted average is the average of all vehicles falling into each resulting subgroup. Prices were then indexed according to Australian CPI figures for the December Quarter in each year and expressed in 2009 dollars.

It is notable that there is no consistent trend in prices within segments. There have been, since 2000, increases in the average RRP in Medium and Light segments ($265/year and $571/year) but declines in the average price of Large and Small vehicle segments (-$400/year and -$179/year). The decline in the weighted average RRP of all vehicles (-$1000/year) reflects a lower representation of larger vehicles among vehicles sold new in recent years.

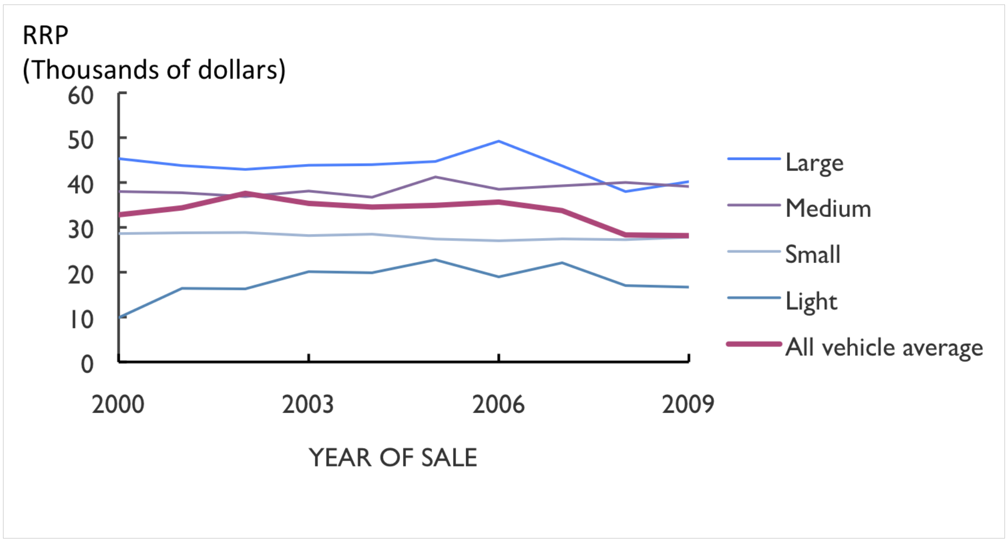

Figure 3.2
Real costs of new vehicles by segment (based on a 2010 NSW registered fleet sample), 2009 dollars. Note that the all vehicle average includes people movers and sports vehicles in the calculation, but excludes prestige and luxury segments.

3.4.2 Some examples of changes in optional costs of technology

The sample of the currently registered passenger vehicle fleet in New South Wales used in the previous analysis was used to examine the optional costs of certain safety technologies that have become more common in recent years. In each case, the prevalence of the technology was low in early model years and almost ubiquitous in late model years. Hence, for both early and late model years, the costs apply to relatively few vehicles; in early years because it was generally unavailable on the remaining vehicles and in later years because it was generally standard on many of the remaining vehicles.

The reduction in cost of an optional front passenger airbag shown in Figure 3.3 represents a rate of reduction of about 24 per cent per 5 years.

The reduction in cost of optional ABS shown in Figure 3.4 represents a rate of reduction of about 29 percent per 5 years.

However, it is not clear, whether the reduction in cost of a technology as an option really reflects its cost when fitted as standard. Indeed, we consider these rates of reduction insufficient to explain the growth in standard fitting of these technologies: when standard, they may be effectively much cheaper than in the later years of being optional. This is borne out of the analysis of new vehicle prices in the previous Section.

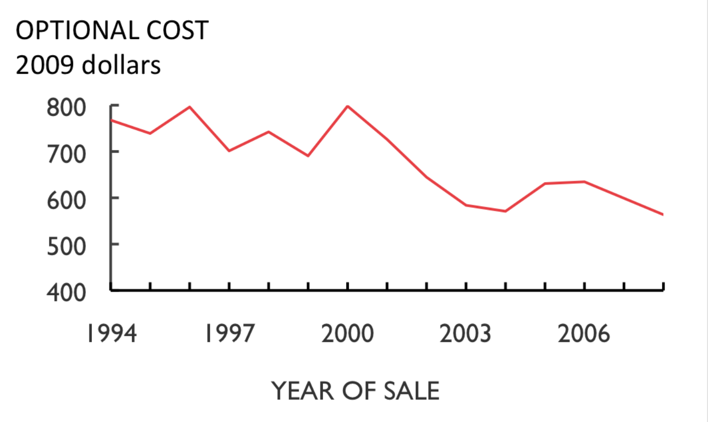

Figure 3.3
Optional cost of front passenger airbags for those vehicle in the sample in which it was available as an option as a function of the year of first sale.

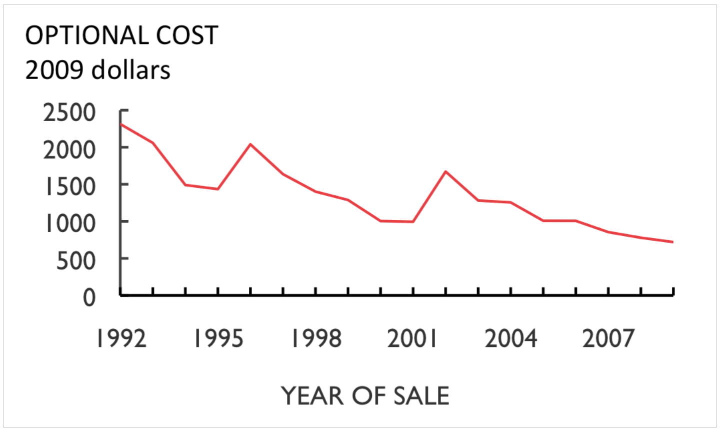

Figure 3.4
Optional cost of ABS for those vehicle in the sample in which it was available as an option as a function of the year of first sale.

3.4.3 Approximate relationship between effectiveness and cost

Answers to questions regarding an appropriate cost to use in the benefit cost analysis would clearly depend on the decision being faced, the beneficiaries of the decision, and the purpose of the analysis, and consequently general answers cannot be given. But several points can be made, that together suggest the use of quite low costs, even if the technologies are, in some instances, expensive at present.

The discussion here refers to technologies that work, in the sense that they have been invented, have been developed sufficiently that they can be routinely installed in a motor vehicle, and that they prevent or reduce the severity of a substantial proportion of some important class of accidents.

The average cost of road accidents per vehicle is relevant background. Per year, road accidents cost about $1350 per vehicle (total accident costs divided by total registered vehicles). If a vehicle stays in the fleet for 20 years, the average cost of accidents associated with that vehicle is about $27000 (undiscounted). Or given the above analysis of the ages of vehicles in crashes the total cost might be closer to $14,600 (discounted as described above). These are approximate figures, but are accurate enough for present purposes. They indicate that to achieve a saving of 1 per cent of crashes, chief interest is likely to lie in technologies costing in the low hundreds of dollars, and to achieve a saving of 10 per cent of crashes, chief interest is likely to lie in technologies costing in the low thousands of dollars.

3.4.4 Practical difficulties of determining costs

As a preliminary, we should acknowledge practical difficulties in costing new technologies. These include the following: commercial secrecy; variation between different companies or between different systems having the same general aim; policies about prices, and variation in prices between different operating units (perhaps in different countries) of the same company; specialists in a particular technology may not know; specialists in a particular technology may not tell us what we want to know; ambiguity over what point in time we are referring to; perhaps no one really knows.

Let us consider the costs of the technology under three headings.

> (A) Research and development. In this case, the effort has already been expended, the money has been spent. Whether or not the technology reaches mass production, the costs cannot be recovered.
>
> (B) Manufacturing set-up costs. The investments necessary for mass production have not yet been made.
>
> (C) Marginal unit costs (that is, per vehicle) when in mass production.

There may be other cost headings in particular circumstances.

The question is which costs should be considered: should past costs, (A), be excluded in some instances where the technology is already well developed? Is the unit cost that seems most relevant somewhere between what it is with present manufacturing arrangements, after (A) but before (B), and what it would be after further investment, i.e., (C)? Difficulties arise here because this discussion is simplistic for a number of reasons, including the following.

- Improvement through research and development may continue for several decades,
- it could be argued that if the technology were truly successful, the costs at (B) would become negligible as they would be spread over millions of beneficiaries,
- it is frequently not clear whether an element of cost is truly marginal or should be included among the fixed costs at (B), and there is no mention of taxation policy.

The price of a safety technology that is observed when it is new and only available on a limited number of expensive vehicle models is presumably roughly "what the market will bear".

- If the take-up of the safety technology is left to the market and individual choice, the high price is likely to mean take-up is slow and the technology may or may not break through into the mass market. The great majority of consumers will miss out on the safety benefits in the short term and may do so in the long term. The developers of the technology will miss out on the profits from a successful invention. Of course, if the technology is something that the market wants, that is it is not a burden that consumers will resist, then widespread take up is to be expected. The point is, that this cannot be assumed.

- If the take-up, on the other hand, is encouraged or required via government action such as regulation, the risks of capital investment are reduced, the price of the technology is likely to fall sharply, and it does reach the mass market.

There is, we accept, no guarantee that the story has a happy ending for any given technology. But remember we have in mind a technology that is successful in experimental situations and apparently relevant to an important class of accidents. We further assume that the political environment is not hostile to government intervention where justified to improve public safety. Given those conditions, these arguments have some force in pointing towards assuming a mass market created by stimulation from the government, and thus a mass market price rather than a luxury price for the technology.

The appropriate choice of costs is, as indicated, likely to be controversial both for practical reasons and because the principles are not clear. Nevertheless, we can offer two tentative conclusions.

- The principles of costing tend to suggest the use of some sort of marginal production cost rather than one that includes research and development that has already occurred.

- The practical context suggests that, in the case of a technology that has been demonstrated to work in experimental situations and which is applicable to a substantial proportion of some important class of accidents, a rather low cost should be suggested, as total costs will be spread over many millions of vehicles. Furthermore, trends in optional pricing and the prices of vehicles suggest that the marginal costs of vehicle features declines over time.

These are probably the conventional wisdom. Certainly they in line with the overview that Robertson (1989) provided of vehicle safety improvements in the U.S.A. in the 1970's.

In any case, it was practicable in the present study to use the costs as quoted to us by manufacturers and suppliers. The discussion above is included here to emphasise the probable fact that the cost today is not what it might be in the future, and hence costs quoted may tend to overestimate the cost in some future scenario where there is wide-scale up take of the technology (if historical precedence is a guide).

It is recommended that emphasis should be given to break-even costs, and where benefit cost ratios are marginal, more effort be made to confirm likely costs in a future where the associated technology is commonplace or mandatory. Given the decline in optional pricing given as examples earlier in this Section, where costs roughly half over the period considered, a marginal benefit cost ratio might be considered to be 0.5.

4 The analysis of crash data to determine the number of crashes likely to be influenced by emerging vehicle safety technologies

The potential benefits of emerging vehicle technologies may be estimated by examining crash data. Because many technologies are so new, formal evaluations are rare, and so estimating crash reductions through the application of empirically derived estimates of effectiveness is difficult.

However, because the technologies are designed to work in specific ways, it is possible to identify those crashes whose outcomes are likely to be sensitive to each technology. These crashes may be used to represent the subset of all crashes for which the technology is likely to be effective.

The approach taken in this report is to examine Definitions for Coding Accidents (DCA) codes in crash data (see Section 3). While somewhat standardised, DCA codes may not be entirely consistently recorded from State to State (Metcalf and Smith, 2005). Nevertheless, with careful application, these codes are defined in such a way as to allow an approximate identification of those crashes likely to be sensitive to a particular technology. For technologies that target crash factors not indicated by DCA codes (alcohol use, fatigue) other crash variables are used to identify crashes likely to be sensitive to the technology in question.

A straightforward disaggregation of the data according to DCA codes provides an immediate picture of the relative proportions of crashes likely to benefit from general crash avoidance technologies. When a crash type is shown to be affected by a particular technology, crashes of that type can then be further disaggregated to draw attention to specific issues in relation to each technology (speed zone, alcohol involvement etc.)

For technologies that tackle impaired driving, DCA codes are not useful. Instead, indications of fatigue, and drivers who had illegal blood alcohol concentrations are used to identify crashes likely to be sensitive to such technologies.

4.1 Forward collisions

Several technologies may be grouped together insofar as they act to prevent, or reduce the severity of, forward collisions. These technologies range from emergency brake assist to forward collision warning with automatic braking. These technologies are:

- Emergency brake assist.
- Adaptive cruise control.
- Following distance warning/Forward collision warning.
- Following distance warning/Forward collision warning with automatic braking.

In Section 4.2.1, we will consider adaptive cruise control with automatic braking, being in this context quite a narrowly focused intervention. In Section 4.2.2, we will consider what benefit might be obtained if a system or systems were to apply or assist with full emergency braking across a wider range of driving conditions.

First consider all crashes for which some kind of forward collision intervention would be effective. As mentioned in Section 2, it is possible to identify those crash types that fall into a narrow set of configurations that accord closely with the mechanism of crash prevention with these sorts of technologies. Primarily we can consider a collision between a passenger vehicles/truck with another vehicle, other road user or object directly in the path of the vehicle. Furthermore, there is a range of other crash configurations that fall into a broader group that include a forward collision of a passenger vehicle or truck, but for which the effectiveness of any system may be reduced due to factors associated with the crash configuration. Such crash configurations might include cross-path crashes and sudden lane changes where a driver may gain limited assistance from a reduction in the delay before brake initiation or from improved braking force.

The New South Wales crash data were queried to identify crashes falling into narrow or broad groupings of such crash configurations, according the DCA code for each crash. Attention was paid to the vehicle types nominated as the primary vehicle and secondary vehicles (where appropriate). These vehicles have special meanings in DCA codes such that the movement of each of the first one or two vehicle in the crash can be determined. A crash was deemed to be sensitive to forward collision mitigation only if the DCA code fell into the groups described in Section 2, and if the relevant vehicle was of the appropriate type (in this case being a passenger vehicle or a truck).

4.1.1 Adaptive cruise control with automatic braking

Primarily, rear-end crashes occurring in a cruising environment seem likely to benefit from current adaptive cruise control technology. For example, the adaptive cruise control system typically must be manually activated and only operate at speeds greater than 60 km/h. In attempting to evaluate this technology, strictly, there is no reason to include more crashes than those occurring with an object in the path of a vehicle in speed zones 80 km/h or above. As mentioned earlier in this Section, future developments in this technology are likely and a wider range of performance is to be expected. A scenario in which forward sensing technology is wide-ranging in its performance is considered in the following subsection.

An estimate of the number of relevant crashes in the NSW sample was found by looking for crashes occurring in the same direction, where the speed limit was greater than or equal to 80 km/h. 92 fatal and 7398 injury crashes satisfied these criteria (2% of all fatal and 4% of all injury crashes). The number of crashes in which a passenger vehicle was the striking car was 55 (1% of all fatal crashes) and crashes in which a truck was the striking vehicle numbered 37 (1% of all fatal crashes). More broadly, a range of crash configurations that might be sensitive to such a system, might include head on crashes, either because of overtaking or for other reasons, and pedestrian crashes. Filtering the crash data on these criteria identifies 1202 fatal crashes (1079 passenger vehicle and 356 truck – 25% of all fatalities – and 16,208 injury crashes (15,411 passenger vehicles and 1273 trucks – 8% of all injury crashes.

To come to some estimate of overall effectiveness, we assumed that the technology is effective in 75 percent of narrowly selected crash types and in 25 percent of the balance of broadly selected crash types. For passenger vehicles, this leads to reductions of about 370 fatality crashes over 10 years and 9600 injury crashes. Annualising these figures and assuming a system cost of $2,700 leads to BCR values of 0.2 for passenger vehicles and 1.1 for heavy trucks.

Table 4.1
Crashes sensitive to forward collision avoidance technologies in New South Wales (1999-2008) in speed limit areas 80 km/h and greater

Vehicle type	Numbers of crashes in narrowly effective crash configurations (percentage of all crashes of relevant severity)		Numbers of crashes in broadly effective crash configurations (percentage of all crashes of relevant severity)		Estimate of total crashes prevented[1]		Benefit cost analysis	
	Fatal	Injury	Fatal	Injury	Fatal	Injury	Break even cost	BCR[2]
Passenger vehicle	55 (1%)	6888 (3%)	1079 (23%)	15411 (8%)	311 (7%)	9019 (4%)	$650	0.2
Truck	37 (1%)	501 (<1%)	356 (8%)	1273 (<1%)	117 (3%)	694 (<0.5%)	$2,900	1.1

[1] Estimate is 75% of narrowly selected crash types and 25% of broadly selected crash types

[2] Based on a $2,700 unit cost. Benefit period 16 years for passenger vehicles and 13 years for trucks, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW with PDO costs imputed, and numbers of registered vehicles in NSW in 2006.

It is unclear what allowance needs to be made for speeding vehicles in the analysis – it is possible that systems will have a lower effectiveness when vehicles are travelling at high speed – however, removal of crash benefit where speeding was involved only reduces BCR values slightly.

4.1.2 Forward collision warning with automatic braking across all vehicle speeds

Now consider a technology or combination of technologies that can mitigate forward collision over all speeds. When the NSW crash data is examined to include crashes occurring in all speed zones, the proportion of fatal crashes occurring in narrowly selected configurations, sensitive to forward collision prevention, is double the number found to occur in higher speed zones alone. Importantly, a significant proportion of injury crashes would be sensitive to the technology (20% if narrowly sensitive crash configurations are considered, or more than 50% if broader configurations are included).

Table 4.2 shows crashes sensitive to such a technology and an estimate of total crashes prevented. The BCR for passenger vehicle systems (1.3) is an improved figure over that estimated for higher speed zones alone, and the BCR for trucks is now 1.8.

Table 4.2
Crashes sensitive to forward collision avoidance technologies in New South Wales (1999-2008) in all speed zones

Vehicle type	Numbers of crashes in narrowly effective crash configurations (percentage of all crashes of relevant severity)		Numbers of crashes in broadly effective crash configurations (percentage of all crashes of relevant severity)		Estimate of total crashes prevented[1]		Benefit cost analysis	
	Fatal	Injury	Fatal	Injury	Fatal	Injury	Break even cost	BCR[2]
Passenger car	119 (3%)	43156 (21%)	2075 (45%)	108169 (57%)	578 (12%)	47754 (25%)	$3,500	1.3
Heavy truck	45 (1%)	1099 (1%)	498 (11%)	9858 (2%)	147 (4%)	3370 (1%)	$4,900	1.8

[1] Estimate is 75% of narrowly selected crash types and 25% of broadly selected crash types

[2] Based on a $2,700 unit cost. Benefit period 16 years for passenger vehicles and 13 years for trucks, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW with PDO costs imputed, and numbers of registered vehicles in NSW in 2006.

It is clear that the magnitude of the effectiveness of frontal collision avoidance technologies will largely depend on the range of configurations to which positive effects can be extended. As mentioned, a great number of crashes occur in an approximately frontal configuration and efficient braking is therefore potentially important, even if the per-crash effectiveness is not high in certain configurations. On the other hand, the fact that many fatal crashes occur in lower speed zones may be indicative of driver behaviours not necessarily mitigated by forward collision avoidance. Note too that pedestrian crashes are included in the broad category of crashes considered for this technology.

However, there are two main reasons to be cautious in expanding the number of crash configurations in which the present state of technology might be effective. These are a) the nature of those crashes in the broader category of frontal collision types, and b) issues surrounding reliable detection.

In expanding the number of crashes sensitive to forward collision mitigation to a broader group of crash configurations, head on crashes and crashes occurring in cross-path configurations are included. Head on crashes may occur due to the loss of control of a vehicle, or through errors in judgement when over-taking. In both cases, the effectiveness of an intervening system is highly dependent on the timing of the crash events and ability of the technology to intervene in time to act effectively. Where a system's 'preview' of an imminent crash is too short to prevent a crash, the system may aid by effectively reducing or eliminating the driver's reaction time and by increasing brake forces, but may not prevent a crash from occurring. While even small reductions in impact speed may substantially improve the chances of surviving a crash, it is improbable that the system would be as effective where the timing of detection would reliably stop a vehicle before a collision might have taken place. The system's effectiveness will therefore depend on any additional impact speed reduction that may be gained by the automated system. In some cases, such as cross-path crashes, it may only be feasible for present systems to assist the driver to increase braking forces, rather than reliably detect the other vehicle. In such crashes, the driver may on occasion be a better 'detector' of the other vehicle than a radar system, which may be tuned to focus on objects in the forward path of the vehicle rather than objects approaching from the side. Manufacturers of passenger vehicles who are early adopters of this technology see the potential effectiveness in such situations as positive, but only marginal. However, if marginal effectiveness in this case means effectiveness, say, only 33 percent of the effectiveness in a narrow specific crash type, the proportion of fatal crashes likely to be avoided through this technology may double to about 14 percent of all fatalities.

The other problem with expanding the number of scenarios in which forward collision warning and intervention can effectively intervene, is likely to be one of reliable detection – too many false positive warnings/interventions may distract and annoy the driver, but false negative warnings diminish a system's effectiveness. Currently, two separate systems are typically offered for frontal collision mitigation – a full-time system that only operates at speed (or sometimes speed differences) below about 30 km/h. These systems are promoted as being effective in stop-start traffic – and a manually activated radar adaptive cruise control system with auto-brake in some installations operating only above 60 km/h. For full effect, these technologies need to find some convergence so that they can operate reliably full-time across all speeds.

Communication from Autoliv Inc. indicates continued development of these systems with full rollout of systems including "City ACC" during the next five years.

In summary, and considering the foregoing, wide-scale take-up of a comprehensive forward collision detection and intervention technology of the kinds considered above, in passenger vehicles and truck fleets, may result in estimated fatal crash reductions of about 14 percent and estimated reductions in injury crashes of 25 percent with benefits biased toward minor injury crashes such as urban rear-end crashes. If the requisite suite of technologies can be delivered for $3,500, the argument for widespread deployment of comprehensive systems in vehicles is supported by benefit-cost analysis, and therefore the development of systems that can operate across driving environments should be encouraged. For now, while systems operate only on a part time basis at higher speeds, there is little justification for widespread deployment in passenger vehicles on a benefit-cost basis. However, the argument for the widespread deployment of such systems on trucks is vindicated on benefit-cost grounds.

4.2 Lane change warnings/blind spot warnings

Technically, lane change warnings and blind spot warnings may be separate technologies. Lane change warnings that are designed to react to what the system perceives as an unintentional lane change via image analysis are examined in the following Section. What is considered here are rearward looking systems that might use, for example, a RADAR to warn the driver that a lane change manoeuvre is unsafe. The lane change is intentional and signalled by the driver.

It is difficult in crash data to isolate crashes that might be attributable to an *intentional* lane change manoeuvre. However, it is possible to identify crashes positively identified as being the result of a lane change manoeuvre, or where there was a left or right turn resulting in a side-swipe of another vehicle via the DCA codes presented in Section 2. The results of the query applied to the New South Wales dataset are shown in Table 4.3.

One percent of fatal crashes and around three percent of injury crashes might be sensitive to this technology. It is worth noting that these crashes would include some in which no lane change was indicated. Therefore these numbers must be considered an over-estimate (possibly substantial) of sensitive crashes. However, where lane change indication was made, we expect a high effectiveness. For the purpose of estimating benefits, 75% effectiveness was applied.

Based on currently quoted prices, this technology is unlikely to be cost effective. However, it is possible to imagine that in an integrated RADAR monitoring system, the marginal cost of the rearward facing sensors may be small and within range of the break even price.

Table 4.3
Crashes sensitive to lane change warning technologies in New South Wales (1999-2008) in all speed zones

Vehicle type	Numbers of crashes in narrowly sensitive crash configurations (percentage of all crashes of relevant severity)		Estimated reduction in crashes[1] (percentage of all crashes of relevant severity)		Benefit cost analysis	
	Fatal	Injury	Fatal	Injury	Break even cost	BCR[2]
Passenger car	46 (1%)	5717 (3%)	35 (1%)	4288 (2%)	$280	0.2
Truck	13 (<0.5%)	714 (<0.5%)	10 (<0.5%)	536 (<0.5%)	$1000	0.7

[1] Estimate is 75% of narrowly selected crash types and 25% of broadly selected crash types

[2] Based on a $1,400 unit cost. Benefit period 16 years for passenger vehicles and 13 years for trucks, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW with PDO costs imputed, and numbers of registered vehicles in NSW in 2006.

4.3 Lane departure

Almost all crashes that would benefit from lane departure prevention would typically be identified in Australian crash data as a loss of control. A typical scenario for such a loss of control crash is one where a vehicle drifts onto a soft unsealed shoulder, and the driver encounters difficulty in returning the vehicle to the carriageway. This situation, where the left and right hand wheels experience different levels of traction, is one scenario in which electronic stability control assists. Crashes occur when the vehicle understeers back onto the sealed surface, whereupon the steering being applied becomes an overcorrection, causing the vehicle to cross the centreline. The resulting crash might be a head on collision, or a collision with a roadside object on the far side or a rollover.

It is well known that common factors in such crashes include high speed, alcohol and fatigue (sometimes in combination), and so when examining the effectiveness of lane departure warnings, some attention must be paid to other factors that might mitigate against the effectiveness of the technology. Furthermore, with the wide-scale take-up of electronic stability control systems, such lane departure events will, on average, be less likely to result in catastrophic consequences.

A straightforward analysis of the New South Wales crash dataset shows that 2269 fatal crashes (49% of the total number of fatal crashes) and 48441 injury crashes (24% of the total number of injury crashes) would include some that would potentially benefit from lane departure warning technologies. Note that these crashes would contain only very few vehicles equipped with ESC. It is not possible to identify crashes specifically benefiting from the technology and so this group represents a very broad group of which an unknown proportion would benefit. However, it is probable that lane departure warnings work most effectively when the driver drifts off the road due to inattention/distraction or due to fatigue.

Of the 2269 fatal crashes that fall into this category, 19 percent involved drivers with legal alcohol levels and who were not speeding. Filtering these crashes further to those occurring in higher speed zones, where we might expect the kind of loss of control crashes that are caused by lane departure, reduces this number to 15 percent of all fatal crashes.

Further consideration needs to be given to the environment in which such crashes occur. Lane departure technologies rely on image analysis and so require adequate edge line markings to operate effectively. Approximately nine percent of all fatal crashes in NSW, involving passenger vehicles and trucks, where there is no indication of illegal alcohol use, or speeding, where lane departure warnings may assist, occur on major highways or expressways[2].

Table 4.4 shows the results of all such considerations. Setting aside those crashes where the police nominated excessive speed and/or alcohol use (but preserving fatigue crashes) suggests that 19% of fatal crashes might be sensitive to this technology. As the technology requires reliable detection of the road edge, further restriction in respect of the crash environment might be warranted. Even then, perhaps nine percent of all fatal crashes might be sensitive to this technology.

---

[2] Major highways indicated by route numbers 1-29, 78, 905, 6002-6009

Table 4.4

Crashes sensitive to lane departure warning technologies in New South Wales (1999-2008). Successive rows place further restrictions on the characteristics of crashes considered. Figures in italics are likely to be excessively optimistic, with better estimates in the range of remaining figures.

	Numbers of crashes in relevant crash configurations (percentage of all crashes of relevant severity)		Estimated reduction in crashes[1] (percentage of all crashes of relevant severity)		Benefit cost analysis	
					Break even cost	BCR[2]
	Fatal	Injury	Fatal	Injury		
All lane departure crashes						
Passenger	*2130 (46%)*	*46517 (23%)*				
Truck	*139 (3%)*	*1924 (1%)*				
+ No illegal alcohol or speeding						
Passenger	811 (17%)	23488 (11%)	609 (13%)	17616 (9%)	$1,500	1.1
Truck	80 (2%)	1004 (<0.5%)	60 (1%)	753 (<0.5%)	$2,300	3.6
+ 80 km/h zones or higher						
Passenger	659 (14%)	11039 (5%)	494 (11%)	8279 (4%)	$850	0.6
Truck	69 (1%)	767 (<0.5%)	52 (1%)	575 (<0.5%)	$1900	2.9
+ Major highways / expressways[1]						
Passenger	370 (8%)	4815 (2%)	278 (11%)	3611 (2%)	$400	0.3
Truck	56 (1%)	525 (<0.5%)	42 (1%)	394 (<0.5%)	$1,400	2.2

[1] Estimate is 75% of selected crash types

[2] Based on a $1,400 unit cost for passenger vehicles and $650 for heavy trucks. Benefit period 16 years for passenger vehicles and 13 years for trucks, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW with PDO costs imputed, and numbers of registered vehicles in NSW in 2006.

4.4 Heavy vehicle stability

In this Section, the possible benefits of heavy vehicle stability and roll over stability is examined. Crashed vehicles that were categorised as being an articulated truck or a heavy truck were extracted from the New South Wales dataset.

Narrowly selected crashes are those for which the ‘first impact type’ was ‘Rollover’. To identify a broader number of crashes in which the technology might be beneficial, the DCA codes associated with those crashes were used to check for crashes of similar configuration but which did not result in a rollover (such as those where a truck hit a fixed object etc.) To these DCA codes, two others were added: “left off carriageway into object” and “right off carriageway into object”.

If ESC effectiveness in SUV-type vehicles is any guide, then a very high effectiveness might be envisaged for this technology. It is possible that in the broadly selected group of crashes described above, effectiveness might be better than 25%. However, in the table of results for this technology (Table 4.5) a BCR of 1.7 is produced assuming a 75% effectiveness in narrowly selected crash types and 25% in the balance of more broadly selected crash types.

Table 4.5
Crashes likely to have been sensitive to truck stability systems in New South Wales (1999-2008) and estimated benefits of such systems

Vehicle type	Numbers of crashes in narrowly selected crash configurations (percentage of all crashes of relevant severity)		Numbers of crashes in broadly selected crash configurations (percentage of all crashes of relevant severity)		Estimated reduction in crashes[1] (percentage of all crashes of relevant severity)		Benefit cost analysis	
	Fatal	Injury	Fatal	Injury	Fatal	Injury	Break even cost	BCR[2]
Atriculated and heavy rigid trucks	60 (10%)	1,143 (5%)	132 (12%)	2,049 (6%)	63 (8%)	1084 (4%)	$2,900	1.5

[1] Estimate is 75% of narrowly selected crash types and 25% of broadly selected crash types

[2] Based on a $2,000 unit cost. Benefits 13 years for trucks, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW with PDO costs imputed, and numbers of registered vehicles in NSW in 2006.

4.5 Alcohol interlocks

The role of alcohol in the drivers of passenger vehicles, trucks and motorcycles, as recorded in the New South Wales crash dataset, is given in Table 4.6. To look at the benefits of alcohol interlocks, consideration must be given to the reduction in crash rates associated with the use of alcohol interlocks. For this, the results of Bjerre (2005) appear useful. Bjerre examined the experience of driving-while-intoxicated (DWI) offenders in Sweden in the years before, and then during/after an interlock program, noting that DWI offenders typically have injury crash rates five times the Swedish average. A straightforward inference of Bjerre's results is that interlocks, in the best case, reduce crash rates by around 80%.

The New South Wales dataset was queried to identify drivers and motorcycle riders who were positively identified as having an illegal blood alcohol concentration at the time of the crash. There were almost no crashes in which two drivers/riders had an illegal BAC. As Bjerre did not distinguish fault but merely examined rates of crash involvement, these may be applied to the New South Wales data to estimate reduced numbers of crashes from the use of alcohol interlocks. The results of the analysis are given in Table 4.6. Note that the 80% reduction in crashes has been applied to all severities of crash.

Benefit cost ratios are greater than one for trucks and motorcycles. The BCR for passenger cars is 0.4, but note that an alcohol interlock described by Lahausse and Fildes (2009) is priced less than the break-even cost shown below. (Lahausse and Fildes also found that the device might be generally cost-beneficial.) However, this device is not that used in interlock programs to-date and does not have the same guards against circumvention, and so may also have a lower effectiveness.

Table 4.6
Crashes likely to have been sensitive to alcohol interlock technologies in New South Wales (1999-2008)

Vehicle type	Numbers of crashes in narrowly selected crash configurations (percentage of all crashes of relevant severity)		Estimated reduction in crashes[1] (percentage of all crashes of relevant severity)		Benefit cost analysis	
	Fatal	Injury	Fatal	Injury	Break even cost	BCR[2]
Passenger car	610 (13%)	8741 (4%)	488 (11%)	6993 (3%)	$770	0.5
Truck	138 (3%)	1265 (1%)	110 (2%)	1012 (1%)	$3,700	2.5
Motorcycles	125 (3%)	1059 (1%)	94 (2%)	847 (1%)	$3,000	2.0

[1] Estimate is 80% reduction in crash rate

[2] Based on a $1,500 unit cost. Benefit period 16 years for passenger vehicles,13 years for trucks and 11 years for motorcycles, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW with PDO costs imputed, and numbers of registered vehicles in NSW in 2006.

4.6 Fatigue

Fatigue is a commonly nominated factor in crashes. Between 1999-2008 in New South Wales, according to police reports, 565 fatal crashes involved a driver of passenger vehicles who was fatigued and 174 involved a fatigued truck driver. Many affected drivers have illegal blood alcohol levels as well.

It is probable that the definition of fatigue used by police understates the importance of fatigue in crashes. Haworth (1998) discusses this at some length and estimates of fatigue as a cause of fatal crashes in Australia are as high as 20% of fatal truck crashes and 17% of all fatal crashes in NSW.

For the purposes of the present analysis, benefits will be assumed to apply to those crashes positively identified as arising from fatigue in the driver of a passenger vehicle or truck. The results of the benefit cost analysis can then be modified according to assumptions about any under-reporting of fatigue involvement in crashes.

As with other Sections, narrowly selected crashes will have a higher effectiveness value than broader definition of crashes. In relation to fatigue, the most sensitive types of crash are likely to be those that result in loss-of-control crashes in which no illegal alcohol use was identified, and in which the driver was nominated as suffering from fatigue. Over half of these crashes are loss-of-control crashes. A broader selection of crashes includes those in which the driver also had an illegal blood alcohol concentration. To these we have assumed a 75% effectiveness rate in the narrowly selected group and a 25% in the balance of those crashes in the broadly selected group. The results of the crash query and the benefit-cost calculations are given in Table 4.7.

Table 4.7
Crashes likely to have been sensitive to fatigue management technologies in New South Wales (1999-2008)

Vehicle type	Numbers of crashes in narrowly selected crash configurations (percentage of all crashes of relevant severity)		Numbers of crashes in broadly selected crash configurations (percentage of all crashes of relevant severity)		Estimated reduction in crashes[1] (percentage of all crashes of relevant severity)		Benefit cost analysis	
	Fatal	Injury	Fatal	Injury	Fatal	Injury	Break even cost	BCR[2]
Passenger car	454 (10%)	9263 (5%)	565 (12%)	11406 (6%)	368 (8%)	7483 (4%)	$710	0.5
Truck	135 (3%)	1797 (1%)	174 (3%)	2143 (1%)	111 (2%)	1434 (1%)	$4,400	2.9

[1] Estimate is 75% of narrowly selected crash types and 25% of broadly selected crash types

[2] Based on a $1,500 unit cost. Benefit period 16 years for passenger vehicles and 13 years for trucks, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW with PDO costs imputed, and numbers of registered vehicles in NSW in 2006.

In interpreting the results in Table 4.7, the central questions are the extent to which the 10% of fatal crashes nominated by the police as involving fatigue in the driver of a passenger car is an underestimate, and the effectiveness of the fatigue management device (in stopping the driver from driving a car in that state).

4.7 Pedestrian detection

Pedestrian detection systems that are currently being offered by some manufacturers consist of some form of ranging system (LASER or RADAR) in combination with cameras coupled to image analysis software. Coupled with low-speed forward collision avoidance systems, the system may initiate automatic braking if the driver is not reacting to the presence of the pedestrian. These systems require daylight to operate.

Pre-dating these systems are those that use infrared technology to detect the presence of a pedestrian or cyclist, and these are likely to be of benefit in crashes occurring in the dark.

The starting point for the crash analysis was those crashes involving pedestrians or cyclists hit by either passenger vehicles or trucks in New South Wales between 1999 and 2008. After considering the DCA code of each crash, the crashes were then categorised according to whether the pedestrian/cyclist was in the path of the vehicle prior to the crash (travelling with or against the direction of movement of the vehicle), or whether the pedestrian/cyclist entered the path of the vehicle just prior to the collision (for example, entering the roadway from an adjacent footpath).

Crashes in the first category are a narrowly selected group of configurations where automatic detection and braking is likely to have a greater effect. It is expected that there will be benefits also in the second, broadly selected group of crash configurations, but less so. The numbers of crashes in the New South Wales dataset are given in Table 4.8.

Table 4.8

Crashes sensitive to pedestrian detection warning technologies in New South Wales (1999-2008) in all speed zones

Vehicle type	Numbers of crashes in narrowly effective crash configurations (percentage of all fatal crashes)		Numbers of crashes in broadly effective crash configurations (percentage of all fatal crashes)	
	Fatal	Injury	Fatal	Injury
Passenger car	176 (4%)	4651 (2%)	708 (15%)	23379 (11%)
Truck	36 (1%)	171 (<0.5%)	103 (2%)	409 (<0.5%)
Overall	212 (5%)	4822 (2%)	811 (17%)	23788 (12%)

Now consider the two separate systems relevant to these crash types: those systems adapted to be most effective in dark conditions, and those relying on natural ambient light to recognise pedestrians and cyclists. Table 4.9 and Table 4.10 split the crashes given in Table 4.8 according to the ambient light conditions at the time of the crash, given in the CrashLink record, and present the results of benefit-cost calculations for each type of technology.

BCR values are generally low, but as mentioned when discussing forward collision avoidance, it is probable that further integration of forward collision detection systems will take place, and that effectiveness in the balance of more broadly selected passenger crashes may be higher than we have assumed. Nevertheless, on current assumptions, the marginal costs required to achieve a BCR equal to one in passenger cars are in the $100-$300 range.

Table 4.9

Crashes likely to have been sensitive to pedestrian detection and warning technologies operable in dark conditions in New South Wales (1999-2008)

Vehicle type	Numbers of crashes in narrowly selected crash configurations (percentage of all crashes of relevant severity)		Numbers of crashes in broadly selected crash configurations (percentage of all crashes of relevant severity)		Estimated reduction in crashes[1] (percentage of all crashes of relevant severity)		Benefit cost analysis	
	Fatal	Injury	Fatal	Injury	Fatal	Injury	Break even cost	BCR[2]
Passenger car	119 (3%)	1100 (0.5%)	350 (8%)	5337 (3%)	147 (3%)	1894 (1%)	$180	0.0
Truck	26 (0.5%)	26 (<0.1 %)	46 (1%)	69 (<0.5%)	25 (<0.5%)	30 (<0.1%)	$490	0.1

[1] Estimate is 75% of narrowly selected crash types and 25% of broadly selected crash types

[2] $4,000 unit cost. Benefits for 16 years, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW, and numbers of registered vehicles in NSW in 2006. No savings in PDO costs are associated with this technology.

Table 4.10
Crashes likely to have been sensitive to pedestrian detection and warning technologies operable in non-dark conditions in New South Wales (1999-2008)

Vehicle type	Numbers of crashes in narrowly selected crash configurations (percentage of all crashes of relevant severity)		Numbers of crashes in broadly selected crash configurations (percentage of all crashes of relevant severity)		Estimated reduction in crashes[1] (percentage of all crashes of relevant severity)		Benefit cost analysis	
	Fatal	Injury	Fatal	Injury	Fatal	Injury	Break even cost	BCR[2]
Passenger car	57 (1%)	3551 (2%)	358 (8%)	18004 (9%)	118 (3%)	6277 (3%)	$350	0.2
Truck	10 (<0.5%)	145 (<0.5%)	57 (1%)	340 (<0.5%)	19 (<0.5%)	158 (<0.1%)	$540	0.3

[1] Estimate is 75% of narrowly selected crash types and 25% of broadly selected crash types

[2] Based on a $1,500 unit cost. Benefits for 16 years, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW, and numbers of registered vehicles in NSW in 2006. No savings in PDO costs are associated with this technology.

4.8 Motorcycle ABS, and TCS and airbags

4.8.1 ABS

The study of Rizzi et al. (2009) would seem to be most relevant when estimating benefits of motorcycle anti-lock braking systems. Rizzi et al. found, through in depth crash investigation, that head on crashes were the type with the least potential to be affected by ABS. Through crash data analysis, they then made estimates of effectiveness relative to head on crashes, by comparing crash patterns amongst bikes with and without ABS fitted. Their results gives a lower limit of effectiveness, as there is an assumption that head on crashes are not sensitive at all to ABS. They found that fatal crash rates in motorcycles with ABS were 53% lower than non-ABS bikes. Fatal intersection crashes were reduced by 71%. The corresponding reductions in injury crashes were 41% and 43%.

Before applying the results of Rizzi et al., the New South Wales crash dataset was disaggregated to examine the types of location at which motorcycle crashes occurred. The CrashLink data was queried to return all motorcycles involved in any crash in NSW between 1999-2008. The details of related crashes where the crash was fatal or injury was examined. This subset of crashes was disaggregated by crash location type. The results are given in Table 4.11.

Table 4.11
Location types of motorcycle crashes in New South Wales (1999-2008)

Location	Non-head on		Head on	
	Fatal	Injury	Fatal	Injury
1-way street	1	75		2
2-way undivided	284	8383	112	649
Divided road	58	1805	5	22
Dual freeway	11	420		2
Intersection	164	9273	7	99
Other	7	161	1	2
Single limited access		35		
Total	525	20152	125	776

Applying the results of Rizzi et al to this data suggest the following:

- A 53 percent reduction in fatal non-head on crashes is a reduction of 280 fatal crashes.
- A 71 percent of fatal intersection crashes is a reduction of 116 crashes.
- Overall reduction in fatalities might have been 43 percent of fatal motorcycle crashes.
- Applying appropriate reductions to the New South Wales data gives a reduction in injury crashes of 8260, 3990 at intersections.
- Percentage reductions in injury crashes are 39 percent of injury motorcycle crashes.

Note that the predicted reductions are much the same as the estimate of a 38 percent reduction made by Teoh (2010).

The results are summarised with those pertaining to traction control systems for motorcycles in Table 4.13 in the next Subsection.

4.8.2 Traction control system for motorcycles

While some traction control systems (TCS) that are currently offered for motorcycles do not work during steering manoeuvres, systems are being installed that include banking sensors and operate effectively in cornering manoeuvres. Unfortunately, no estimate exists for the effectiveness of TCS. However, it is possible to identify those crashes that would have been likely to be sensitive to TCS, and here the analysis focused on cornering crashes. Note that while no detailed analysis of crashes or effectiveness was identified, Gail et al. (2009) considered the performance of TCS in cornering in test track conditions.

First consider all relevant crashes in NSW. The subset of crash configuration descriptions (DCA descriptions) for all such motorcycle crashes in New South Wales is given in Table 4.12.

Table 4.12
Motorcycle crashes in New South Wales (1999-2008) that might potentially benefit from cornering stability

Description	Fatal	Injury
Left off cway into object	28	360
Off carriageway to left	5	333
Off cway left bend	10	306
Off cway right bend	13	616
Off left bend into obj	49	450
Off right bend into obj	94	858
Out of control on bend	54	1742
Out of control on cway	30	2571
Right off cway into obj	12	214
Total	295	7450
Total as a proportion of all motorcycle crashes	45%	36%

First, note that in 250 of the 295 fatal crashes in Table 4.12, the police concluded that speed was involved in the crash and in 118, alcohol, fatigue or both were factors. However, there is some cause to be optimistic about the potential for TCS in the case of speed related crashes, because TCS acts to cut power to the bike where traction cannot be maintained, or lean angles become to steep. In 177 of the 295 crashes no alcohol or fatigue was thought to have played a role. In 152 of these 177 fatal crashes, speed was thought to have been a major factor in the crash.

Given the foregoing, an assessment was made that positive effects may reasonably have been expected in about half of all fatal crashes in Table 4.12, or about 20% of all motorcycle fatal crashes. To this we must assume some kind of effectiveness. An effectiveness of 25% will be assumed to come to some estimate of cost-benefit. The results of this assumption are given in Table 4.13, and note that the break-even cost and the BCR value are high, giving some latitude for effectiveness to be less without degrading the cost-beneficial aspect of the technology.

Table 4.13
Crashes where at least one motorcycle rider was injured or killed New South Wales (1999-2008)
and benefit-cost results for ABS and TCS interventions

Technology	Numbers of Motorcycle crashes (percentage of all crashes of respective severity)		Reduction in crashes (percentage of all crashes of respective severity)		BCR analysis	
	Fatal	Injury	Fatal	Injury	Break even cost	BCR[1]
Anti-lock braking system	650 (11%)	20925 (10%)	280 (6%)	8262 (4%)	$13,700	27
Traction control system			33 (1%)	1064 (1%)	$1,700	1.7

[1] Based on a $500 unit cost for ABS and $1000 for TCS. Benefit period 11 years, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW with PDO costs imputed, and numbers of registered vehicles in NSW in 2006.

4.8.3 Airbags for motorcycles

Motorcycle airbags are designed to lessen the severity of injuries in frontal collisions. Consequently, a query similar to that used for forward collision avoidance can be used to identify crashes that might be sensitive to this technology: specifically, collisions between motorcycles and passenger vehicles are likely to be most sensitive.

The results of the query are shown in Table 4.14. Ten percent of fatal motorcycle crashes and about 2% of motorcycle injury crashes fall into this category of crash. Assuming that about ten precent of these crashes might be avoided with an airbag, and at a unit cost of $6,000 (Honda Gold Wing) leads to a BCR of 0.03. Substantial reduction in cost would be required to achieve a BCR of 1.

Table 4.14
Crashes where at least one motorcycle rider was injured or killed in New South Wales (1999-2008)
where a motorcycle airbag may have been of benefit and approximate benefit-cost results motorcycle airbags

Technology	Numbers of Motorcycle crashes (percentage of all crashes of respective severity)		Reduction in crashes (percentage of all crashes of respective severity)		BCR analysis	
	Fatal	Injury	Fatal	Injury	Break even cost	BCR[1]
Motorcycle airbags	65 (1%)	493 (<0.5%)	7 (0.1%)	49 (<0.05%)	$167	0.03

[1] Based on a $6000 unit cost. Benefit period 11 years, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW, and numbers of registered vehicles in NSW in 2006. No savings in PDO costs are associated with this technology.

4.9 Seat belt enhancements

4.9.1 Seat belt reminders and interlocks

Crashes that would have potentially benefitted from the installation of a seat belt interlock or reminder are those with an occupant who was injured or killed and was positively identified as not wearing a belt in the crash record. The extent to which fatalities and injuries might have been reduced depends on the seatbelt effectiveness rate and the interlock/reminder effectiveness rate.

The New South Wales CrashLink database was queried to identify those occupants who were either killed or injured. As benefits in this report are per crash rather than per casualty, a crash with multiple casualties was considered only once, categorised by the most severely injured unrestrained occupant. The numbers of crashes identified in the New South Wales dataset are summarised in Table 4.15.

Note previous comments made in Section 2: there is an unresolved discrepancy between observation of restraint use in surveys and the rate of non-wearing in crashes, and so the results here are somewhat contingent on that discrepancy being resolved.

Seat belt effectiveness was taken from Elvik and Vaa (2004) who give best estimates of a 50% reduction in the probability of being killed for drivers wearing a seat belt and a 28% reduction in probability of being injured, across crash types. These figures were applied to both front seating positions. For rear seat positions the reductions in risk applied were 25% and 21% for fatal injury and non-fatal injury (Elvik and Vaa, 2004). The latter estimate was applied when a more severely injured occupant was in a rear position (a minority of cases). An additional factor needed to be applied to account for less than 100 percent effectiveness of any interlock/reminder system. Lie et al (2009) found that, in Europe, 80% of those who otherwise do not wear belts, do so with an obvious audio-visual reminder. Benefit cost calculations in Table 4.15 therefore consider two systems: an interlock system that cannot be by-passed, and a system with 80% effectiveness.

Table 4.15
Crashes where at least one unrestrained occupant was injured or killed New South Wales (1999-2008) and benefit-cost results for seatbelt wearing interventions

Vehicle type	Numbers of crashes (percentage of all crashes of respective severity)		Reduction in crashes due to interlock – 100% effectiveness / audio visual warning – 80% effectiveness		BCR analysis (interlock – 100% / audio-visual warning – 80%)	
	Fatal	Injury	Fatal	Injury	Break even cost	BCR[1]
Passenger car	560 (12%)	2415 (1%)	265 / 212	591 / 473	\$210 / \$170	1.6/1.3
Truck	68 (1%)	417 (<0.5%)	17 / 14	104 / 83	\$430 / \$350	3.3/2.7

[1] Based on a \$130 unit cost. Benefit period 16 years for passenger vehicles and 13 years for trucks, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW, and numbers of registered vehicles in NSW in 2006. No savings in PDO costs are associated with this technology.

4.9.2 Rear seat restraint enhancements such as pretensioners

Crashes were identified in which occupants of passenger vehicles were injured or killed in rear seating positions, and who were positively identified as wearing restraints at the time of the crash.

164 crashes were identified where a rear seat occupant was restrained (but not in a child restraint) but nevertheless killed. As mentioned in the previous section, rear-seat restraint use has an apparent effectiveness of 25% (Elvik and Vaa, 2004). That being the case, the 164 crashes notionally represent 164/(1-0.25) = 219 crashes of equivalent severity in which rear seat occupants were restrained, the difference between 219 and 164 being crashes in which rear seat occupants survived.

Now, an improved rate of survival can be applied with an enhanced restraint system in mind. If a seat belt-plus-enhancement increases the probability of survival by 30% over the unrestrained condition (compared with 25% for seatbelt alone), then we would expect 153/219 crashes to have been fatal, representing a reduction of 11 fatalities, or 7%, over the seatbelt system alone. Similar calculations may be applied to injuries. While optimistic, these improvements lead to a break-even cost of \$38, which must be distributed amongst two or three seating positions. These results are summarised in Table 4.16.

Table 4.16
Crashes in which a rear seat occupant restrained with a seat belt was injured or killed New South Wales (1999-2008) and concomitant benefit-cost results for rear seat pretensioners assuming a 25% seat belt effectiveness an additional 15% in effectiveness due to pretensioning.

Vehicle type	Numbers of crashes (percentage of all crashes of respective severity)		Potential reduction in crashes (percentage of all crashes of respective severity)		BCR analysis	
	Fatal	Injury	Fatal	Injury	Break even cost (total for all rear seating positions)	BCR[1]
Passenger car	164 (4%)	10179 (5%)	11 (<1%)	1357 (<0.5%)	\$38	0.1

[1] Based on a \$140 unit cost x 3. Benefit period 16 years, 5.5% p.a. discount rate. Calculation based on annualised crash costs over 1999-2008 in NSW, and numbers of registered vehicles in NSW in 2006. No savings in PDO costs are associated with this technology.

5 Factors affecting the take-up and prevalence of vehicle technologies

Short of regulation, mechanisms may be required to encourage the flow-through of technologies to those currently at risk of crashing. It is likely that certain social disparities exist with respect to access to safety technologies; for example, the median age of vehicles crashed by young drivers tends to be much higher than the average, and young drivers may not see the benefits of new technologies until 10-20 years after the broad take up the technology, as crashes involving 10-20 year old cars involving young drivers are common (Anderson et al., 2009). While it may not be within the remit of authorities to provide direct access to new vehicles to those disadvantaged when it comes to new technologies, certain strategies can be implemented to encourage flow through as quickly as possible.

To understand the dynamics of vehicle technology in the fleet, some information is presented in the present section. First, data that describes the origin of vehicles is presented. New car buyers determine the stock of vehicles in the country and so understanding the relative contributions to the stock of vehicles by different kinds of buyer may be of use in devising strategies to encourage take up.

Second, trends in the installation rates of some historical technologies are presented. Even if installation rates of a new technology may accelerate quickly to high levels, there may be considerable lag before the majority of all registered vehicles are equipped with the technology. The examples presented below provide information on the pattern of deployment to be expected with the introduction of technologies that are installed on new vehicles.

5.1 Technologies in the registered fleets of SA and NSW

The fleets of New South Wales and South Australia will be described below. They are compared and contrasted for several reasons: NSW has newest fleet of any State (except NT), and is a net exporter of second hand vehicles, whereas SA has one of the oldest fleets and is a net importer of second hand vehicles. Figure 5.1 shows where the vehicles in each state were originally purchased: about 12 per cent of the NSW fleet was first purchased outside NSW, and about 27 per cent of the SA fleet was first purchased outside SA. With respect to the current fleets of each State, there have been net flows of 157,000 vehicles from NSW to South Australia and 46,000 vehicles from South Australia to New South Wales. Figure 5.2 shows that private fleets and Government vehicles have a bigger effect on SA stock than the NSW stock, but it is large in both cases. Private fleet and government purchasing policies in NSW evidently affect the vehicle stock in SA and other states.

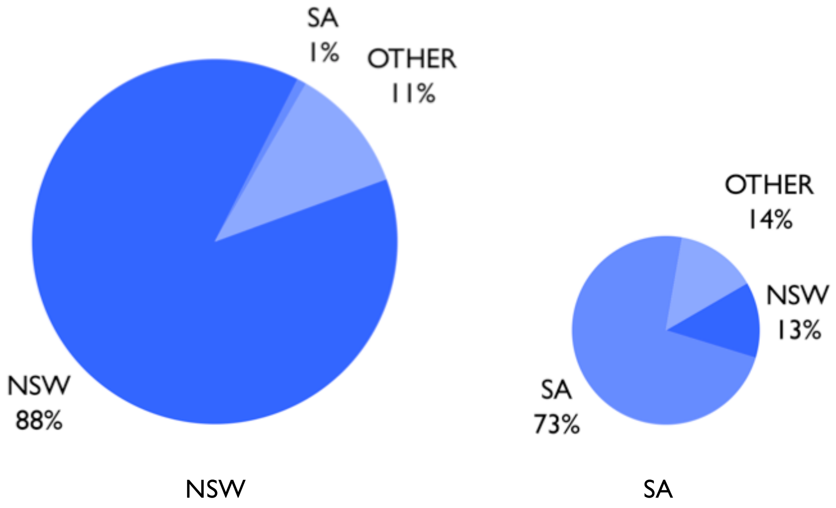

Figure 5.1
State of origin (original purchase) of vehicles in New South Wales and South Australia.
Areas represents relative sizes of the registered fleet.

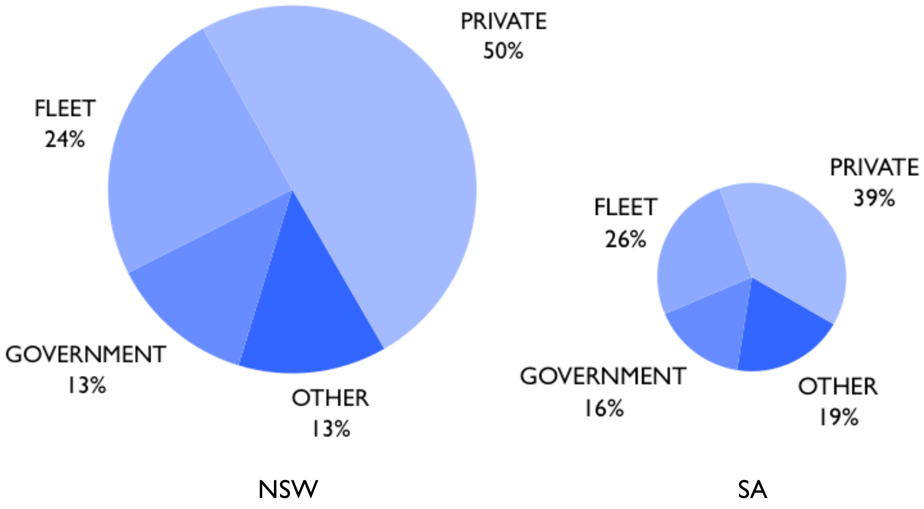

Figure 5.2
Original buyer type of vehicles in New South Wales and South Australia.
Areas represents relative sizes of the registered fleet.

5.2 Patterns of the introduction of some existing technologies

Saturation of new vehicle technology can take considerable time. Vehicles remain in the fleet for more than a decade, and tend to be equally represented in crashes for about 16 years.

It is possible to illustrate the pattern of introduction of technologies by taking a sample of the current registered fleet, disaggregating according to the year of the sale of the vehicle and to look at the prevalence of technology in each year-of-sale cohort. Through the VIN of each vehicle, characteristics can be ascertained to a certain level: RL Polk Australia maintain a database of vehicles sold in Australia. For every vehicle, the model can be identified and generic specifications obtained.

Three specific technologies will be considered below: ESC, driver airbag, and ABS. Of particular interest is the prevalence of these technologies in both the newest vehicles, and overall. These data give some indication of the time required to deploy technologies widely into the registered fleet.

The December 2009 quarterly extract of the registered light passenger vehicle fleet (< 2500 kg) in New South Wales was sampled. A sample of 1880 vehicles with decoded VINs (and therefore safety specifications) was obtained. Some 11.5 per cent of vehicles were lost at this stage: the great majority of these were pre-1991 vehicles. The safety features to be discussed were unavailable in pre-1991 vehicles, and the percentage penetration into the totality of vehicles (i.e., including the pre-1991 ones) is calculated on the basis of this assumption. In the case of air bags, this will slightly understate the proportion of vehicles having them.

The presentation of the data will be as follows.

- For the fleet as a whole, the proportions having the technology installed as standard and for which it was available as an option are stated.
- There is a graph giving the percentages of the fleet that date from different years of sale. This is the same for each technology, of course, but the total is shown split according to presence/absence of the technology, which is different in each case.
- A second graph gives the percentages of the fleet in each year-of-sale cohort having the technology. This refers to vehicles in the fleet at present. It gives some idea of the historical availability of the technology in new vehicles, but the validity of this interpretation naturally depends on survival in the fleet being unaffected by having the technology or the technologies installed with it.

Driver airbag

In 68 percent of the fleet, a driver airbag is installed as standard. It was available as an option in a further 11 percent, but the take-up rate in this group is not known.

The top panel of Figure 5.3 shows the composition of the NSW light fleet at the end of 2009. The black line indicates the numbers of vehicles of different years of sale that are still in the fleet, and the coloured bands indicate driver airbag status.

The bottom panel shows the proportion of vehicles in each year-of-sale cohort with driver airbag. This refers to vehicles in the fleet at present, and so it is an approximation of the proportions of vehicles with and without airbags at the time of sale. For example, approximately 50% of vehicles sold in 1997 were installed with a driver airbag as standard.

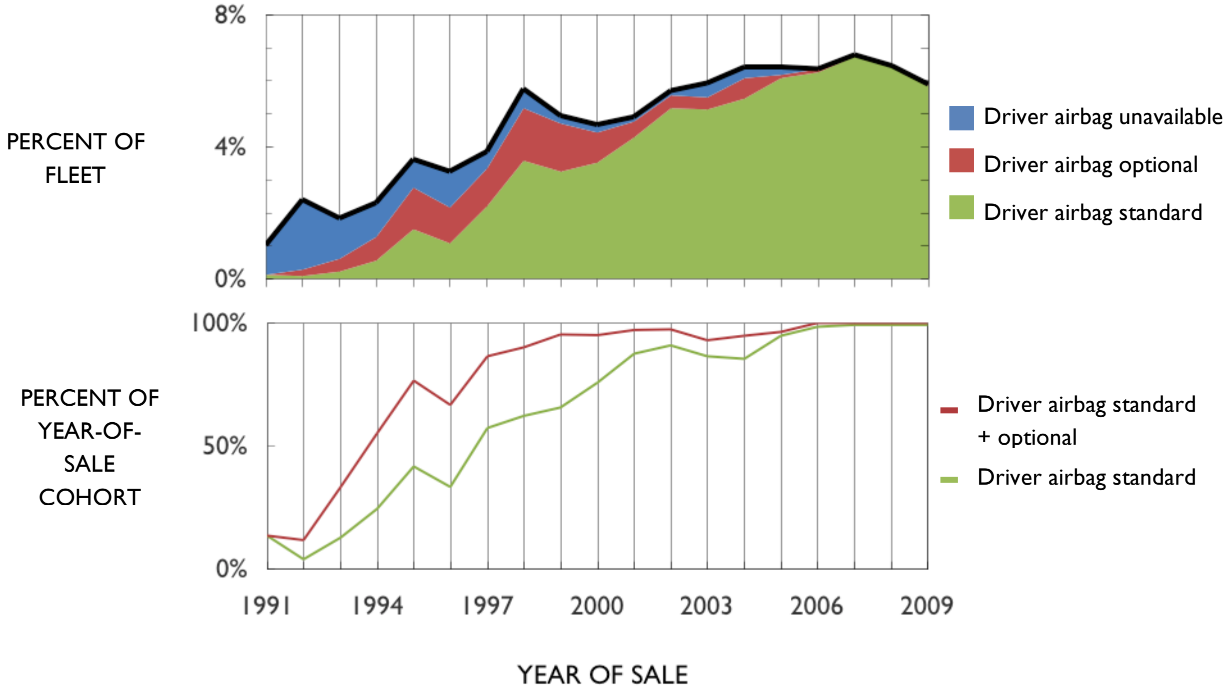

Figure 5.3
Driver airbag in registered light passenger vehicles in NSW at the end of 2009.

ABS

In 46 per cent of the fleet, ABS is installed as standard. It was available as an option in a further 21 percent.

The top panel of Figure 5.4 shows the composition of the NSW light fleet at the end of 2009. The black line indicates the numbers of vehicles of different years of sale that are still in the fleet, and the coloured bands indicate ABS status.

The bottom panel shows the proportion of vehicles in each year-of-sale cohort with ABS. This refers to vehicles in the fleet at present. While installation rates in the newest vehicles are around 90 percent, the overall installation rate is still below 50 percent.

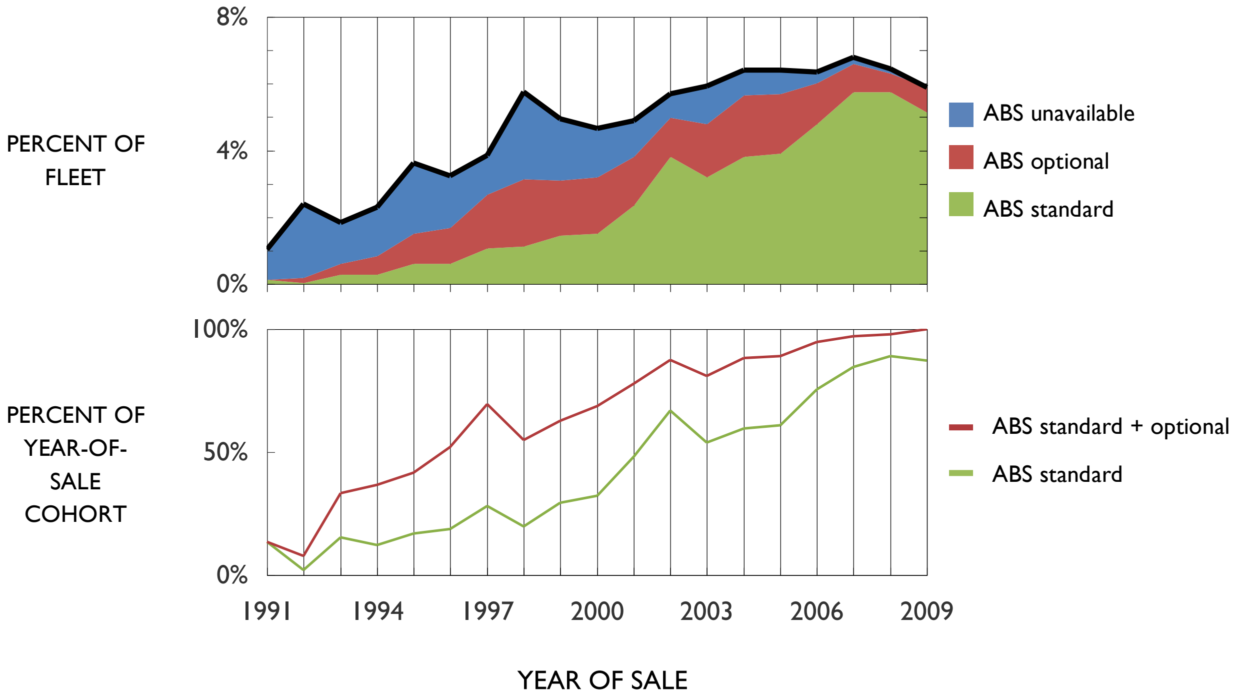

Figure 5.4
ABS in registered light passenger vehicles in NSW at the end of 2009.

These graphs describe the evolution of safety technology in the fleet as a whole. It is evident that the age of the fleet means that it can take considerable time after the introduction of a safety technology, before even half the vehicles are equipped with the technology. Given the frequency of older vehicles in crashes, the prevalence of a technology in the registered fleet is likely to overestimate the proportion of crashes affected at any given time. This means that a significant proportion of the benefit arising from any given technology can be delayed for some years.

5.3 Electronic stability control

In 13 per cent of the current NSW fleet, ESC is installed as standard. It was available as an option in a further three percent, but the take-up rate in this group is not known.

The top panel of Figure 5.5 shows the composition of the NSW light fleet at the end of 2009. The black line indicates the numbers of vehicles of different years of sale that are still in the fleet, and the coloured bands indicate ESC.

The bottom panel shows the proportion of vehicles in each year-of-sale cohort with driver airbag. This refers to vehicles in the fleet at present.

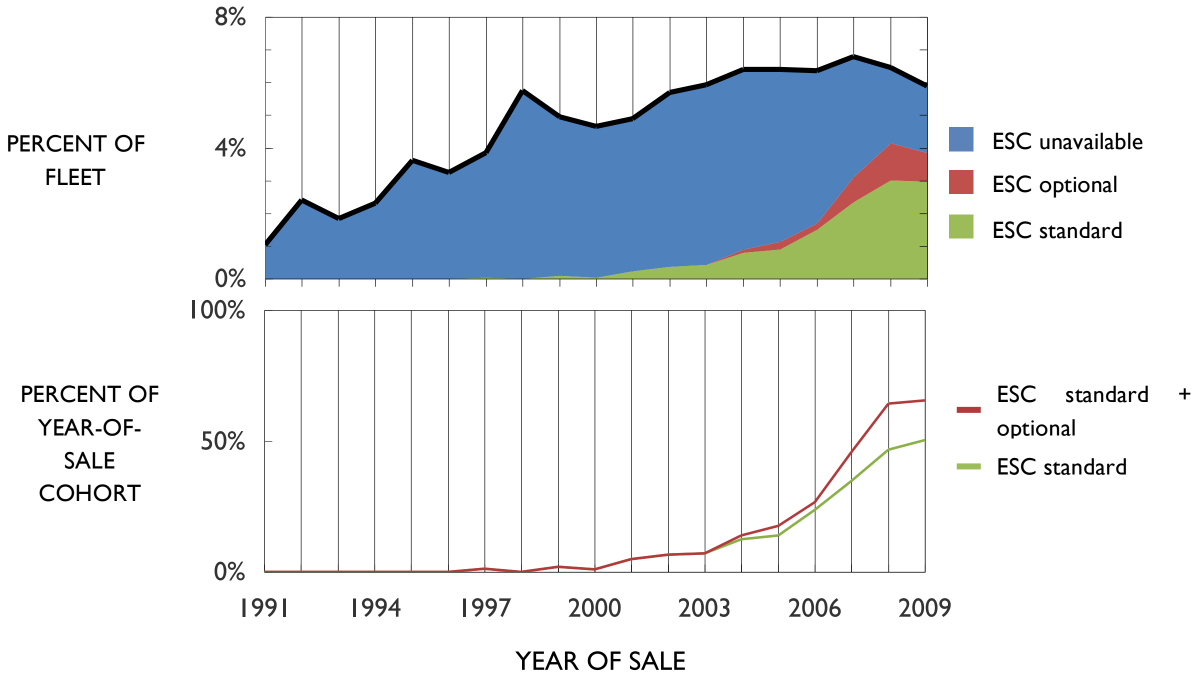

Figure 5.5
ESC in registered light passenger vehicles in NSW at the end of 2009.

5.4 Commentary

- A driver airbag has been in over 95 per cent of new cars since 2006. The length of time between reaching the level of 20 per cent of new cars and 80 per cent of new cars was about 7 years (1994 to 2001).

- ABS is in about 90 per cent of new cars. The length of time between reaching the level of 20 per cent of new cars and 80 per cent of new cars was about 10 years (1997 to 2007).

- ESC is in about 50 per cent of new cars. The length of time between reaching the level of 20 per cent of new cars and 50 per cent of new cars was about 3 years (2006 to 2009), and thus the length of time between reaching the level of 20 per cent of new cars and 80 per cent of new cars is likely to be about 6 years.

As mentioned earlier, this interpretation of the data is only correct if survival in the fleet is largely unaffected by having the technology or the technologies installed with it.

Penetration of the total fleet is much lower, at 68, 46, and 16 per cent for these three technologies (plus a little more from models in which the technology was available as an option).

These figures give some insight into the speed of take-up of technologies. It is apparent that a considerable period can elapse between the introduction of a technology and the time at which a majority of vehicles will be fitted with the technology.

Many vehicles in the entire stock of vehicles in Australia are bought by either government or fleet buyers. If fleet purchasing policies prioritised the take up of new safety technologies, it would follow that the prevalence of those technologies in the entire fleet would accelerate.

6 Overview of benefits and discussion

In Section 4, New South Wales crash data was used in conjunction with estimates of the costs and number of crashes to derive potential benefits of each technology. These benefits were expressed in terms of 10 year crash reductions and percentage reductions. The numbers of registered vehicles in New South Wales were used to derive total costs of each technology for use in calculating benefit-cost ratios. Section 5 discussed some factors affecting the prevalence of new technologies into the fleet.

This purpose of this section is to draw together the results of the previous sections to give an overview of how predicted benefits might lead to national crash reductions. Further, the various analyses are discussed in light of the results and some of their limitations.

6.1 Extending estimated benefits to the whole of Australia

In this section, the estimated percentage reductions in crashes derived in Section 4 will be applied to national crash statistics to estimate potential annual reductions in crashes that would be expected across the country from the implementation of the technologies examined in this report. Clearly, an underlying assumption will be that crash patterns across Australia can be approximated by crash patterns in New South Wales.

Consistent with Section 4, monetised crash savings are based on estimated percentage reductions in fatal and non-fatal injury crashes, with crash costs associated with property damage only crashes imputed from non-fatal injury crash costs.

First, an estimate of the total number of crashes occurring annually in Australia is presented. In the following subsections, results are presented by vehicle type: passenger vehicles, trucks and motorcycles. Finally, a summary of benefits is presented.

6.1.1 The numbers of crashes in Australia

BITRE (2009) estimate the number of crashes occurring annually in order to monetise the crash problem in Australia. As mentioned in Section 3, BITRE estimate that the number of non-fatal crashes far exceeds the number of non-fatal crashes recorded by state transport authorities. Their estimates of the number and costs of crashes were used in the calculations presented in Section 4. It is appropriate to use BITRE estimates to extrapolate those benefits to the rest of the country.

BITRE (2009) does not explicitly present the totality of crashes used in their report. However, they were able to supply the authors of this report with the relevant numbers. Their estimates of the numbers of crashes in Australia is given in Table 6.1.

Table 6.1
Estimated number of crashes in Australia, 2006

State	Severity				Total
	Fatal	Hospitalised injury	Non-hosp. injury	Property damage only	
NSW	449	8332	61495	130897	201173
VIC	309	6721	49607	114174	170812
QLD	313	4887	36073	86658	127932
SA	104	1959	14457	31988	48508
WA	184	2041	15066	56207	73498
TAS	43	636	4692	8381	13752
NT	41	382	2817	3483	6722
ACT	12	541	3993	6912	11457
Total	1455	25498	188200	438700	653853

Source: BITRE Estimates

Applying percentage crash reductions likely from the adoption of each technology (Section 4) to the figures in Table 5.1 allows an estimate to made of the crash reductions likely across Australia from the full deployment of each technology. Note that such estimates relate to the total number of crashes in 2006.

6.1.2 Passenger vehicle technologies

First, reductions in crashes due to technology installed in passenger vehicles are presented. These vehicles constitute the largest segment of vehicles and are responsible for the largest proportion of crashes and so one might expect that effects on the crash rate of this group will have the largest bearing on the overall national road toll.

The estimates of potential benefits from the installation of safety technologies in passenger vehicles across Australia is given in Table 6.2. The technologies have been ranked according to potential savings in monetised crash costs.

Immediately apparent is the potential of forward collision detection and avoidance technology. However, there are several other noteworthy aspects to this table. First, several technologies have a large potential to reduce crashes (>5% of fatalities), but the associated BCR estimates appear poor to marginal. The low BCR values arise, despite large potential crash reductions, from a combination of a) the fact that so many vehicles need to be fitted with the technology, b) the expense of the technology, and c) low average crash rates.

At this point, it is worth reiterating that there is uncertainty with respect to the BCR estimates (particularly on the cost side of the equation) such that technologies with BCRs as low as 0.5 in the Table 5.2 might be considered worthy of further exploration to examine, for example, whether the costs of the technology used in this report might be overstated with repect to some future scenario, producing pessimistic BCR values.

Nevertheless, there is a consistent message in Table 5.2 that despite significant potential for crash reductions, such reductions might come at significant relative cost.

Table 6.2
Summary of potential crash reductions, monetised crash savings and benefit cost ratios of **passenger vehicle** technologies examined in this report

Technology	Estimated annual crash reductions in Australia[1]		Monetised crash savings[2] (2006 dollars, millions)	Estimated benefit cost ratio
	Fatality (percentage of all fatals)	Non-fatal injury[1]		
Forward collision avoidance, all speeds	181 (12%)	52,886	3,927	1.3
Alcohol interlocks	153 (11%)	7,294	883	0.5
Fatigue management systems	115 (8%)	7,805	816	0.5
Forward collision avoidance in 80 km/h and greater speed areas	93 (6%)	7,611	744	0.2
Dedicated pedestrian detection - Daylight	37 (3%)	6,546	391*	0.2
Lane departure warnings	87 (6%)	3,767	477	0.3
Lane change warnings	11 (1%)	4,472	320	0.2
Seatbelt interlocks	83 (6%)	617	249*	1.6
Dedicate pedestrian detection – Darkness	46 (3%)	1,975	211*	0.0
Seatbelt reminder (disruptive)	66 (5%)	493	199*	1.3
Rear seatbelt improvements	4 (0%)	743	58	0.1

[1] Based on BITRE estimates of the numbers of crashes in Australia, 2006

[2] Property damage only crash costs imputed from injury costs except where indicated (next note)

* Property damage only crash costs excluded from estimate

6.1.3 Truck technologies

The estimates of potential benefits from the installation of safety technologies in trucks across Australia is given in Table 6.3. As in the previous subsection, the technologies have been ranked according to potential savings in monetised crash costs.

Table 6.3
Summary of potential crash reductions, monetised crash savings and benefit cost ratios of **truck** technologies examined in this report

Technology	Estimated annual crash reductions in Australia[1]		Monetised crash savings[2] (2006 dollars, millions)	Estimated benefit cost ratio
	Fatality (percentage of all fatals)	Non-fatal injury[1]		
Forward collision, all speeds	46 (3%)	1,419	215	1.8
Fatigue	35 (2%)	1,496	190	2.9
Alcohol interlocks	35 (2%)	1,056	161	2.5
Forward collision, 80 km/h and greater	34 (2%)	593	129	1.1
Truck stability	20 (1%)	1,130	126	1.5
Lane departure	13 (1%)	411	62	2.2
Lane change	3 (0%)	559	45	0.7
Pedestrian detection - Daylight	6 (0%)	164	23*	0.3
Pedestrian detection - Dark	8 (1%)	32	22*	0.1
Seatbelt interlock	5 (0%)	109	19*	3.3
Reminders	4 (0%)	87	15*	2.7

[1] Based on BITRE estimates of the numbers of crashes in Australia, 2006

[2] Property damage only crash costs imputed from injury costs except where indicated (next note)

* Property damage only crash costs excluded from estimate

In contrast to the results for passenger vehicles, the consistent message in Table 5.3 is one of positive BCRs for the majority of the technologies considered, but in the presence of more modest reductions in crashes. The potential crash cost reductions are such that they would occupy low positions on the table of benefits for passenger vehicle technologies (Table 5.2).

The generally positive BCR values arise because the size of the truck fleet is relatively small in comparison to the fleet's crash involvement. Hence the "per-crash fitment rate" would be higher relative to the equivalent rate of passenger vehicles. However, the totality of truck crashes is sufficiently small to mean that, even with such positive benefits, the effect on overall crash numbers is attenuated.

6.1.4 Motorcycle technologies

The estimates of potential benefits from the installation of safety technologies in motorcycles across Australia is given in Table 6.4. As in the previous subsection, the technologies have been ranked according to potential savings in monetised crash costs.

Table 6.4
Summary of potential crash reductions, monetised crash savings and benefit cost ratios of **motorcycle** technologies examined in this report

Technology	Estimated annual crash reductions in Australia[1]		Monetised crash savings[2] (2006 dollars, millions)	Estimated benefit cost ratio
	Fatality (percentage of all fatals)	Non-fatal injury[1]		
Motorcycle ABS	88 (6%)	8,618	795	27
Alcohol interlocks	29 (2%)	884	136	2.0
Motorcycle traction control	10 (1%)	1,091	98	1.7
Motorcycle airbags	2 (0.1%)	51	8*	0.03

[1] Based on BITRE estimates of the numbers of crashes in Australia, 2006

[2] Property damage only crash costs imputed from injury costs except where indicated (next note)

* Property damage only crash costs excluded from estimate

With the exception of motorcycle airbags, the BCR values are a positive indication that the installation of ABS, traction control and alcohol interlocks is warranted on economic grounds. But on similar grounds to those detailed for truck crashes, there is limited opportunity for large effects on the overall road-toll. Motorcycles are over-represented in crashes and in serious crashes, but nevertheless comprise a minority of all crashes, and hence there is a limit to how much motorcycle crash prevention can make to the overall road toll.

6.1.5 Benefits across vehicle types

Table 6.5 summarises results across all vehicle types. The table indicates benefits arising from implementation of technologies across multiple vehicle types simultaneously.

Here, it being assumed that technologies would be simultaneously deployed across vehicle types where possible. Notable is that, for those technologies that are applicable to passenger vehicles and to either trucks or motorcycles, the magnitude of potential crash savings is largely driven by crashes involving passenger vehicles; typically around 90% of the benefit would come from intallation of technologies in passenger vehicles. (Examination of numbers in Tables 5.2, 5.3 and 5.4 will bear this out.)

Table 6.5
Summary of potential crash reductions, monetised crash savings and benefit cost ratios of technologies examined in this report

Technology	Estimated annual crash reductions in Australia[1]		Monetised crash savings[2] (2006 dollars, millions)	Estimated benefit cost ratios		
	Fatality (percentage of all fatals)	Non-fatal injury[1]		Pass.	Truck	M/cycle
Forward collision avoidance, all speeds	227 (16%)	54305	4,143	1.3	1.8	-
Fatigue management systems	150 (10%)	9301	1,007	0.5	2.9	2.0
Alcohol interlocks	217 (15%)	9233	992	0.5	2.5	-
Forward collision avoidance in 80 km/h and greater speed areas	127 (9%)	8204	873	0.2	1.1	-
Motorcycle ABS	88 (6%)	8618	795	-	-	27
Dedicated pedestrian detection - Daylight	43 (3%)	6711	415*	0.2	0.3	-
Lane departure warnings	100 (7%)	4177	539	0.3	2.2	-
Lane change warnings	14 (1%)	5031	365	0.2	0.7	-
Seatbelt interlocks	88 (6%)	726	268*	1.6	3.3	-
Dedicate pedestrian detection – Darkness	54 (4%)	2007	233*	0.0	0.1	-
Seatbelt reminder	71 (5%)	580	214*	1.3	2.7	-
Truck stability	20 (1%)	1130	126	-	1.5	-
Motorcycle traction control	10 (1%)	1091	98	-	-	1.7
Rear seatbelt improvements	4 (0%)	10617	43*	0.1	-	-
Motorcycle airbags	2 (0.1%)	51	8*			0.03

[1] Based on BITRE estimates of the numbers of crashes in Australia, 2006
[2] Property damage only crash costs imputed from injury costs except where indicated (next note)
* Property damage only crash costs excluded from estimate

6.2 Discussion

6.2.1 Discussion of estimated benefits

The largest potential gains in coming years are likely to come from forward collision detection and avoidance technologies. These technologies currently include emergency brake assist, ‘city-safe’ low speed obstacle detection with automatic braking, and adaptive cruise control with automatic braking (operating sometimes only above, for example, 60 km/h). In next five years, it is expected that the technologies will continue to develop such that there will be complete convergence in the operable range of systems, and a complete integration of the sensing and intervention technologies. It is from such future systems that the largest road safety gain is likely to be made. This report estimates that about 220 lives per year might be saved in Australia with the adoption of this technology. Our conclusion is consistent with that of Farmer (2008) who though the technology relevant to 38 percent of crashes in the USA.

The components that forward collision warning and mitigation systems use --- those for detection, decision, and intervention --- may soon be thought of as mature, from which time their full integration cannot be long delayed. Recent successes of vehicle manufacturers in reducing the costs of technologies that seemed science fiction only a few years before suggests the same success in future with collision warning and mitigation. Consequently, it is reasonable to think that the costs might indeed fall to the hundreds of dollars within a few years of effectiveness being demonstrated empirically.

Most other technologies considered offer crash reductions in the order of 1-10%. But some may be cost prohibitive at this time (noting previous comments on cost). But for trucks and motorcycles, most emerging technologies appear to promise positive returns in terms of monetised crash reductions, even while addressing a small proportion of the totality of crashes. These include:

- Stability control/rollover prevention, higher speed adaptive cruise control with braking, lane departure and lane change warnings for trucks
- Motorcycle anti-lock braking systems and cornering traction control

As mentioned, for those technologies that are applicable to passenger vehicles and to either trucks or motorcycles, the magnitude of potential crash savings is largely driven by crashes involving passenger vehicles. So for alcohol and fatigue management technologies, it should be noted that large potential reduction in crash costs are being estimated in the absence of a compelling benefit-cost ratio. However, as discussed in Section 3, there is a degree of uncertainty regarding the costs of these technologies and it is not beyond reasonable speculation to expect that unit costs could be reduced to within the range of break-even costs of these technologies.

An important difference between trucks and motorcycles on the one hand, and passenger vehicles on the other hand, is their relative crash rates and the severity of crashes when they do happen. Data on crashes in New South Wales in Section 3.1.1 indicates that the fatality rates of crashes involving trucks and motorcycles are higher than for those crashes involving passenger vehicles, indicating that the average cost per crash are higher for truck and motorcycle crashes. Furthermore, because of exposure factors (in the case of trucks which see large annual distances travelled) and inherent riskiness (in the case of motorcycles), the rate of crashing per vehicle is also higher. It is therefore not surprising that benefit cost ratios are more likely to be favourable in these classes of vehicle, and less so in passenger vehicles.

Limitations

“Never make predictions, especially about the future” is usually good advice, but when considering technologies at an early stage of development, we have to put it aside. For emerging safety technologies considered here, the design of the intervention is clear. Many technologies tackle known crash factors. It is to be expected that they will have benefits. The difficulty is determining the magnitude of the effect. Some limitations that apply to this analysis have been alluded to above in respect of the costs of technology. Some further limitations are given below.

As already mentioned, BCR values presented in this report are based mostly on information about the costs of the technology to consumers. Furthermore, they do not take into account components sometimes considered in, for example, regulation impact statements. Similarly, the starting point has been that the technologies are virtually un-implemented in the fleet and prospective benefits are being estimated assuming that crashes in the historical dataset represent the population of crashes likely to be affected by new technology in the future. Therefore BCR values estimated in the future, for example when considering any justification for regulation, might be quite different to those presented here.

There are difficulties with precisely estimating crash reductions. The level of information contained in police reported data is certainly useful but also provide a fairly blunt guide to those crashes likely to be positively affected by each technology. Some crash factors might be reported fastidiously in serious crashes but might be considered less important at lower severity levels (seat belt wearing is an example where this might occur).

The efficacy of the technology is also uncertain. The approach taken was to assume that technologies will be very effective in a narrow range of scenarios closely related to the function of the technology, and somewhat effective in a broader range of scenarios where the technology is still likely to function, but with less effect. There is also uncertainty in the range of conditions.

Thus there are limitations in the results of this report that are a consequence of the imprecision of identifying relevant crashes using police data in the way that has been done, and from assumptions about effectiveness and costs.

In relation to fatigue management systems: the effectiveness of these systems is almost completely unknown, and so this report envisages a system that is indeed effective in preventing such crashes. Note too that the reductions in the rows of the tables presented above are not necessarily additive. For example, a significant proportion of fatigue crashes are also alcohol crashes. It may turn out, that the most effective fatigue management system is an alcohol interlock, with relatively small marginal benefits of an additional fatigue management system.

Similarly, no allowance has been made for crashes that might be prevented by ‘upstream’ technologies. For example, electronic stability control will affect estimated effectiveness of lane departure warnings, and even seatbelt reminders and interlocks, as lane departure events may, on average, become more benign.

Tables 6.2 to 6.5 show estimated crash reductions disaggregated by crash severity. Some features of the disaggregation may cause surprise, and need comment: the ratio injured/fatal in Table 6.1 is about 150, and if the corresponding ratio of savings is very different from 17 in Table 6.5, some reason should be adduced.

These reasons include ones that are very familiar in road accident research. Different types of crash do differ in severity, and potential savings will consequently be biased towards one end or the other of the severity spectrum. Fatal crashes are relatively few in number, and consequently are subject to considerable random variation. Technologies differ in the speeds and thus severities of crashes that are prevented or mitigated. And the lists of technologies in Tables 6.2 to 6.5 include some classed as primary safety (preventing crashes) and some as secondary (reducing severity of injury, given that a crash has occurred).

However, other reasons are consequences of the assumptions and approximations made in the analysis. These will potentially feed forward into different effects on fatal and nonfatal crashes. Each benefit cost ratio that is reported is derived from data on crashes of many severities and in many circumstances, and it may be that the final result is fairly insensitive to any single assumption or approximation. Some sensitivity testing has been conducted, and this appears to be the case. This is in the context that predictions of effectiveness in the future and predictions of costs in the future are both highly debatable.

6.2.2 Encouraging the take-up of safety technologies

There are several varieties of encouragement available to help new safety technologies become more common.

- Encouragement directed at fleet managers. A large proportion of new vehicle sales are to fleets. The people making decisions are thus highly influential in deciding the speed of take-up of a safety technology. Persuading quite a small number of people to take the lead on this would have disproportionate benefits.

- Encouragement directed at private buyers of new vehicles.

- Encouragement directed at private buyers of second hand vehicles. The re-sale value is one of the things that influences buyers of new vehicles. Thus if buyers of second hand vehicles demand safety features, there would be a knock-on effect in the new car market. However, second hand buyers are restricted to choose from the existing stock of vehicles, and so demand from buyers of second hand vehicle is likely to be a much less effective pathway.

A large proportion, up to 50%, of the stock of vehicles in the registered fleet is determined by the purchases of government and non-government fleets. Purchasing polices that include requirements for effective safety technologies are likely to be cost-beneficial for the fleet purchaser as well as improve the efficiency of technology take-up in the entire fleet, as ex-fleet vehicles continue their service life in the second hand vehicle market. Such policies are also more likely to lead to lower marginal costs for manufacturers and purchasers alike, further encouraging take-up by all buyers.

A major tool of encouragement is ANCAP, the Australasian New Car Assessment Program. Certain aspects of safety of a car model are summarised by a star rating. Where fleets adopt policies to buy ‘safe’ cars, it is reasonable to assume that the ANCAP rating will figure largely in such a policy. ANCAP therefore also have an important role to play in encouraging take up of technologies at the purchasing stage. Of course, they are likely to also have a direct influence on manufacturing decisions through stipulation of technologies in assessment protocols.

Governments also have coercive options available. For new vehicles, the Australian Design Rules impose certain standards, and are updated from time to time as technology advances. The current policy is one that moves regulation into the international arena, and hence future regulation is likely to be tightly linked to international processes such as the World Forum for Harmonization of Vehicle Regulations (WP.29) of the United Nations Economic Commission for Europe.

With 4 or 5 stars for occupant passive safety having become common, it might be asked whether further improvement is at all likely. There is some positive (albeit limited) evidence from French accident data. Page et al. (2009) made estimates of the safety benefits of adding Emergency Brake Assist to cars with 4 EuroNCAP stars, and benefits of Emergency Brake Assist and a fifth star given that the car has 4 stars, and other possibilities. Their conclusion was that even among cars with at least 4 stars, further safety features lead to substantial (10 to 40 per cent) reductions in injury crashes. Consequently, improvement vehicle safety is worth encouraging even amongst car makes and models that already perform reasonably well by current standards.

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