



Emerging Vehicle Safety Technology

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Title

Emerging vehicle safety technologies and their potential benefits in Australia

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Abstract

New vehicle safety technologies continue to be developed. This report aims to assess the future impact of light vehicle safety technologies in Australia over the next 30 years. This report includes a literature review, consultation with experts regarding the possible trend in injury reduction over the next 30 years from AEB (Autonomous Emergency Braking) and V2V (Vehicle-to-Vehicle communication). The experts suggested that the most important emerging vehicle safety technologies are primary safety systems that provide increasing levels of autonomy, driver warnings and driver monitoring. AEB was consistently identified as having the most potential in the near future, and this was confirmed in the review of literature. Results demonstrated the importance of introducing new safety technologies as early and as quickly as possible. The experts suggested this could be achieved through mandating the installation of safety technologies, reducing insurance premiums for vehicles with safety technologies, and encouraging their uptake through consumer information and new vehicle assessment programs.

Key Words

Vehicle safety, autonomous emergency braking, vehicle-to-vehicle communication, expert opinion, uptake of new technology.

Disclaimer

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List of Abbreviations

ACN	Automatic collision notification
AEB	Autonomous emergency braking
ECU	Electronic control unit
ESC	Electronic stability control
FCAT	Forward collision avoidance technologies
GPS	Global positioning system
HMI	Human machine interface
HUD	Heads-up display
ISA	Intelligent speed adaptation
RADAR	Radio detection and ranging
SONAR	Sound navigation and ranging
V2I	Vehicle-to-infrastructure
V2P	Vehicle-to-pedestrian
V2V	Vehicle-to-vehicle
VII	Vehicle infrastructure integration

Key Findings

- Many new vehicle safety technologies will be increasingly present in the vehicle fleet over the next 20 years. Due to the effectiveness of current secondary safety systems, the focus for new technologies is on primary safety through increasing levels of autonomy, providing warnings to the driver and driver monitoring.
- Current literature and expert opinion suggest that the most promising technology in the short term is Autonomous Emergency Braking (AEB) and in the longer term, Vehicle-to-Vehicle (V2V) communications.
- To realise the full potential of safety benefits, it is vital that these technologies are introduced into the Australian vehicle fleet as soon as possible. This could be achieved by using mechanisms such as government regulation, insurance discounts, and consumer information and marketing

Executive Summary

New vehicle safety technologies continue to be developed. This report aims to assess the future impact of light vehicle safety technologies in Australia over the next 30 years.

This report includes a literature review, a summary of interviews with automotive safety experts and a quantitative analysis of two technologies. The analysis considers the impacts of the two technologies that are most likely to have a significant benefit in the short and medium term future, AEB (Autonomous Emergency Braking) and V2V (Vehicle-to-Vehicle communication).

Literature review and expert views

The literature review and expert responses suggested there are many useful safety technologies that are close to introduction. At any other time in history these would be considered major steps forward. However, they are small compared to the revolutionary improvement in safety that may come from AEB. V2V technologies may eventually lead to another substantial improvement but probably over a longer time scale than AEB.

Other emerging technologies combat driver drowsiness, distraction, or failure of concentration, alcohol interlocks, advanced cruise control, warnings (lane keeping, blind spot, speed relative to speed limit), advanced lighting systems, autonomous braking when reversing, automatic collision notification, Vehicle-to-Infrastructure (V2I), Vehicle-to-Pedestrian communication systems (V2P) and night vision.

It is worth noting the expert responses suggest that the most potential lies in primary safety technologies that act to prevent a vehicle from crashing, or reduce the severity of a crash. There was little focus on further improvements in secondary safety technologies (such as airbags) that mitigate the effects of a crash.

Quantitative analysis

Assumptions were made about the effectiveness of AEB and V2V systems and about the time scales over which they would come into the new vehicle fleet. From these assumptions, annual percentage reductions in fatalities were calculated up to 2045. The results of this analysis demonstrated the rate of introduction of these technologies has a direct influence on how quickly safety benefits can be realised.

Encouraging early adoption of safety technologies

There are still important unsolved technical challenges with AEB, V2V, and other technologies. Nevertheless, it is realistic to take the view that these are on track to being at least partially solved. However, due to scrappage of old cars being quite slow, it takes a significant amount of time for new technologies to become common in the fleet as a whole. Consequently, this report highlights the importance of introducing new technologies into new vehicles as early and as quickly as possible.

Delaying the introduction of vehicle technologies that are effective at preventing injury crashes will result in significant and cumulative financial and societal costs.

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1 Introduction

1 Outline

New vehicle safety technologies continue to be developed. This report aims to assess the future impact of light vehicle safety technologies in Australia over the next 30 years

The RACV (Royal Automobile Club of Victoria) commissioned this report to gain a better understanding of new vehicle safety technologies and their potential impact on road trauma.

Three tasks were undertaken include:

- a literature review
- consultation with experts from Australia and overseas about future vehicle safety technologies.
- a quantitative analysis of the possible trend in injury reduction over the next 30 years from Autonomous Emergency Braking (AEB) and Vehicle-to-Vehicle communication (V2V).

2 Literature review

There is a significant amount of research taking place throughout the world on new vehicle safety technologies as part of a major effort to find specific ways of preventing or mitigating particular crash types.

There is widespread optimism about the potential of autonomous emergency braking (AEB) and vehicle-to-vehicle (V2V) communications to prevent or mitigate many different types of crash, particularly any crash involving a frontal collision.

There are also other technologies that may not receive the same level of attention as AEB and V2V communications but nevertheless may be beneficial in preventing or mitigating crashes. These include technologies that seek to enforce driver behaviour (alcohol and seat belt interlocks, and fatigue warning systems), technologies that encourage safer driving behaviours (lane change assist warning, lane departure warning, adaptive cruise control, reverse visibility systems) and technologies that help after a crash has occurred (automatic collision notification). These technologies may be packaged with each other and may use the same basic technology in different ways: for example, adaptive cruise control generally uses the same hardware and software as AEB.

It is important to emphasise that while many of the emerging vehicle safety technologies are in production, the prevalence of these technologies is low. Hence, the potential effectiveness of the technologies reported in the literature may not yet be reliable.

2.1 Australasian New Car Assessment Program (ANCAP)

Autonomous emergency braking (AEB) refers to the vehicle detecting an obstacle in its path and braking without any intervention by the driver. These obstacles may include pedestrians and cyclists, and so AEB is a technology that has the potential to prevent injury to both vehicle occupants and vulnerable road users. It is a new technology, and so there is only limited experience of how effective it truly is. Present effectiveness estimates are based on extrapolating from how the systems are supposed to work or are observed to work in controlled tests, to the spectrum of crashes that are observed on the road.

An analysis of US crash data by Farmer (2008) found that AEB was the most promising of five different emerging vehicle technologies and could address 38% of crashes in the US. Jermakian (2011) updated the estimates of Farmer by accounting for known limitations in the current technologies. AEB remained as the technology with the greatest potential, however the proportion of crashes that were considered relevant was reduced to 20%.

Kusano and Gabler (2011) simulated a representative sample of US rear end collisions and found that AEB could reduce the number of moderate to fatal injuries in striking vehicles by 36%, and by 28% for struck vehicles.

The Highway Loss Data Institute (2011) looked at insurance data for the Volvo City Safety AEB system in particular, which at the time was only operational at speeds of under 31 km/h. Nevertheless, their analysis of insurance data suggested a 22% reduction in crashes compared with similar vehicles that did not have an AEB system. Hummel et al. (2011) also looked at insurance claims, but from Germany and suggested that an AEB system that could detect other vehicles would reduce all crashes by 20%. If the system could also detect pedestrians this increased to 25% and if cyclists could also be detected this increased further to 43% (note that this was based on German data where cyclists and pedestrian accidents may be more common).

Rosén et al. (2010) performed a series of simulations of pedestrian accidents that had been investigated in depth in Germany, with and without an AEB system included in the simulation. They looked at two different fields of view for the AEB detection system. At a field of view of 180 degrees, their results suggested a reduction of 44% in pedestrian fatalities and 33% of serious injuries. At a field of view of 40 degrees the reductions were 40% and 27%, but below 40 degrees the benefits were markedly reduced.

In a previous CASR study, Anderson et al. (2012) simulated the effects of FCAT¹ systems while assuming a range of system characteristics (range, angle, reaction time etc.) and reconstructed crashes that had been investigated in-depth.

¹ FCAT is a rather broader term than AEB, and the long-range systems are built upon adaptive cruise control systems. FCAT systems incorporate technology designed to assist with general forward collision avoidance, including various collision alerts and warnings, and progressive brake intervention that may occur prior to autonomous emergency braking.

They estimated that the best model, a dual system with both long- and short-range capabilities, would reduce fatal crashes by 39% and injury crashes by 48% (this includes pedestrian crashes). Some reservations in particular need to be mentioned. Firstly, in making their estimates of effectiveness, Anderson et al. did not make allowance for unreliability in the operation of the systems. Unreliability might arise from, for example, environmental conditions such as darkness and rain, or the complexity of the scene detected by the sensors and then processed. Additionally Anderson et al. were rather optimistic about the performance of system characteristics in some instances (reaction time particularly but also brake force build up) so estimates are likely to be higher. Regardless, the analysis shows the potential of such systems. Finally, because of the high cost of the systems, Anderson et al. considered that benefit-cost ratios would be less than one for passenger vehicles (though much greater than one for heavy vehicles).

Those reservations may not be as serious as they appear. Anderson et al. estimated that a short-range system that examines a relatively narrow field in front of the vehicle and intervenes with full braking after a short reaction time, would reduce fatal crashes by 28% and injury crashes by 34%, not as great as the 39% and 48% mentioned earlier but still very considerable. Anderson et al. note that a halving of system costs would mean benefit-cost ratios exceed one, and that the costs of the systems may indeed fall considerably in future years (if the cost fell by 20%, it would approximately halve in three years and be a quarter of the original cost after about six years.)

Thus, there is reason to believe that AEB has the potential to substantially reduce deaths and injuries for both vehicle occupants and pedestrians. However, the above studies are based on simulations and analysis of past insurance and in-depth crash data. As AEB systems have found their way into more vehicles in the real world, some limitations of AEB effectiveness have become apparent:

- There were several papers relevant to AEB at the recent (23rd) Enhanced Safety of Vehicles (ESV) Conference. Three papers give evidence that AEB systems are at an early stage. Tests of two AEB systems by Ando and Tanaka (2013), using a dummy pedestrian, found that one system was reliable only below about 30 km/h and the other system was reliable only below about 10 km/h. The maximum speed from which a vehicle can be stopped before reaching an obstacle is typically 25 km/h. That is the median for the 11 AEB systems tested by Hulshof et al. (2013) using a dummy car as an obstacle (the minimum was 20 km/h and the maximum was 50 km/h). Referring to tests at up to 40 km/h with a dummy pedestrian, the results of Lemmen et al. (2013) show that in some cases the vehicle stopped and in others it did not; Lemmen et al. note that in some cases good performance was achieved by braking early thus increasing the possibility of false positives.
- Results of Euro NCAP tests using a stationary target have been announced (Euro NCAP, 2013). The maximum speed from which the vehicles stopped before reaching the target was typically 27 km/h, and the maximum speed at which there was impact mitigation was typically 32 km/h (the medians of 6 vehicles tested).
- Detecting and classifying possible obstacles and deciding what action to take is difficult. In the context of pedestrians, Gerónimo et al. (2009) reviewed the image processing aspects of this topic, and took the view that technical problems were not yet solved. Even if and when the image processing aspects are overcome, prediction of movement a second or two in advance will remain so. Improvements in camera technologies, software and integration of systems are occurring. An example is the next generation Subaru 'eyesight' system that utilizes a colour camera that allows improved detection range and can function at higher operating speeds (Subaru, 2014b).

Despite the limitations in performance that might exist at this stage, AEB remains a very promising technology for the near future: it appears from the literature discussed above that somewhere around 20-40% of crashes may be prevented with AEB. Even if these crashes are not completely prevented, the reductions in speed may be sufficient to prevent death and serious injury. The cumulative effect of small reductions in speed across a large number of crashes might lead to significant overall benefits (Anderson et al., 2012).

2.2 Connected vehicles

New technologies are being developed that will allow vehicles to connect to each other and to the surrounding infrastructure. These are often referred to as vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I). Vehicle-to-vehicle technologies allow vehicles to send messages to one another regarding their position and speed, and potentially any emergency information. Vehicle-to-infrastructure technologies allow the infrastructure on the road to send messages to nearby vehicles regarding traffic signals, intersections, stop signs, and possibly traffic flow.

A number of studies on vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) have taken place in the last five years, and many are ongoing and currently awaiting results.

V2I technologies have been shown to be technically achievable in some small field studies. Brewer et al. (2011) conducted a pseudo-naturalistic study on a closed track with vehicles equipped with V2I systems, which were successful in stopping the drivers from running red lights and stop signs. A large field operational trial was conducted in Japan of 2000 vehicles equipped with V2I, in order to test signal and stop sign recognition (Fukushima, 2011). Vehicles equipped with the system

came to a complete stop at one of the stop signs 76% of the time, compared to 41% of the time for vehicles without the system. The percentage of vehicles that were exceeding the speed limit on the approach to the intersection was also reduced from 41% to 23% with the system. For the traffic signal warning the rate of speeding on the approach reduced from 70% to 56%. For the crossing collision prevention application, the rate of 'crash unavoidable vehicles' reduced from 38% to 22%, though it is unclear what 'crash unavoidable vehicle' means (Fukushima, 2011).

A large scale field operation trial of V2V and V2I in 3,000 vehicles is currently being conducted by the University of Michigan Transportation Research Institute (UMTRI) on behalf of the US Department of Transportation. The UMTRI trial is using retrofitted V2V communications devices, which demonstrates that this technology can be retrofitted if required. The project appears to be ongoing at present with no results yet published (Rakouth et al. 2013; UMTRI 2014a). In April 2014, UMTRI announced that they plan to increase the number of vehicles in the trial to 9,000 (UMTRI, 2014b).

User acceptance of V2V and V2I technologies has been shown to be high. Green (2012) and Lukuc (2012) showed a high level acceptance of V2V amongst drivers in the US and that most drivers would be willing to pay at least \$250 extra for vehicles that had V2V systems installed. Results from the European Cooperative Vehicle-Infrastructure System (CVIS) project published by Kompfner (2010) showed a high level of acceptance from drivers for V2V and V2I systems, but drivers were less likely to want to pay extra for them. However, another study in Europe (SAFESPOT) published by Francano et al. (2010) showed a high level of acceptance for V2V technologies amongst 1,825 survey respondents, with 93% of respondents rating it as very useful (69%) or useful (23%). A slight majority in the survey thought that V2V should be mandatory, and the majority were willing to pay €150-350 for an entire system. A large field operational trial in Europe that is currently underway (Drive-C2X) has shown a high level of acceptance for V2V and V2I technologies (Malone and Rech, 2013).

Several studies have presented cost and benefit calculations. An early proof-of-concept study, branded the 'Vehicle Infrastructure Integration' (VII) program, was conducted in the US between 2005 and 2008 on V2I communications technologies (RITA, 2008). The study considered fourteen possible applications of V2I, of which four were related to safety (signal violation warning, stop sign violation warning, curve speed warning, and electronic brake lights). The study assumed a 25% efficacy for these applications. Overall, a benefit-cost ratio of 1.6 was calculated, and the safety applications contributed to 95% of the total estimated benefit of \$US 44.2 billion. The benefit-cost ratio was sensitive to the assumptions of efficacy. The same project continued into 2010 under the name 'Intellidrive' and was expanded to look at V2V as well, due to widespread availability of 3G and GPS technology (RITA, 2010), although no specific results regarding V2V could be found.

Luedeke et al. (2010) performed a cost benefit analysis that assumed a fleet penetration of 4.2% was required for V2V to have any benefit, and that covering 50% of roads with V2I infrastructure would cover almost all relevant crashes. For V2V, the benefit-cost ratio was 1 to 1.1 at fleet penetrations of 6.1-8.7%, and for V2I the benefit-cost ratio was 0.21 to 0.36 for penetrations of 5.4-9.5%. It was suggested that highly targeted infrastructure may achieve a benefit-cost ratio of one or higher for V2I.

Kompfner (2010) looked at a wide range of V2I and V2V technologies related to mobility, and one on safety (focussed on warning drivers of the traffic situation ahead). The safety technologies accounted for 93% of the total calculated benefit and a benefit-cost ratio of around 1.5 can be inferred from figures given.

A common theme of several research projects is the relationship between sensor based AEB systems and connected vehicle technology. The authors of a report on the US research project 'VSC-A' concluded that connected vehicle technology can address several known limitations of sensor based AEB systems and it is likely that vehicles will be equipped with both technologies (Ahmed-Zaid et al., 2011). The European 'PREVENT' project seeks to develop an electronic safety zone around a vehicle that would utilise both typical AEB sensors as well as connected vehicle technology (Schulze et al., 2008). The Japanese 'ASV' project also considered the relationship between the two technologies and stated that the desired role of connected vehicle technology was to cover events that would be invisible to a sensor based AEB system (Wani, 2006). Furthermore the 'SAFESPOT' project included a radar sensor in its system costing to match what was used at their test sites (Luedeke et al., 2010). The consensus among the research projects that did consider the relationship between sensor based AEB systems and connected vehicle technology is that connected vehicle technology will be used to complement a sensor based AEB system to provide a comprehensive collision avoidance system.

While there are yet to be results published from any large-scale V2V and V2I field studies, there appears to be overall a high level of confidence in the safety benefits of these technologies. The US Department of Transportation announced early in 2014 a commitment to taking steps to enable V2V communication technology for light vehicles, a decision enabled in part by the early results of the UMTRI pilot study (NHTSA, 2014a).

While V2V technology has no dependence on the surrounding infrastructure and may detect impending crash situations that AEB does not, it requires both vehicles involved in a potential crash to have the technology in order for the crash to be avoided or mitigated. This delays the usefulness of V2V; even if 50% of vehicles had V2V systems, it would only be useful in 25% of two-vehicle encounters.

2.3 Alcohol interlocks

An alcohol interlock is a small breath-testing device connected to a vehicle's ignition circuit. It measures the driver's breath alcohol level and prevents the driver from starting or operating the vehicle after drinking alcohol. Various technologies are now available.

Alcohol interlocks have generally been viewed as one of the sanctions against drink-drivers that are aimed at reducing the number of drink-driving offences and crashes. They may have other purposes, such as encouraging a long-term reduction in drink-driving by these offenders, contributing to the alcohol rehabilitation of these offenders, and reducing drink-driving in the general population (i.e., drivers who have not been detected drink-driving).

To achieve the last purpose mentioned, alcohol interlocks would need to be fitted to the vehicles of the general population. This could even be made mandatory for new cars to be fitted with an alcohol interlock. Regan et al. (2002) discussed the merits of several in-vehicle intelligent transport systems aimed at improving safety. According to the Executive Summary (p. xvii), "the Alcohol Interlock was predicted to lead to the greatest reduction in crash numbers and costs, preventing 906 crashes and saving \$263 million per year". Regan et al. had in mind a system that is in all vehicles, and assumed that the interlock is 96% effective in preventing all crashes where BAC exceeds .05. A presentation by Coxon (2005) was also optimistic about the benefits from having all vehicles fitted with interlocks. Recommendation 20 of the Inquiry into National Road Safety by the (Australian) House of Representatives Standing Committee on Transport and Regional Services (2004) was that an Australian Design Rule be introduced requiring alcohol interlocks on all new vehicles.

More recently, there has been discussion by (for example) Bailey et al. (2013, p. 5) and Radun et al. (2014) regarding the broader application of alcohol interlocks in new vehicles. Indeed, according to Radun et al. (2014), "More and more stakeholders, including the industry and politicians, directly or indirectly support an interlock as standard equipment".

The chief concern of the paper by Radun et al. is that a number of possible behavioural responses of individuals could reduce the effectiveness of such technology. They give some evidence to suggest that instead of abstaining from alcohol before driving, drivers may be more likely to drink and rely on the interlock to tell them whether they had exceeded the legal limit. They also give evidence that drivers may learn to circumvent alcohol interlocks. Radun et al. suggest that police may pay less attention to enforcing drink-driving laws once interlocks are installed on all new vehicles, although there is no evidence to back this claim. Their strongest points are perhaps that it is often many years before a technology introduced in new cars achieves high penetration of the total fleet; and that many hard-core drinkers (defined by Radun et al. as repeat offenders with a BAC over 0.12), who constitute a large part of the drink-driving problem, are not able to buy a newer car, or would avoid doing so in order to continue drinking and driving.

2.4 Lane departure warning systems

This driver assistance technology monitors the position of a driven vehicle within a lane and gives a warning to the driver when the vehicle is considered to have deviated significantly from within the lane. Utilising a forward viewing camera integrated with a central computer, image processing software technology identifies lane markings on a road or the edge of a road. The system establishes the vehicle position within the identified lanes and using steering wheel angle information and direction indicator use, the system can determine if the driver is unintentionally leaving the intended driving path. If this is the case, the driver will be alerted via audible, visual and/or tactile warnings so that driver corrective action can be undertaken prior to complete unintended lane departure. Advanced systems may also attempt to correct the situation by applying counter-steer to maintain vehicle lane position.

This technology may be relevant in as many as 8% of crashes (Farmer, 2008). Gottselig et al. (2008) found it might be relevant in only 4% of cases and the trauma reduction might be much less than this, consistent with Paine et al. (2008) who suggested a 2% reduction in trauma. More recent studies (Jermakian, 2011) indicate that this technology may have been relevant in as many as 179,000 crashes per year including 7,529 fatal crashes and 37,000 non-fatal injuries per year in the US for the 2004 - 2008 crash period. Anderson et al. (2011) estimated fatality reductions of 7% (100 fatalities) and 4,177 non-fatal injury reductions for lane departure warning systems.

One issue around lane departure warning systems is that of false positives: user acceptance is reduced when false positives are more common (Johnson, 2008) and thus if the system can be manually disabled, a high rate of false positives may lead to drivers switching it off.

2.5 Fatigue warning system

The intention of fatigue warning systems is to monitor and assess a driver's level of alertness and give warning when this is determined to have degraded beyond a threshold. This can be done directly, with technology that monitors eyelid movements of a driver, particularly the length of time over which they are closed, a longer period generally indicating

higher fatigue levels. An infra-red camera and image processing technology is used to measure 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 the 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 and assess steering wheel movements and speed of steering movements. A baseline level of driving performance is established when the driving task first begins and is continuously monitored as the driving duration increases. This allows the system to detect degradation of driving performance through erratic steering or significant deviations from the baseline driving performance and indication of potential fatigue and alert the driver. 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. These systems may be limited to vehicle travel speed thresholds: fatigue warning systems such as Mercedes-Benz Attention Assist are active between speeds of 80 km/h and 180 km/h although recent enhancements on some vehicles (Mercedes-Benz S and E Class) allow a wider speed range of 60 km/h to 200 km/h (Daimler, 2014), and Subaru have a system that only operates at a vehicle speed of approximately 60 km/h or more (Subaru, 2014a).

There is an underlying responsibility of a driver to take action (e.g. a rest break) once a vehicle detects the fatigued state of a driver. Therefore, any effectiveness of such a system in alerting a driver that they might be fatigued may be considered independent of the effectiveness of such a system in preventing crashes. Euro NCAP (2014) suggest that "... even modest assumptions regarding the numbers who are likely to respond [to a warning and take appropriate action] leads to an estimation that a system like Attention Assist [a Mercedes-Benz system] could prevent 1,875 injury accidents involving a passenger car every year in Europe."

Results of a closed-track overnight driving experiment by Vincent et al. (1998) 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% reduction in crashes. Paine et al. (2008) judged that this technology might lead to a trauma reduction of 2%.

2.6 Seat belt interlocks

Seat belt usage can be monitored via sensors in both the seat belt buckle and the seat itself for one or all seating positions. Seat belt reminders are common in new vehicles and will display visual and/or auditory warnings if any occupants are detected and their seat belt remains unbuckled above a vehicle speed threshold. Seat belt interlocks are stricter than this: should a driver (or any occupant) be detected and a seat belt remain unbuckled during an attempt to start the vehicle, a seat belt interlock will prevent vehicle operation until all detected occupants are wearing seat belts. Seat belt reminder systems are likely to increase seat belt wearing rates without requiring a full interlock, but some users may still choose to ignore a reminder and thus interlock systems may play a role in further increasing seat belt use.

A seat belt interlock is both an old technology and future vehicle technology. Seat belt interlocks rose to prominence in the US in 1974, where they were made mandatory on all new vehicles. Despite surveys beforehand that indicated high levels of public acceptance, and increased belt usage for the vehicles with seat belt interlocks, they were widely criticised and after one year were no longer mandatory (Perel and Ziegler, 1971; Robertson, 1975).

Since the US experience of 1974, few studies have tried to evaluate the effectiveness of seat belt interlocks. Van Houten et al. (2005) showed increased rates of seat belt wearing in a small sample of five van drivers that did not habitually wear seat belts. Turbell et al. (1996) suggested a strong benefit of seat belt interlocks, with a benefit-cost ratio of 100:1. An analysis by Searson and Anderson (2013) suggested that fatality rates in South Australia could be reduced by 2% and serious injuries by 7% by 2030 if seat belt interlocks were made mandatory from 2015 onwards.

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

2.7 Automatic collision notification

While not a new technology, for all intents and purposes this technology is still emerging. Automatic collision notification (ACN) systems are able to reduce the delays associated with the notification of emergency medical services following a serious crash. Additionally, ACN overcomes issues related to conveying a crash location. This technology is "...designed to detect the involvement of a motor vehicle in a crash, to obtain information about the severity of the crash where possible,

² Under ideal conditions. This system may not be effective under poor lighting, poor visibility, adverse weather conditions or where lane markings may be missing or in poor condition. Additionally, the technology is only applicable or functional when travelling above a speed threshold, for example 40 mph (Jermakian, 2011).

and to notify emergency response personnel either automatically or through a response centre.” (Austroads, 2004, p. 2).

A basic ACN system consists of a programmed vehicle electronic control unit (ECU) consisting of a GPS and cellular communication system (generally part of a broader telematics system) connected to an external antenna and an airbag ECU.

Three key basic mechanisms of an ACN system are collision detection, location identification and subsequent notification of the collision and location. Sophisticated supplementary vehicle safety systems exist in most new cars today that enable detection of collisions of sufficient severity that warrant deployment of the required safety system (airbags, seat-belt pre-tensioners etc.). Location information and communication of this information can be enabled through an integrated in-vehicle telematics system and monitored by a telematics service provider (as described in Ponte et al., 2013a) or alternatively through Bluetooth smartphone interaction (for example Ford’s “SYNC® Assist”, see Ford, 2011).

A number of studies have examined the potential effectiveness of such a system. Clarke and Cushing (2002) estimated fatality reductions in the US of between 1.5% and 6%; most recently Wu et al., (2013) found there would be a 1.8% fatality reduction in the US with earlier crash notification. Sihvola et al. (2009) estimated that 3.6% of all fatalities or 4.4% of vehicle occupant fatalities in Finland would probably have been avoided with eCall (European equivalent of ACN). Chauvel and Haviotte (2011) examined crashes involving vehicles that were currently already fitted with eCall in France, related it to the fatalities in France in 2009 and estimated that eCall would have resulted in a 2.8% reduction in fatalities in France. In South Australia for the period 2008-2009, Ponte et al., (2013b) estimated that an effective fully deployed ACN system may have resulted in a reduction in all fatalities of around 2.2% or a reduction of 2.8% for passenger vehicle occupant fatalities.

2.8 Following distance warning/adaptive cruise control

Following distance warning systems generally comprise a laser/radar or camera attached to the front of the equipped vehicle that 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 time or distance 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.

Adaptive cruise control uses a similar hardware arrangement to the following distance warning system. Using information from this hardware system, combined with data from the vehicle speed sensor, the adaptive cruise control system can be used to determine approach speed to the car ahead. The system then decides if it is safe to continue travelling at the pre-set cruise speed or whether brake application is required 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 pre-set cruise speed (Marsden et al. 2001).

Paine et al. (2008) judged that following distance warning technology might lead to a trauma reduction of 2%, as well as estimating a 1.5% reduction for adaptive cruise control. For heavy vehicles, Murray et al. (2009) estimated benefits of following distance warnings coupled with adaptive cruise control in heavy vehicles in the United States. They thought industry estimates of effectiveness of between 21% and 44% for heavy vehicles striking other vehicles in rear end crashes to be credible. The estimate of 21% 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.

Forward collision mitigation technology came top of the list of five technologies considered by Farmer (2008) using crash data from the US. The criterion used was the number of crashes potentially prevented. Farmer considered that this technology is potentially relevant to 38% of crashes. Gottselig et al. (2008) came up with a lower figure, 10%, 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 these studies, and summed up by saying that “Preliminary research results indicate a significant benefit in terms of decreased number of collisions”.

2.9 Lane change assist warning and blind spot detection systems

This technology is able to detect the presence of other road users alongside a vehicle, through the use of RADAR, SONAR or video cameras and image processing technology. Combined with information from a number of sensors (e.g. lateral acceleration, steering wheel angle, indicator usage), 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 to their presence via an audible or visual response, allowing enough time for corrective action to be taken. Sensors or cameras are usually located on the side of the vehicle. One system installed on a Porsche Cayenne has radar sensors located in

the corners of the rear bumper and covers the majority of the blind spot region as well as the driving lane and left and right hand neighbouring lanes to a distance of up to 70m behind the vehicle.

Paine et al. (2008) judged that this technology might lead to a trauma reduction of 0.5%. Gottselig et al. (2008) found that this technology might be relevant in 1% 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 cyclists. As a result, the actual effectiveness of this technology would be much less than 1%, so their findings are consistent with the 0.5% from Paine et al. Visvikis et al. (2013) estimated an effectiveness of between 0-60% for lane change warning systems fitted to light passenger vehicles based on a UK study. Anderson et al. (2011) estimated fatality reductions of 1% (35 fatalities) and 4288 non-fatal injury reductions for lane change warning systems.

2.10 Reversing visibility systems

Reverse collision warning systems utilise either a rear-mounted camera that provides visual assistance to a driver while reversing, or rear-proximity sensors (using ultrasound or radar) that detect obstructions behind a reversing vehicle and provide an audible alert varying with increasing proximity to a detected obstruction. Some vehicles utilise a combination of visual and proximity systems and it was initially believed that combinations of such systems were likely to be most effective (RTA, 2005). While designed primarily as a parking aid, this technology was suggested by Henderson (2000) as having the potential to reduce backover or reversing collisions with vulnerable road users, particularly children in driveways.

The National Highway Traffic Safety Administration (NHTSA, 2006) found that proximity based sensors (ultrasonic and radar) were not so effective in detecting child pedestrians behind a vehicle, and were limited in preventing collisions under various combinations of reversing speeds, system detection ranges and available stopping distances. This was also highlighted by Paine et al. (2003). A recent study by the Insurance Institute for Highway Safety (2014) found that camera systems in isolation were more effective in reducing backover crashes with simulated pedestrians than proximity sensors in isolation. Further, camera systems alone were more effective than combined camera/proximity systems. However, the effectiveness of camera systems are limited by camera performance, lighting and weather conditions (NHTSA, 2006).

Very little data exists on the effectiveness of reverse collision warning systems, however NHTSA (2014b) have issued a final rule for a Federal Motor Vehicle Safety Standard for Rear Visibility. This standard specifies the area behind a vehicle that must be visible to a driver when reversing (as well as related performance requirements), and will apply to all light passenger vehicles³ manufactured on or after May 1, 2018. It is expected that camera based systems will be designed to meet this final rule. NHTSA (2014b) report that 210 fatalities in the US are attributable to backover crashes involving light vehicles and with full deployment of backover technology (expected by 2054) resulting in 58 to 69 (28% to 33%) lives saved. Better visibility or detection of objects behind a reversing vehicle is likely to be effective in preventing backover collisions. However, the effectiveness is reliant on both system performance and the driver's response to information provided by the systems.

Future technologies that incorporate vulnerable road user detection and autonomous emergency braking while reversing may be more effective in preventing backover collisions, although there is little information available on such systems. That being said, car maker Infiniti have now incorporated "Backup Collision Intervention™ System" (Infiniti, 2014), that automatically intervenes when a driver fails to acknowledge information provided by the vehicle's reverse warning system (not specific to vulnerable road users). An aftermarket product "Reverse Alert" (Reverse Alert, 2013) is a sensor based automatic braking system that has been designed to detect obstructions behind a reversing vehicle and automatically brake a vehicle (targeted toward protecting vulnerable road users). Finally, Bosch Australia is currently developing a backover avoidance system for vehicles (Bosch, 2013; Devic, 2014).

2.11 Improvement to brakes and tyres

Although it may seem out of place to mention brakes and tyres in a report about new technologies, not all braking systems are equal, and advances in braking and tyre technology could bring about notable reductions in crash speeds. Tyre technology improvements are largely incremental with improved and more efficient compounds being continually made available. Advanced braking may be considered alongside AEB: most methods proposed for testing AEB systems test the whole vehicle, and thus are sensitive to the braking system and tyres as well as to the AEB system.

³ Passenger cars, trucks, passenger vehicles, buses, and low-speed vehicles with a gross vehicle weight of less than 10,000 pounds.

There were several relevant papers at the 23rd Enhanced Safety of Vehicles (ESV) Conference that discuss these improvements:

- The importance of the braking system is emphasised by Eckert et al. (2013, p. 7). In a scenario of stopping from 41 km/h for a pedestrian 18 m in front of a vehicle, three braking systems were considered. The first was a current 'standard' braking system (Continental MK 100 2PP) that resulted in an impact at 24 km/h. The second was a current 'premium' braking system (Continental MK 100 6PP) that resulted in an impact at 15 km/h. The third was an unreleased 'advanced' braking system (Continental MK C1) that avoided the impact altogether. The MK C1 braking system achieves faster braking by integrating the components for brake actuation, brake boosting and control systems for ABS and ESC into a single unit (SAE, 2012).
- Hayashi et al. (2013) also emphasise the importance of the braking system.
- Eckert et al. (p. 7) and Chauvel et al. (2013, Table 1) consider that deceleration of up to 10 m/s² (much greater than figures around 7 m/s² that used to be quoted) may be achievable in emergency braking, and this was indeed the case for some vehicles in the tests reported by Hulshof et al. (2013).

The data presented by Eckert et al. (2013) suggested that an advanced braking system might be able to improve on today's standard systems by 0.19 seconds. If, because of improved brakes, deceleration at 10 m/s² is achieved 0.19 seconds earlier than otherwise, impact speed is reduced by 1.9 m/s. That is 10% for an impact at 19 m/s (68 km/h), and the probability of death might be reduced by 30% of what it would otherwise be.

2.12 Night vision enhancement

Night vision for drivers can be enhanced through the use of a forward facing infrared sensor attached to the vehicle. Either a passive or active sensor is used depending on system requirements. The passive sensor detects ambient infrared levels and has a potentially longer detection range whilst the active sensor, designed to pick up reflected infrared 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.

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 around how the infrared images were presented to the driver and whether or not a driver would be able to identify real world objects based on the infrared image. They suggested that infrared systems might work best when they identify relevant and necessary information, instead of just enhancing general visibility. There have been demonstrations that such a system does lead to earlier detection of hazards in test conditions (Mahlke et al., 2007).

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%. There is also 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.

2.13 Encouraging early adoption

There is some optimism about the effects that future vehicle technologies will have. Consequently, the question arises, how can accelerated introduction of these technologies into the total car fleet be promoted? Retrofitting of many technologies is unlikely to be technically feasible.

The question of accelerated introduction has two parts to it: how can quick introduction of any new safety technology into new cars be encouraged and how can turnover of the fleet (introduction of new cars and scrapping of old cars) be encouraged? Tools available to the government can mostly be classed as either monetary (taxation and subsidy) or regulatory (compulsion). Advocacy groups such as ANCAP, motoring organisations and insurance companies also have an influential role in encouraging early adoption of vehicle safety technologies. This is achieved through consumer testing programs, fleet purchasing policies, publicity, lobbying and insurance schemes.

Advertising campaigns have been run in the past to publicise the need for vehicle safety features, and these may be an effective means to communicate with vehicle purchasers. For example, the Victorian Transport Accident Commission (TAC) ran a campaign in 2009 to promote purchasing used vehicles that had ESC and side curtain airbags (TAC, 2014). The various ANCAP "Stars on Cars" marketing programs conceived in Western Australia and Victoria in 2008 and 2009 and in South Australia in 2011, appear to be associated with increased sales of ANCAP five-star cars (Leyson, 2013). Given the increasing requirement for vehicle "safety assist technologies" under the ANCAP Rating Road Map (ANCAP,

2012), it follows that promoting ANCAP five-star rated cars, concurrently promotes vehicle safety technologies.

A safer vehicle campaign promoting ESC in regional and remote areas of Western Australia during various periods of 2012 and 2013 was evaluated by Painted Dog Research (2013). The authors reported good levels of campaign message awareness (12% unprompted awareness and 77% prompted awareness). Additionally, Painted Dog Research (2013) indicated a positive impact on vehicle purchasing behaviour intentions – of those who saw the campaign 71% said they were more likely to choose a vehicle with ESC when considering their next vehicle purchase.

The Department of Infrastructure and Regional Development (2013) highlight a real-world advertising campaign by Mitsubishi, for the 2008 Outlander, which focussed on ESC as a standard feature; there was a 9.1% increase in sales for the month of February. The authors attributed this increase to the promotional campaign.

Tingvall (n.d.) indicated that ESC was the most effective vehicle safety system second to seatbelts. ESC has had the fastest penetrations of a new vehicle technology and this was achieved particularly by stimulating the market (Tingvall, (n.d.)). Furthermore, Lie (2005) states “Consumers should be recommended to buy cars with ESC, and automotive industry should only market cars with ESC as quickly as possible. Such a policy statement has increased the fitment rate on new cars in Sweden to almost 70% in less than two years”. It is possible that similar approaches for promoting emerging technologies could also increase uptake in new vehicle sales.

Fleet purchasing policies can influence proliferation of safer vehicles. In South Australia, the Government has mandated ANCAP five-star passenger vehicles for the state Government passenger vehicle fleet (Government of SA, 2011). Additionally, BHP Billiton has documented in their ‘fatal risk controls’ to ‘transition all light vehicles to a 5 Star NCAP safety rating by 01 Jan 2016’ (BHP Billiton, 2012). These purchasing policies inevitably influence the general fleet composition.

It is important to emphasise that the total market for cars, old as well as new, is large and complex and a simple policy is likely to have a number of effects. Sales of new cars with a technology are competing with sales of both new and old cars without the technology. A total policy of subsidy, taxation, and compulsion needs to be carefully designed if it is not to have unintended consequences. For example, subsidy of new car sales with the technology would tend to reduce the demand for all cars without the technology. However, when demand falls, price also falls, tending to check the fall in demand. Thus it is not clear to what extent a subsidy will influence the market demand for cars without the technology. Previous subsidy schemes, encouraging “greener” cars have been implemented overseas (e.g., Lane and Potter, 2007; Borthwick and Carreno, 2011).

It is also worth noting that if some future vehicle safety technology were to be very effective, then a strong policy intervention might be justifiable. Consider a technology that is 20% effective at preventing deaths and injuries. For such a technology, every year of delay in its introduction will cost, over the lifetime of vehicles sold in that year, 20% of the annual crash costs. Crash costs in Australia are roughly \$25B per year (ATC, 2011, p. 4), and thus each year of delay in introducing such a technology will cost around five billion dollars. While only a rough calculation, it demonstrates the significant crash cost savings that are possible from a technology such as AEB, which may have an effectiveness of around 20% (See Section 2.1).

3 Consultation

The purpose of the consultation was to obtain expert views about the uptake and potential of the various new and future technologies. Topics included most promising technologies, implementation issues, time frame, limitations, and opinions on future technologies, 20-30 years from now.

This section summarises the key points arising from the interviews, with an additional focus on autonomous emergency braking (AEB) and vehicle-to-vehicle Technology (V2V).

3.1 The experts interviewed

Interviews were conducted with a wide cross-section of experts from the automotive industry and related organisations. In total 16 interviews were conducted, with nine Australian-based experts and seven international experts:

Table 3.1 Interviewees by expert category

Expert category	Australian	International
Vehicle manufacturing industry *	3	-
Automotive safety technology/parts supply industry	1	1
Automotive communications industry	2	-
Consumer vehicle testing programs	1	1
Government institutions	1	1
Automotive insurance industry	1	1
Academic/research institute (universities)	-	2
Research institute (non university)	-	1

3.2 The interview structure

The questions were consistent across all interviews, with the exception of the initial 'pilot' interview. The aim of the questions was to encourage discussion about the technologies and the questions were not asked in a way that encouraged precise answers (for example, about the number of years before a technology provides a benefit). There was a generally open-ended and informal tone to the interviews.

The full interview script is available in Appendix B.

3.3 Summary of responses

The first question was designed to elicit responses from the experts regarding safety technologies that were forthcoming in new vehicles in the short term (5 to 10 years), that they perceived would most likely have the greatest impact on road deaths and injuries. There were 12 categories of technologies that were mentioned by more than one expert:

- Autonomous emergency braking (AEB)
- Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications
- Driver drowsiness/fatigue, distraction, or failure of concentration: detection and warning/intervention
- Alcohol interlocks
- Adaptive/advanced cruise control
- Warning/intervention (lane keeping/departure, blind spot, speed relative to speed limit, reverse collision systems)

- Advanced lighting systems
- Autonomous vehicles
- Autonomous braking when reversing
- Automatic collision notification
- V2P: Vehicle-to-pedestrian communication systems
- Night vision

The responses were wide-ranging and there was significant variation of opinion regarding which technologies were the most important and their timeframe for introduction. The experts made several suggestions on the best ways to accelerate take up of these technologies including government regulation, consumer information and reduced insurance premiums (discussed further in Section 3.3.2). Despite this variety of viewpoints, several common themes were present, in particular concerning AEB and V2V.

Nine types of technologies were only identified by a single expert as having a potential for significant impact on road deaths and serious injuries, these were:

- Feedback on risky behaviours and environments
- Vehicle prognostics (avoiding breakdowns in bad places)
- Better awareness of road and traffic conditions
- Seat belt interlocks
- Advanced whiplash protection
- Pedestrian airbags
- Rear seat safety
- Cap or hat that protects a pedestrian's head
- Technologies to reduce occupants' rotational head injury

The international experts were more likely to discuss vehicle monitoring systems and probably were more likely to mention things Australian experts had not considered (e.g. advanced lighting, advanced steering systems). This may be because they already have high market penetrations of other technologies such as AEB, so they are looking even further forward to the next technology.

Australian experts had higher levels of optimism of AEB and V2I systems and this optimism may be based on the anticipated potential of these systems. Europeans were more likely to be cautious, possibly based on what they have observed in relation to the performance of current systems (in tests or in the field). In particular, European experts expressed concerns about varying levels of performance of AEB systems, specifically those that do not work above a threshold speed. Based on recent literature, these concerns may be justified (Husholf et al. 2013, Ando and Tanaka, 2013).

Some experts suggested that there is a lack of (acknowledged) Australian-specific research that would provide manufacturers with justification for the installation of emerging vehicle safety technologies and that there is a tendency for Australia to rely on technologies filtering through from overseas some time after their introduction.

A few Australian experts mentioned technologies that can prevent driveway reversing accidents. These technologies are relevant in an Australian context given the high profile nature of driveway deaths in Australia. On average, seven pedestrians aged 0-14 years were killed each year between 2001 and 2010 (BITRE, 2012) and it is estimated that every week in Australian driveways one child (usually a toddler) is run over (CARRS-Q, 2011).

The following sections discuss issues raised in the interviews about the technologies highlighted by the national and international experts. Some additional comments are also provided regarding the two technologies considered most promising by the experts. A summary of the interviews is provided in Appendix C.

3.3.1 Time frame until measurable benefit

Most experts believed that it would take many years to achieve the benefits of the new technologies. Most of the technologies were some years away from initial introduction and consequently would then be some years before the technologies became common in new cars. There would then be a further ten years or so before it became common in the total fleet. There was some optimism about AEB, which is still an emerging technology, as well as drowsiness-monitoring technologies which have been in development for quite some time but are only now being fitted to new vehicles.

The term 'measurable benefit' was interpreted differently by various experts. Some stated that the benefits of safety technologies were immediate for the owner of a vehicle with a particular safety technology. One respondent believed that with AEB a benefit might be gained within as little as two years. Another expert said, "Airbags and ESC and the market penetration of these technologies provide a good guide to any future benefit of emerging vehicle technologies. In 1992 Australia first had airbags, and now we are at pretty much 100% of new cars sold. ESC has gone from concept to almost 90% of new cars sold, quite quickly, another model for the introduction of a safety technology".

The same expert indicated that "For society it is dependent on penetration, penetration is based on three key players: the vehicle manufacturer (they have to provide the technology), the government (need to regulate the technology or regulate the need for it) and the consumer (they can choose to buy it when it's made available by the manufacturer, or they can wait until it's a standard feature, either by manufacturer goodwill or encouraged by ANCAP or by Government regulation)".

3.3.2 Accelerating uptake

The experts highlighted a number of mechanisms for accelerating the introduction of various technologies. These included Government regulation and increased action by consumer advocacy groups (NCAP). Financial incentives were also highlighted as a potential method to accelerate the introduction of technologies. This could be achieved by comprehensive insurance premium reductions⁴ or reductions in registration fees.

One expert indicated that accelerating uptake could be achieved by increasing fitment in the highest selling vehicles "... fit [AEB] to the most popular or highest selling cars, e.g. Corolla, Mazda3⁵ and i30, this would push massive numbers of this technology into the market."

Some experts highlighted the importance of influencing fleet vehicle buyers and encouraging this group to require fitment of safety technologies. Smart marketing campaigns and promotion of safety technologies to consumers of vehicles were also highlighted by the experts. One expert indicated that we "can accelerate the take up of technologies by heavily promoting it to consumers, either by educating consumers about the technology or promoting vehicles that have it already, there needs to be an awareness of the technology among consumers."

Technologies that can be retrofitted may achieve benefits sooner, but there was little optimism about the practicability of this. Warning or advisory systems were seen as more feasible for retrofitting, but were not seen as effective as intervention systems.

3.3.3 Limitations and potential negative impacts of technology

A number of the respondents pointed out that despite numerous benefits of safety technologies, there are also some limitation and negative consequences. The limitations can be classified as technical, human, socio-economic and legal.

Technical limitations included the limited ranges and applicability of sensors used for AEB. It was noted that some conflict situations and vehicle speeds are beyond the capability of current sensors. Systems relying on GPS positioning (eg. for V2V, ISA) are subject to the inherent limitations of GPS accuracy. Issues relating to reliability of safety systems were also highlighted. Some systems may be limited to certain ideal conditions (fine weather, daylight, sealed roads, no sudden impositions etc.) whereas the biggest benefits are more likely in adverse conditions.

A number of human limitations were identified, particularly regarding drowsiness, fatigue, lack of alertness, and inattention. These behaviours are complex to predict and monitor and technologies for monitoring driver condition may be prone to failure. Warning systems also have the limitation that if there are false positive warnings, the driver may become habituated and ignore the signal, or even switch off the technology if the warnings are annoying.

The human machine interface (HMI) was highlighted as an issue, as drivers must be able to understand various safety systems and then acknowledge, interpret and react correctly. There was also concern with information overload, bombarding drivers with information, warnings and false detections that may divert driver attention from the primary task of driving. With regards to warning systems, one expert pointed to research they had undertaken "... that found people don't always make the right response when appropriate warnings are given".

⁴ A 20% premium reduction on Comprehensive Motor Insurance was offered by Allianz Australia at the launch of the Subaru Eyesight, a system incorporating many new safety technologies. NRMA insurance also offered a 20% reduction on insurance premiums for Volvo's City Safety system.

⁵ Enhanced safety features are available on all 2014 Mazda3 models as an optional, additional cost safety pack which includes smart city brake support (a low speed AEB 4 – 30 km/h), blind spot monitoring system and rear cross traffic alert (Mazda, n.d, Mazda Global, n.d).

Additionally, overreliance on the various technologies or complacency was also highlighted as a potential issue. A related issue to this was 'driver adaption', in that people may push the boundaries of these devices once they become familiar with them.

Another highlighted risk was that safety systems might not work as intended. For example even with a fatigue monitoring system, drivers would still need to self-regulate.

A major current socio-economic limitation is cost. Many experts saw the cost of new technologies as an important barrier to their introduction. A number of safety systems already exist in Australia and can be found in relatively low cost vehicles (for example the base model Mazda3 has low speed AEB as an optional extra). However, the experts suggested that new technologies are often only found on higher specification or prestige/luxury models of vehicles. These vehicles are generally not accessible to society in general. It may be noted that the core functionality of AEB (for example) is that braking is applied in an emergency, and this functionality may never be used: many people drive a car for decades without getting into an emergency situation. However, paying for something that may never be useful is familiar from many established safety technologies, such as seat belts. This issue was also highlighted by one expert who indicated, "... of all the vehicles in Japan only 0.3% of vehicles will ever have an airbag deployment".

There was concern about liability and litigation with implementing vehicle technologies. This included issues such as systems being imperfect or not working as intended. For example, one expert stated that "some of these technologies are imperfect and won't be perfect for years, and liability is something that everyone wants to avoid". Responsibility and liability was also raised as a concern, technologies are designed as 'driver assistance systems', hence the driver should always be responsible. Hacking of V2V and V2I systems was mentioned as a danger in addition to privacy concerns regarding wireless communications.

There may be specific opposition to technologies that attempt to control drink-driving and high speed. One expert acknowledged, "consumer resistance, especially for alcohol monitoring. It is a relatively small group who are drinking and driving. We need to target them but we do not want to inconvenience those who are doing the right thing as well." Another expert indicated that for some technologies there may be a "Driver's perception that it is taking control away from them".

3.3.4 Infrastructure requirements

Generally it was thought that few modifications to infrastructure would be required except in the case of V2I technology, which is heavily reliant on communication infrastructure changes. Some technologies will require supporting communication or road infrastructure. Some safety technologies rely upon ideal conditions, infrastructure changes that could improve conditions (e.g. improved lighting, enhancing of road edges) were considered important, particularly for vehicle guidance systems. Several experts highlighted the need for good delineation markings and good road contrast.

Consistency and clarity of signage was also highlighted as important. Two experts indicated that traffic sign recognition systems needed to present standard and consistent information to function correctly. One expert said that "A major manufacturer introduced a device that could read speed signs – however this did not work in Australia because of inconsistencies in signage. Signage should be standardised with other markets, otherwise manufacturers will delete such capabilities from their vehicle models." Another expert gave the example of speed signs on the back of trucks confusing a sign recognition system in the following vehicle. (While we are unable to validate these statements regarding Australian speed sign detection, the Ford Kuga may be an example of a vehicle that only has this capacity in Europe due to signage consistency: see Cartwright, 2013).

For V2I and V2V communication, infrastructure was highlighted as being very important. The experts suggested that there is a need for government commitment to communication infrastructure and that they need to regulate the communication frequencies. A recent Austroads report also suggested a frequency be reserved for future use (Austroads, 2013). One expert summarised two core issues: "Having infrastructure that produces data that can be 'published', this has to be made available by transport authorities. Infrastructure must be in place to broadcast suitable content".

3.3.5 Impediments to adoption

The cost of new technologies was seen as an important barrier to their introduction. One expert indicated that the Australian vehicle market was large and overcomplicated. "There are too many makes and models on Australian roads, there are about 50-60 makes and hundreds of models and variants. This is too many for a total market of one million or so cars per year. The market here is also very price sensitive, and so safety features are often removed to sell cheaper models".

The economic climate was also highlighted as an issue: "The market is in recession in Europe, people are not buying new vehicles as often. Or if they do, they go for budget models for maximum size at the lowest cost. This is a big challenge, as these budget models may be 10 years behind in terms of safety".

Public awareness was highlighted as an impediment to the adoption of new technologies, it was considered important to make “consumers more aware of the technologies they need in vehicles”.

3.4 AEB – additional comments

As mentioned earlier, Australian experts had higher levels of optimism for AEB compared to overseas experts, who were more likely to be cautious. This is perhaps on the basis of current deployment rate differences. In Australia, approximately 5% of new light vehicles were sold with a pre-crash/collision safety system (POLK, Sep-Dec 2013) compared to Japan and Sweden where experts have indicated deployment rates of around 50% of new vehicles sold. (The figure for Australia may increase slightly now that AEB is an optional feature for the 2014 Mazda3.)

Market specific research appears to be necessary to justify a vehicle technology to be incorporated in specific vehicles. One expert said “Automobile makers consider supporting evidence or research to decide if a country needs a technology they have on offer. In Japan for example, AEB would be considered necessary. In China, due to high population and numbers of fatalities, it would also be considered important”. Another expert said “We can’t put every feature in every car, but when you do select the features it would be great to be able to weight them according to what impact they have”.

Australian experts also acknowledge the difference in deployment of AEB between Australia and Europe, (regarding timeframe before AEB has a measurable benefit) saying “It’s already filtering into the fleet. Europe has taken it up faster. ANCAP is pushing manufacturers to include it. From 2014, Euro NCAP will require AEB for a 5-star rating (essentially). ANCAP take up will be slower but AEB will soon be required for a 5-star rating.” The importance of reverse AEB was also mentioned several times by experts.

3.5 V2V – additional comments

Vehicle-to-vehicle (V2V) was mentioned frequently in interviews but since the technology is still in its infancy, respondents were generally unsure of the timeframe for the introduction of V2V and the details of how it might work. V2V was often mentioned as something “beyond a decade” away, or as something that might not be beneficial for 20-30 years.

There was a higher level of optimism about V2V from Australian experts: one respondent suggested that V2V would find its way into vehicles within two years, another suggested that it might begin to appear within 7-10 years.

One of the impediments identified about V2V (and also for V2I) was the need for consistent communications protocols. This would require leadership from the road safety community and government policy. One Australian expert suggested that we might end up following the lead of the US, who are conducting large-scale trials and are moving forward with implementing V2V. A US expert confirmed that a large-scale trial in Michigan has recently been completed and that data analysis is currently taking place.

Another potential limitation discussed for V2V and V2I was the current accuracy of GPS systems in Australia. This would need to be vastly improved in order for these systems to work effectively. One expert suggested that Australian GPS technology currently relies on international satellites whose positions are optimised for other countries, although we are unable to find any information to suggest that this is truly the case, as GPS relies on satellites that are equally spaced around the globe.

One expert from Japan mentioned the need for V2V to be installed in all vehicles of all sizes, including very small vehicles and very large vehicles.

3.6 Future technologies

The experts were asked about the technologies that they thought would be available in new vehicles in the very long term (20 to 30 years). The technology most mentioned, that would have the greatest impact on road deaths and injuries, was autonomous driving technology. This included either fully autonomous or partially autonomous systems. Such autonomous driving technologies would be introduced for both convenience and safety.

Some experts still considered V2V and V2I a long-term future technology, or that V2I and V2V may be a part of more holistic autonomous driving experience where different technologies complement and interact together rather than functioning independently.

The experts generally expected great improvements in road safety over the next 20 to 30 years. Some responses were

very optimistic, for example: cars may become “uncrashable”, there will be “effectively no people killed on the roads”, and “we can wipe out 80% of avoidable collisions”. Others were not as optimistic but still positive about the future of these technologies.

Some respondents suggested that fully autonomous driving could never be possible, as a human driver should always be ready to take control. It was also noted that there would be legal issues surrounding autonomous driving, in terms of responsibility for an accident (would it lie with the driver or the vehicle manufacturer) and also in terms of whether, legally, a human driver needs to be in full control of a vehicle at all times. Some respondents suggested that fully autonomous driving would only be likely to occur on highways, where the traffic system is well defined. One respondent suggested that drivers would control the vehicle’s steering and the vehicle would autonomously control its speed.

A respondent noted that Volvo would soon be releasing vehicles that could autonomously steer, brake and accelerate at speeds of up to 50 km/h. Several respondents also noted recent developments by Volvo (and possibly other manufacturers) into ‘platooning’ technologies that enable several vehicles to sit very close behind a truck for a long journey, in order to save fuel.

There were some other more subtle points raised by the experts that are worth mentioning, in regards to future technologies:

- Narrower lanes may be feasible with autonomous vehicles and vehicle guidance technologies (this may increase road capacity).
- Car travel may diminish with increases in cheap air travel.
- Driver behaviour may be monitored and linked to insurance costs – e.g. drivers that regularly drive over the speed limit may experience higher insurance premiums.
- The whole system of vehicle ownership may change, for example through car sharing systems.
- Other technologies that are important are those that help drivers to personalise their vehicle – e.g. seatbelts that adopt your characteristics for the elderly and children.

4 Analysis

Based on the literature review and interview responses, an analysis was performed on the impacts of two technologies that are likely to have a significant benefit in the short and medium term future. These two technologies were AEB and V2V communications.

AEB was selected as it was identified by every interviewee as being likely to have a significant benefit over the next five to ten years. Based on our literature review, it seems likely that this will be the case, and that the benefits of AEB are potentially large. Previous research from CASR has estimated the effectiveness of different AEB systems based on computer simulations of real crashes (Anderson et al. 2012).

V2V was selected as many interviewees identified it as a technology that may have a significant effect in the longer-term future. In the US, there are serious efforts underway to develop standards for V2V. Although there are no results from long term trials that confirm the promise of V2V, early research is promising and it is likely that V2V may fill the 'gaps' left by AEB by providing emergency braking that avoids or mitigates crashes.

Since previous CASR studies have already estimated the effectiveness of AEB and V2V (Anderson et al., 2012; Doecke & Anderson, 2012), the focus in the present study was on how the rate of penetration into the vehicle fleet would affect the future benefits of these technologies. Thus the aim of our analysis was to determine the year-by-year reductions in fatalities and injuries for crashes occurring on Australian roads due to future rates of introduction of AEB and V2V technologies into the fleet.

4.1 Method

A previous CASR study looked at the potential effectiveness of AEB, based on computer simulations of crashes that had been investigated in-depth (Anderson et al. 2012). In that report, different sensor and braking parameters were used to estimate AEB effectiveness by crash type and speed zone, and then these were aggregated into overall effectiveness estimates.

Since then, an unpublished study conducted at CASR performed a similar analysis but for V2V communications (with braking interventions). The simulations performed by Anderson et al. (2012) were rerun, and the effects of V2V were accounted for by enhancing the capabilities of the 'sensor' to represent the performance of a hypothetical V2V system.

As the same simulations were used, the benefits of V2V were determined both in isolation, and in addition to an AEB system. For the analysis, it was assumed that any vehicle that is introduced into the fleet with a V2V system would also have an AEB system installed. Thus the benefits of V2V would always be applied in addition to the benefits provided by AEB.

The year-by-year reductions were calculated by assuming introduction rates of AEB and V2V into new vehicles, which enabled a calculation of the prevalence of each technology in the entire fleet for future years. In doing this, it was assumed that the vehicle age profile of the entire fleet would remain the same, based on the fact that, over the last decade, the average age of the vehicle fleet in Australia has remained relatively constant (ABS, 2013).

4.1.1 Vehicle age profile

The vehicle age profile was from the 2011 ABS Motor Vehicle Census (ABS, 2011). The census listed the number of registered vehicles by manufacturing year, as of 31 January 2011. As such, the data were adjusted to represent average age in years. The number of vehicles aged zero were those built in 2011 (of which only one month had passed), plus 5/12 multiplied by the number of vehicles built in 2010. The number of vehicles aged one was 7/12 multiplied by the number of vehicles built in 2010, plus 5/12 multiplied by the number of vehicles built in 2009 and so on.

Figure 4.1 shows the percentage of all vehicles by age. Note that for the grouping aged 21-30 years, this is the average percentage per year of age for vehicles in that age group, and similarly for 31-40 and 41-50. Note that the height of the bar for vehicles aged zero is approximately half the height of those following: if it is assumed that a roughly linear introduction of vehicles into the fleet during their year of manufacture, this is what we would expect.

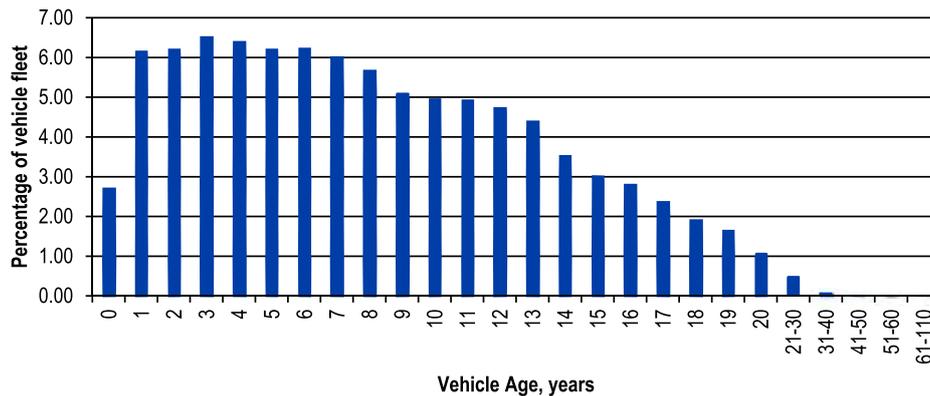


Figure 4.1 Distribution of vehicle ages in the fleet. 2011 ABS data.

4.1.2 Introduction rates of AEB and V2V

Three different introduction rates were used for AEB and V2V. These introduction rates were estimates that corresponded to three different public policy approaches that could be taken.

Aggressive introduction

- In this approach, both AEB and V2V could be strongly pushed into the new vehicle fleet. Possible approaches include the following:
 - AEB mandatory in new vehicle models from 2015 onwards, V2V mandatory from 2020 onwards. Since vehicle manufacturers operate on an approximate five-year model turnaround, new vehicles would gradually approach 100% compliance over a five-year period.
 - A strong research and consumer awareness program (possibly through ANCAP) to demonstrate the benefits of AEB and V2V to the public and government regulators.
 - Standards developed quickly for V2V in Australia in order to meet 2020 introduction.
 - Strong incentives through reduction in registration costs and insurance premiums to encourage model turnover within the five-year introduction period.

Encouraged introduction

- This is the approach that is currently being undertaken. The following measures are possible:
 - Reduced insurance premiums and possibly registration costs for vehicles with AEB and eventually for those with V2V.
 - ANCAP awarding bonus points for vehicles with AEB and eventually V2V.
 - Overseas research programs to develop standards for V2V systems, with a view of them eventually being adopted in Australia.
 - Ongoing local research into AEB and V2V effectiveness to demonstrate benefits.

Slow introduction

- This approach would include no public policy or guidance to encourage AEB and V2V adoption. This is unlikely (based on the consultation) but represents a ‘worst case’ scenario for the introduction of these technologies:
 - No change in insurance or registration costs based on AEB or V2V prevalence.
 - ANCAP rating unaffected or minimally affected, by the presence of AEB or V2V.
 - No local standards developed for V2V, let the market sort it out.
 - No local research into the benefits of AEB and V2V.

These three approaches were used to generate hypothetical introduction rate curves for AEB and V2V by specifying two years: an introduction year and a saturation year. The introduction year was when the technology first began to appear in new vehicles and the saturation year was when close to 100% of new vehicles would have the technology.

The introduction rate curves are normal cumulative distributions: the mean was taken as the average of the introduction year and the saturation year and the standard deviation was one fifth of the time from the introduction year to the saturation year. The introduction and saturation years are shown in Table 4.1.

Table 4.1 Three introduction scenarios for AEB and V2V.

Scenario	AEB		AEB and V2V	
	Introduction year	Saturation year	Introduction year	Saturation year
Aggressive introduction	2015	2020	2020	2025
Encouraged introduction	2015	2025	2025	2035
Slow introduction	2015	2030	2025	2045

The ‘Encouraged introduction’ scenario for both AEB and V2V is comparable to the introduction rate of electronic stability control (ESC). Figure 4.2 shows the ESC uptake curve for new cars (reproduced from Gargett et al., (2011)) as well as the introduction curve based on the ‘Encouraged introduction’ scenario. For illustrative purposes the ‘shifted ESC curve’ has been superimposed on the ‘Encouraged introduction’ curve.

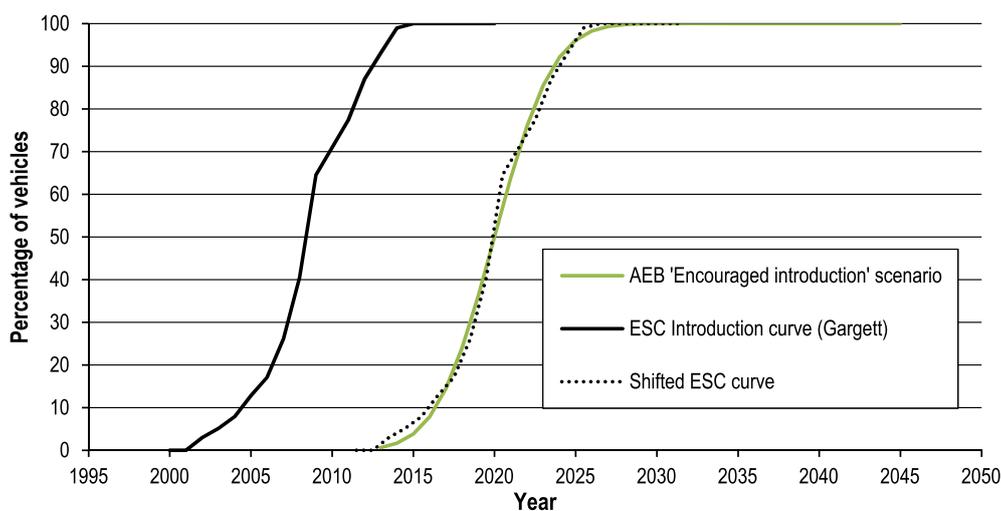


Figure 4.2 ESC uptake curve for new cars with ‘Encouraged introduction’ curve based on - Gargett et al., (2011)

These introduction rates were used to calculate the proportion of vehicles sold in a given year that would have either AEB, or AEB and V2V. (It is assumed that any new vehicle with V2V would also have AEB) .

Based on the age profile of the vehicle fleet, we were able to calculate the hypothetical proportion of the fleet that would have AEB, or AEB and V2V, in any given year.

4.1.3 Effectiveness values for AEB and V2V

The effectiveness values for AEB and V2V were taken from prior CASR studies. The AEB effectiveness values were taken from Anderson et al. (2012). In that report, several variations of AEB systems were considered, based on sensor range, sensor sweep angle, response time and braking force.

For the present study we chose to represent AEB by what is referred to in Anderson et al. as “System G” as it was the most conservative system. This system represented a relatively narrowly focussed sensor in front of the car, with a 4m wide and 40m long area of detection. The system has a 0.1 second computation time, simple prediction method, and would intervene one second before impact with braking force of 0.8g.

In an unpublished study, Doecke and Anderson (2012) repeated the same simulations used as the basis for Anderson et al. (2012) except that the sensor parameters were modified to account for enhanced predictive capabilities of a V2V system. In this case, the ‘sensor’ had an effective range of 100m, with a full 180 degree sweep in front of the vehicle, zero computation time, and an advanced prediction method. The same parameters were used for the braking intervention: one second before impact with a 0.8g braking force. (Doecke and Anderson, 2012, refer to the same system as ‘Restricted view’.)

Table 4.2 gives the parameters of these two systems and the associated injury and fatality reductions found in each report.

Table 4.2 Attribute values for the AEB and V2V system variations*

Attribute	AEB system	V2V system	AEB + V2V
Scan shape	Rectangle	Cone	
Range (m)	40	100	
Angle/width (deg/m)	4	180	
Computation time (s)	0.1	0.0	
Prediction method	Simple	Advanced	
TTC action (s)	1.0	1.0	
System deceleration (g)	0.8	0.8	
Driver supported deceleration (g)	0.8	0.8	
Fatality reduction	28%	+12.2%	40.2%
Injury reduction	34%	+16.4%	50.4%

*V2V reductions are additional to the AEB reductions

4.2 Results

Firstly, the age profile of the vehicle fleet and the three introduction curves described above were used to calculate the resulting prevalence of each technology in the vehicle fleet over time. Secondly, the effectiveness values for AEB and V2V were used to calculate the estimated fatality and injury reductions over the same period.

4.2.1 Introduction rates and fleet prevalence

Figures 4.3, 4.4 and 4.5 show the three introduction rates for AEB and V2V and the resulting fleet prevalence. Note the lag between introduction into new vehicles and the prevalence in the vehicle fleet: in Figure 4.3 we see that by 2020 almost all new vehicles would have AEB. However, it takes until 2025 for half of all vehicles in the fleet to have AEB.

It is worth noting also that these figures are applicable to any technology, given the introduction rates that we have proposed, and assuming that the fleet’s age profile remains the same in the future.

Table 4.3 summarises some of the key results from these figures.

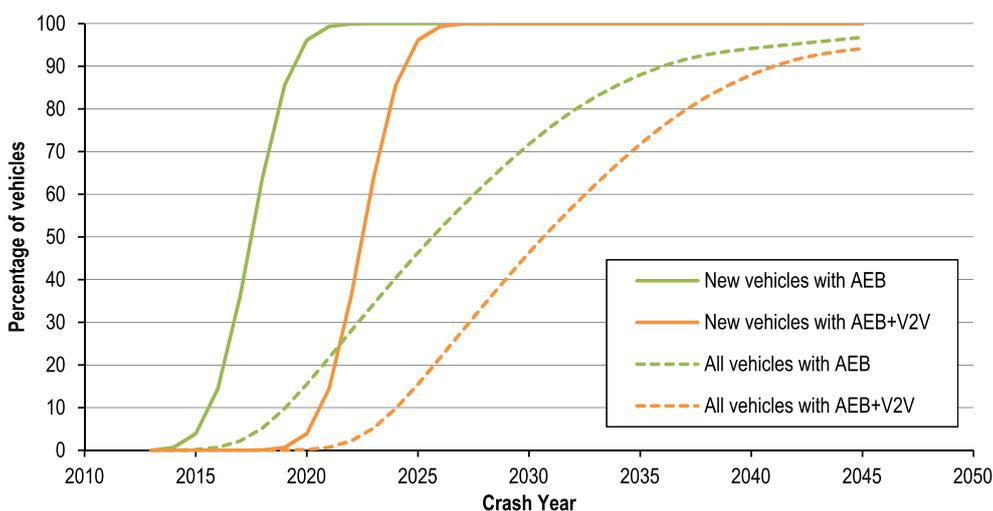


Figure 4.3 Introduction rates and resulting prevalence in all vehicles - ‘Aggressive Introduction’ scenario.

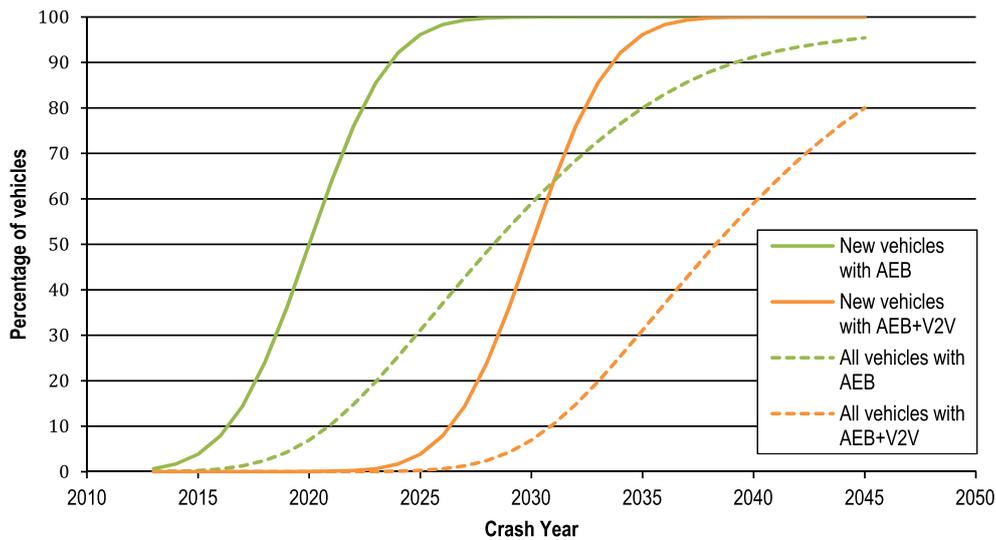


Figure 4.4 Introduction rates and resulting prevalence in all vehicles.- 'Encouraged Introduction' scenario.

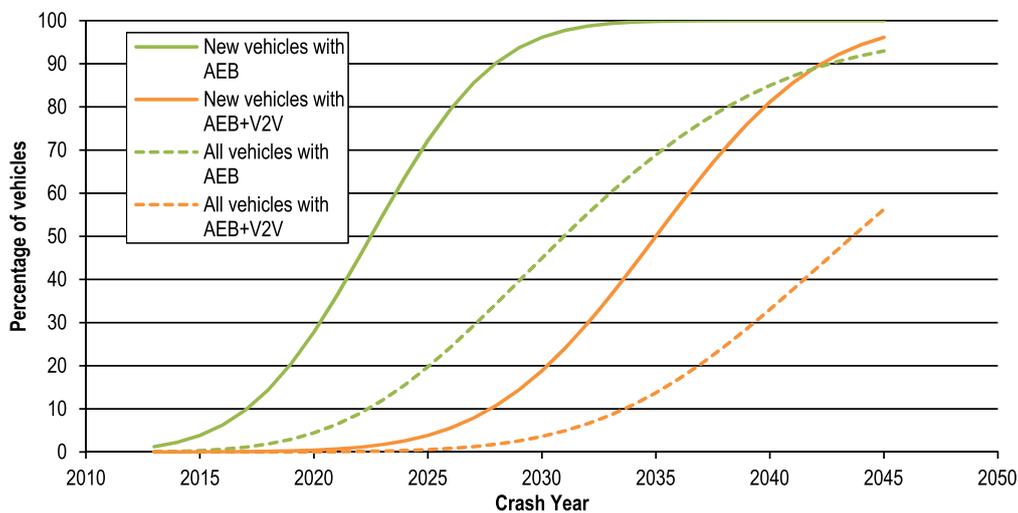


Figure 4.5 Introduction rates and resulting prevalence in all vehicles - 'Slow Introduction' scenario.

Table 4.3 Fleet penetration results for the three introduction scenarios.

Scenario	Percentage of all vehicles with AEB in 2030	Percentage of all vehicles with AEB and V2V in 2030	Year when >50% of all vehicles have AEB	Year when >50% of all vehicles have AEB and V2V
Aggressive introduction	72%	46%	2026	2031
Encouraged introduction	59%	7%	2029	2039
Slow introduction	45%	4%	2031	2044

4.2.2 Fatality and injury reductions

The fleet prevalence of each technology was used estimate reductions in fatalities and injuries over time.

For AEB, the prevalence in the fleet was multiplied by the percentage reductions given in Table 4.2 (28% for fatalities and 34% for injuries).

For V2V, the prevalence in the vehicle fleet was squared, and then multiplied by the values in Table 4.2 (12.2% for fatalities and 16.4% for injuries). The reason for squaring the prevalence values was that V2V requires two vehicles to have the technology in order for it to work. For example, if 50% of vehicles have V2V, there is a 50% chance of the first vehicle in a two-car crash having V2V and also a 50% chance of the second vehicle having V2V. Thus the overall chance of both vehicles having V2V is 0.5 squared, which is 0.25 or 25%.

Figures 4.6, 4.7 and 4.8 show the reduction in injuries and fatalities for each of three scenarios. The reductions for AEB and the reductions due to V2V are shown separately and summed together. The figures demonstrate the lag in effectiveness that occurs with delayed introduction.

Table 4.4 summarises some key results from these Figures. By 2030, the reduction in fatalities is 23% for the 'Aggressive introduction' scenario compared with 17% for 'Encouraged introduction'. For the 'Encouraged introduction' scenario, there is an additional five years taken to achieve a 25% reduction in fatalities, compared to 'Aggressive introduction'.

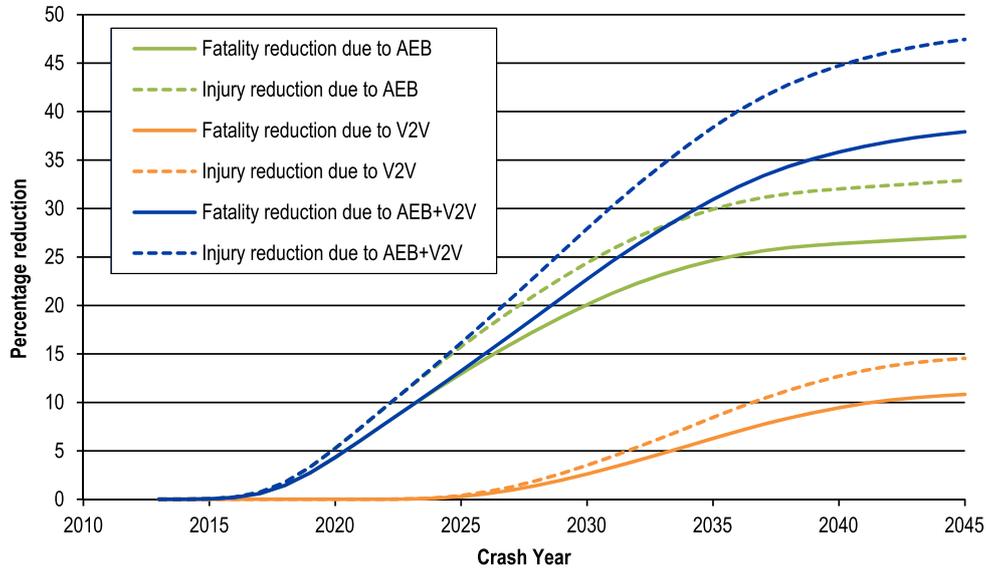


Figure 4.6 Reduction in injuries and fatalities - 'Aggressive Introduction' scenario.

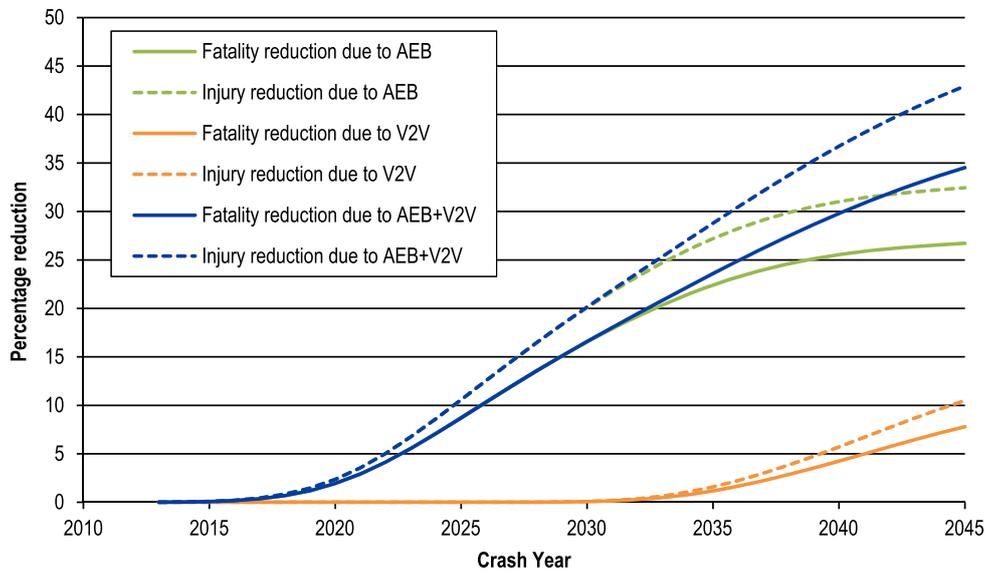


Figure 4.7 Reduction in injuries and fatalities - 'Encouraged Introduction' scenario.

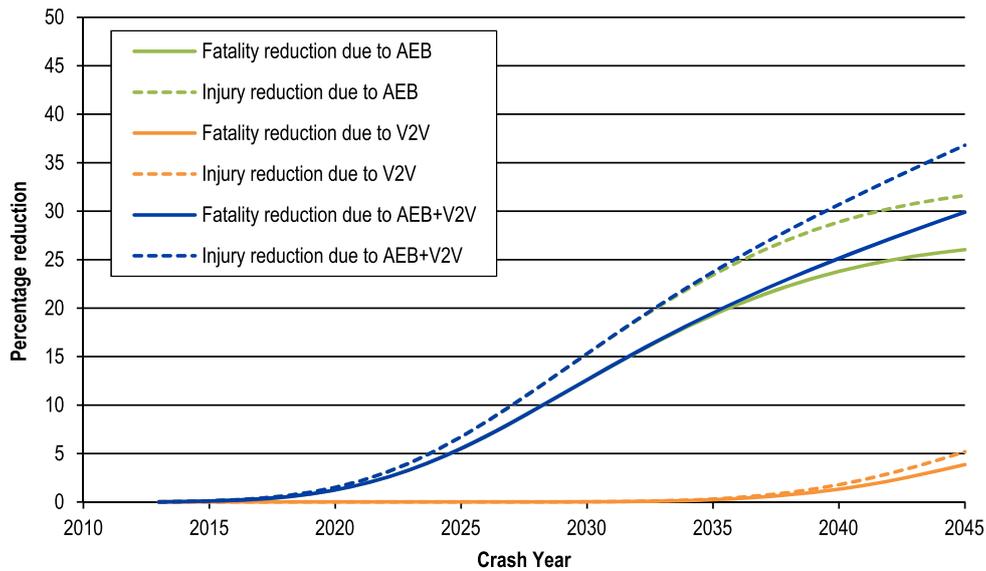


Figure 4.8 Reduction in injuries and fatalities - 'Slow Introduction' scenario.

Table 4.4 Fatality and injury reduction results for the three introduction scenarios.

Scenario	Total reduction in injuries by 2030	Total reduction in fatalities by 2030	Year in which a >25% reduction in injuries is achieved	Year in which a >25% reduction in fatalities is achieved
Aggressive introduction	28%	23%	2029	2032
Encouraged introduction	20%	17%	2033	2037
Slow introduction	15%	13%	2036	2040

4.3 Discussion

The objective of this analysis was to examine the consequences of the rate of introduction of new technologies on future reductions in fatalities and serious injuries. This was done for AEB and V2V, which represent the two most promising technologies in the short-term and medium-term future.

This was done by making assumptions about the effectiveness of AEB and V2V, based on previous studies and about the timescales for their introduction. The assumed effectiveness values were based on computer simulations, and the timescales were based on the interviews in the previous section. Thus the results should be interpreted as an informed speculation of what may occur.

Importantly, the results demonstrate that a delay in introduction, or slower rate of introduction, can have a significant effect on how long it takes for the benefits to be realised in the greater vehicle fleet.

In this analysis, the reduction in fatalities and injuries were calculated as percentage reduction. The absolute values were not calculated, as it is not known what future changes there will be to the 'baseline' numbers of fatalities and injuries outside of the effects of AEB and V2V. However, it would be reasonable to assume that these 'baseline' numbers will reduce with time. This implies that the opportunity for reductions in fatalities and injuries due to AEB and V2V (or any other vehicle safety technology) diminishes with time. This increases the importance that must be placed on introducing such technologies as soon as possible.

The calculations in this analysis were based on the current distribution of crash types, and this distribution may change in the future. As technologies for preventing vehicle-to-vehicle crashes become more common, a greater proportion of road trauma may be associated with vulnerable road users. If this is the case, then technologies that prevent crashes with pedestrians, motorcyclists and bicyclists should be encouraged.

5 Conclusion

This report aimed to look into the future and assess what impact new vehicle technologies are likely to have in Australia over the next 30 years. Only technologies for light vehicles were considered. The report included a literature review, a summary of interviews with automotive safety experts and a quantitative analysis of two technologies, autonomous emergency braking (AEB) and vehicle-to-vehicle Communications (V2V).

The main points from the literature review and expert responses were:

- There are many safety technologies being introduced or are close to introduction, some of these are likely to have a considerable effect on crashes and reducing deaths and injuries.
- The improvement in safety that may come from AEB is most promising, initial research suggests potential reductions of 20-40% of all crashes.
- V2V technologies may eventually lead to another substantial improvement, but probably over a longer time scale than AEB.

The experts varied considerably in their opinions, but nevertheless there were some things in common. The technologies that were most commonly emphasised by the experts were AEB and V2V. AEB was envisaged as starting to become popular in new cars within a few years, and being near-universal in new cars perhaps 10 or 20 years after that. V2V was seen as a longer-term technology, though advice or warning systems might be feasible sooner.

Other technologies about which there was optimism include⁶ :

- technologies to combat driver drowsiness
- technologies to combat distraction
- technologies to combat failure of concentration
- alcohol interlocks
- adaptive cruise control
- warnings such as lane change assist, blind spot detection, ISA
- advanced lighting systems
- autonomous braking when reversing
- automatic collision notification
- vehicle-to-pedestrian communication systems (V2P)
- night vision.

In general, experts did not place much emphasis on further improvements to crashworthiness systems and primary systems such as brakes, tyres and steering. This may have been because the emphasis in the interviews was on new technologies, and not advanced or improved versions systems that already exist. These aspects of vehicles are likely to continue to improve, resulting in a further reduction in crash rates in vehicles sold in the future. (For example, the importance of the braking system is emphasised by Eckert et al., 2013.)

Experts did not identify challenges that new technology might face, given that crash rates have historically been declining. It is very likely that current declines in occupant injuries and deaths are, in large part, due to existing/prior improvements to vehicles. As the crash rates of new vehicles decline, the benefit of new technology becomes more marginal as time goes on; this may be a challenge regarding the economics of developing and installing emerging technologies.

Reduced impact speed is an important intermediate aim, applicable to many technologies, in the pursuit of reduction of deaths and injuries. This underscores the desirability that the technologies operate effectively at the speeds at which serious crashes occur. It will be important that new technologies operate reliably at all speeds and perform when expected to. New car assessment programs have a role to play in this.

⁶ The experts did differ between themselves with many technologies being mentioned by only one person.

The quantitative analysis of the possible future trend in injury reduction was conducted using values for the effectiveness of AEB and V2V systems based on previous CASR studies, and by making assumptions about the time scales over which they would come into the new vehicle fleet. The results demonstrated the effect of delays in implementation, and the rate of implementation, of new vehicle safety technologies. An aggressive introduction will be likely to reduce fatalities by 23% by 2030, compared to a reduction of 13% with a slow introduction.

5.1 Promotion of safety technologies

There are a number of ways to promote the early introduction of safety technologies and these were reflected in the opinions expressed by the experts.

The strongest form of encouraging early introduction is through government regulation that mandates a particular technology in all new vehicles. Often such government regulations are not implemented until a technology has become relatively commonplace in new vehicles already, as has been seen for electronic stability control (O’Kane, 2009).

Technologies may also be encouraged through reductions in insurance premiums for compliant vehicles. In the case of AEB, this has already occurred with Allianz Australia offering a 20% discount for the Subaru Eyesight system (Subaru, 2012), and NRMA Insurance offering a 20% insurance premium discount for the Volvo City Safety system (Blackburn, 2009). In the interviews conducted for this report, insurance discounting was identified by many experts (including those in the insurance industry) as a way of encouraging greater adoption of technologies. Interestingly, in trying to promote safer car choice in Western Australia, RAC Insurance has decided to “...stop insuring or financing vehicles manufactured from 2012 and beyond with an ANCAP rating that is below 4 or 5 stars” (RAC Group, 2012).

Experts interviewed in this report also consistently identified the need for better consumer awareness about safety technologies, and support for new vehicle assessment programs that provide a way for consumers to rank vehicles based on their level of safety technology. A recent survey by the NRMA suggested that although Australians prioritise safety highly when purchasing a new vehicle, they have little knowledge about specific technologies (NRMA, 2014).

As discussed in Section 2.13, there is a range of advertising and consumer awareness programs that may encourage greater uptake of new safety technologies. This includes campaigns run by vehicle manufacturers, motoring organisations, vehicle insurers, consumer advocacy groups and government departments. The 5-Star ANCAP rating is well known and continues to encourage the installation of new safety technologies.

5.2 Recommendations for future research

There are challenges facing policy makers in respect of new vehicle safety technology. These are likely to centre on understanding the likely benefits of each new technology and consequently which technologies to pursue via regulation or consumer programs. This leads to challenges over how the performance of such systems should be assessed and how to stimulate take up amongst new car buyers. These challenges might form the themes of future research.

When it comes to assessing the likely benefits of new technologies, it is important to understand what is currently happening regarding the safety of new vehicles. There have been many improvements to new vehicles over the last decade (or longer) and the lifetime crash risk of a car built today is likely to be substantially less than a car built a decade ago, and less than the average car in the general registered fleet. As cars continue to improve, the effects of any new technology will begin to become marginal. A poor understanding of lifetime crash risk may mean that the estimates of technology benefits are unrealistically high, particularly if the introduction of technology is delayed. However, this is not to say that no future technology will be cost effective. Presently there are few techniques available to policy makers to assist in understand the dynamics of the changing fleet and what this means for estimating net benefits of new technologies.

Regarding the testing and assessment of technologies, it is pertinent to examine AEB in particular, as it is generally thought to be the new technology with the greatest potential. Testing of AEB systems would serve two purposes. Qualitatively, testing would provide a broad-brush idea of how well and in what circumstances the systems work. Quantitatively, test results would permit analysis of how the different AEB systems work, summarising of their performance and prediction of how they would perform under other conditions. The use of such research by new car assessment programs would encourage the installation of the more effective technologies.

As mentioned in Sections 2.13 and 5.1, a variety of approaches may be used to promote early adoption of safety technologies but the effects of such methods may be complex. In the past, accelerating scrappage has been suggested as a method of stimulating the introduction of new vehicle technology, but the brief analysis in this report clearly shows the importance of the rate of introduction of new technologies in the new vehicle fleet. It is currently uncommon for discussions on the rate of introduction of a new technology to include the consequences of delay, in dollars, lives lost or individuals affected by crashes. For Australia, this is an important consideration as the introduction of new safety technologies in this country has been historically relatively slow.

5.3 General recommendations

Based on the findings of this report, some general recommendations can be made for organisations concerned with road safety.

It is apparent that there are many new technologies emerging in the near to long-term future that may offer road safety. It is a difficult task to promote and explain all of these technologies to the public at once. Thus, based on the findings of this report, it is recommended that:

- for Consumers should buy new vehicles with autonomous emergency braking (AEB) technology.
- An ANCAP five-star rating should be promoted as a minimum standard to fleet purchasers and for private new car buyers for.

Achieving rapid fleet penetration is important for all promising new technologies, and delayed introduction is costly both financially and in terms of lives and injuries that could be prevented.

The experts interviewed for this report consistently identified government regulation as having the greatest potential to achieve faster penetration of new technologies. Thus we recommend lobbying the federal and state government for regulations that mandate or otherwise encourage the installation of vehicle safety technologies for new vehicles, particularly AEB.

The experts also consistently identified reduced insurance premiums as a means of increasing fleet penetration of new safety technologies. It is promising to note that this approach has already been taken up by IAG and Allianz Australia, and this should continue to be encouraged and marketed to consumers.

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A Appendix A

Summary of technologies and benefits

Name of Technology	Description	Benefits identified in the report
Autonomous emergency braking (AEB)	Autonomous emergency braking allows a vehicle to detect an obstacle in its path and brake without any intervention by the driver. These obstacles may include pedestrians and cyclists, and so AEB is a technology that has the potential to prevent injury to both vehicle occupants and vulnerable road users.	It is estimated that between 20-40% of crashes, including fatal crashes, may be prevented with AEB (depending on system type). There is also a particular benefit to vulnerable road users, such as pedestrians, with estimates of fatality reductions of up to 44% with AEB. Even if crashes are not completely prevented, the reductions in speed may be sufficient to prevent death and serious injury.
Connected vehicles	<p>These technologies allow vehicles to connect to each other and to the surrounding infrastructure and are often referred to as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I).</p> <p>Vehicle-to-vehicle technologies allow vehicles to send messages to one another regarding their position and speed, and potentially any emergency information.</p> <p>Vehicle-to-infrastructure technologies allow the infrastructure on the road to send messages to nearby vehicles regarding traffic signals, intersections, stop signs, and possibly traffic flow.</p>	While there are yet to be results published from any large-scale V2V and V2I field studies, there is a high level of confidence in the safety benefits of these technologies. Moreover the systems will have the capacity to increase the effectiveness of the other advanced vehicle safety systems described.
Alcohol interlocks	An alcohol interlock is a small breath-testing device connected to a vehicle's ignition circuit. It measures the driver's breath alcohol level, and prevents the driver from starting or operating the vehicle after drinking alcohol. Various technologies are now available.	The literature indicates that there is optimism about the potential effectiveness of alcohol interlocks in reducing crashes, assuming they were installed across all vehicles in the general population.
Lane departure warning systems	This driver assistance technology monitors the position of a driven vehicle within a lane and gives a warning to the driver when the vehicle is considered to have deviated significantly from within the lane. If this is the case, the driver will be alerted via audible, visual and/or tactile warnings so that driver corrective action can be undertaken prior to complete unintended lane departure. Advanced systems may also attempt to correct the situation by applying counter-steer to maintain vehicle lane position.	The estimated effectiveness of this technology is 2% for reduction in trauma and 7% for reduction in fatalities.
Fatigue warning system	Fatigue warning systems use technology to monitor and assess a driver's level of alertness and give warning when this is determined to have degraded beyond a threshold. There is an underlying responsibility of a driver to take action (e.g. a rest break) once a vehicle detects the fatigued state of a driver. Therefore, any effectiveness of such a system in alerting a driver that they might be fatigued may be considered independent of the effectiveness of such a system in preventing crashes.	It is estimated that the effect of fatigue warning systems might be a reduction in crashes by 10% and a trauma reduction of around 2%.
Seat belt interlocks	Should a driver (or any occupant) be detected and a seat belt remain unbuckled during an attempt to start the vehicle, a seat belt interlock will prevent vehicle operation until all detected occupants are wearing seat belts.	Analysis suggests that fatality rates could be reduced by 2% and serious injuries by 7% by 2030 if seat belt interlocks were fitted to all new vehicles from 2015 onwards.

Name of Technology	Description	Benefits identified in the report
Automatic collision notification (ACN)	This technology is designed to detect the involvement of a motor vehicle in a crash, to obtain information about the severity of the crash where possible, and to notify emergency response personnel either automatically or through a response centre.	Overseas studies have indicated that a fully deployed ACN system may result in a reduction in all fatalities of between 1.5% and 6%. In South Australia, ACN was estimated to reduce all fatalities by 2.2% or reduce passenger vehicle occupant fatalities by 2.8%.
Following distance warning/adaptive cruise control	<p>Following distance warning systems generally comprise a laser/radar or camera attached to the front of the equipped vehicle that 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 time or distance margin.</p> <p>Adaptive cruise control uses a similar hardware arrangement to the following distance warning system. Using information from this hardware system, combined with data from the vehicle speed sensor, the adaptive cruise control system can be used to determine the approach speed to the car ahead. The system then decides if it is safe to continue travelling at the pre-set cruise speed or whether brake application is required to maintain a safe following distance</p>	Following distance warning technology has been estimated to reduce trauma by 2%; adaptive cruise control has been estimated to reduce trauma by 1.5%.
Lane change assist warning and blind spot detection systems	This technology is able to detect the presence of other road users alongside a vehicle, through the use of RADAR, SONAR or video cameras and image processing technology. Combined with information from a number of sensors (e.g. lateral acceleration, steering wheel angle, indicator usage), 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 to their presence via an audible or visual response, allowing enough time for corrective action to be taken.	This technology has been estimated to reduce fatalities by 1% and trauma by 0.5%.
Reversing visibility systems	Reverse collision warning systems utilise either a rear-mounted camera that provides visual assistance to a driver while reversing, or rear-proximity sensors (using ultrasound or radar) that detect obstructions behind a reversing vehicle and provide an audible alert, varying with increasing proximity, to a detected obstruction.	Very little data exists on the effectiveness of reverse collision warning system. However there is much optimism about the potential effectiveness of a fully deployed system in reducing reverse collision fatalities.
Improvement to brakes and tyres	<p>Some braking systems can achieve faster braking by integrating the components for brake actuation, brake boosting and control systems for ABS and ESC into a single unit.</p> <p>Tyre technology improvements are largely incremental with improved and more efficient compounds being continually made available.</p>	<p>Many of the technologies listed, including AEB, are ultimately limited by the effectiveness of the vehicle brakes or tyres. Improvements in tyre and brake performance will directly lead to an improvement in the other technologies.</p> <p>With improved brakes and tyres deceleration of up to 10 m/s², compared to current figures around 7 m/s², may be achievable in emergency braking. This may be further improved by technologies that allow the brakes to operate at full effectiveness some 0.19 seconds earlier than on current systems.</p>

Name of Technology	Description	Benefits identified in the report
Night vision enhancement	Night vision for drivers can be enhanced through the use of a forward facing infrared sensor attached to the vehicle. Either a passive or active sensor is used depending on system requirements. The passive sensor detects ambient infrared levels and has a potentially longer detection range whilst the active sensor, designed to pick up reflected infrared 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).	Although there is limited information about the effectiveness of this technology, there is optimism about this technology enhancing visibility at night. It has been estimated that this system might lead to a trauma reduction of 0.4%.

B Appendix B

Details of expert responses

Introduction

Thank you for agreeing to take part in an interview as part of a CASR study on new vehicle safety technologies. Your responses will help inform and guide our future work in the area and will be used as part of a report for the Royal Automobile Club of Victoria (RACV).

Your responses may be directly transcribed or paraphrased or coded for reporting purposes. We are happy with short answers, but feel free to elaborate if you feel it necessary. The questions are intended to give guidance and ideas towards your responses, not to constrain them. You do not have to answer all of the questions: we are more interested in high quality answers than a response to every question.

If you like, your responses may be de-identified before being included in the initial report or in any other publications. We will send you a copy of your responses for your approval before publication.

Questions

1. Of the safety technologies that are being introduced into new vehicles in the next 5 to 10 years, which do you think are likely to have the greatest impact on road deaths and injuries? We are interested in both primary safety and secondary safety technologies.

For each of the technologies identified above:

- a. How many years will it be before we start to see a measurable benefit?
 - b. Are there ways of accelerating the take up of this technology? E.g. can it be retrofitted to existing vehicles?
 - c. What are the major limitations of this technology and are there any dangers that it might inadvertently introduce?
 - d. Are there any changes to road infrastructure that will need to take place for this technology to work?
2. What do you see as some of the impediments to the adoption (or early adoption) of new vehicle safety technologies into the fleet?
 3. Looking far into the future – what safety technologies would you see being introduced in 20 to 30 years time that might have a significant effect on road deaths and injuries?
 4. Are you involved with any unpublished safety technology evaluations that are currently taking place, and are you able to share any results?
 5. Do you have any other thoughts that you would like to share?

Completion of the interview

Thank you very much for agreeing to take part in this study. Your responses are incredibly valuable and we will be sure to be in touch for confirmation before publication.

Are you happy for us to contact you for any further clarification?

C Appendix C

Summary of expert responses

Table B.1 Summary of responses to interview questions

Question	Brief summary of responses
<p>Of the safety technologies that are being introduced into new vehicles in the next 5 to 10 years, which do you think are likely to have the greatest benefit</p>	<p>Autonomous emergency braking (AEB) Vehicle-to-vehicle (V2V) Vehicle-to-Infrastructure (V2I) communications, Driver drowsiness/fatigue, distraction, or failure of concentration: detection and warning/intervention Alcohol interlocks Adaptive/Advanced cruise control Warning/Intervention (lane keeping, blind spot, speed relative to speed limit) Advanced lighting systems Autonomous vehicles Autonomous braking when reversing Automatic collision notification Vehicle-to-pedestrian (V2P) communication systems Night vision Feedback on risky behaviours and environments Vehicle prognostics (avoiding breakdowns in bad places) Better awareness of road and traffic conditions Seat belt interlocks Advanced whiplash protection Pedestrian airbags Rear seat safety Cap or hat that protects a pedestrian's head Technologies to reduce occupants' rotational head injury</p>
<p>How many years will it be before we start to see a measurable benefit?</p>	<p>Immediately, a lot faster than people think 10 years or more, many people still driving older vehicles I would like to see it in 5 years 10-15 years 20 years or more</p>

Question

Are there ways of accelerating the take up of this technology?
E.g., can it be retrofitted to existing vehicles?

Brief summary of responses

Retrofitting intervention devices is not considered feasible. Advisory systems are retrofittable.

Non-regulatory testing (eg. ANCAP). Requirement that a vehicle cannot obtain a 5 star rating without safety technologies

Insurance programs with premiums depending on driver behaviour

Standardisation with international best practice

Road authorities can incorporate programs for high risk drivers (eg. young drivers)

Standardisation of ports to enable data download from vehicles

Make cars cheaper

Discounts or tax free system to improve motivation to buy new car

Pricing and government schemes, subsidy schemes

Reduce insurance or car registration for vehicles with collision avoidance technologies. Reward for installing technology

Combine safety technologies with other popular (options (eg. luxury options)

Marketing campaign to educate consumers and create a market condition

Consumer information has improved interest in the market but has not affected sales

Government regulation requiring technology (in this example AEB)

Mandatory installation

Fit technology to most popular or highest selling cars

Government commitment to infrastructure/network etc (for V2V)

Use of Smartphone App (NSW)

Question

What are the major limitations of this technology and are there any dangers that it might inadvertently introduce?

Brief summary of responses

Driver behaviour – complacency, inattention, changing the attitude of the driver so they overestimate their driving ability, overcompensating, distraction, driver reliance on technology, drivers not self-regulating, people may push the boundaries of the devices, overreliance on technology, may lead to complacency, misuse or misunderstanding, may cause more accidents

Devices may not work as intended

Privacy concerns, abuse or hacking

Cost

Warnings – too many, false warnings and drivers ignoring warnings

Technologies are limited to ideal crash situations

ACN: effective mobile phone communication network

Sensor reliability (particularly with higher speeds)

Technology needs to be highly reliable and thoroughly tested. Actually needs to perform well not just 'tick the box' for having it in the car

After market installation of technology means the technology can no longer be guaranteed by the vehicle manufacturer

Speed – pre-crash technology is designed to work below 40 km/h

System (AEB) designed not to activate at high speeds, or not until very late

Political issues (eg alcohol interlocks)

Accuracy of GPS positioning

Maintaining data set, position accuracy needs improvement (V2V)

Liability

Communication between systems (eg. ISA involves the vehicle, road sign, road)

To consider: does the technology work? Is it counter productive? Should the driver be in the loop?

Consumer resistance (eg. alcohol interlocks)

Vehicle market – many different vehicle models

Market penetration – takes a long time

Are there any changes to road infrastructure that will need to take place for this technology to work?

Very few modifications needed

Signage should be standardized with other markets

V2V: Infrastructure should be in place to broadcast suitable content and make data available to road authorities. Cultural change so road authorities are happy to open up data

Infrastructure based bicycle detection system

General improvements to night time lighting. Enhancing lighting of road edges.

Coordinated approach to setting up autonomous driving and intelligent transport

Improved lane marking, clear road signage, visual consistency, line marking, easy to read signs, detection of white lines and road verges

Government regulated communication frequencies

Static variable signs – issues with changing speed limits (eg. 25 km/h in school zone when children present)

Incremental changes (eg. already information broadcast over radio frequencies, GPS displays)

Possibility that messages will be delivered through the vehicle and variable message signs no longer required

Also to consider: speed limits and drowsy driver monitoring

Question

Brief summary of responses

What do you see as some of the impediments to the adoption (or early adoption) of new vehicle safety technologies into the fleet?

Manufacturers don't want to adapt their technologies for the small Australian market. Market need. Small size of market and overcomplicated market.

Cost. Both to consumer and manufacturer. No financial incentives available to encourage the buying of safer cars. Price sensitive market, safety features often removed. Global turmoil in vehicle manufacturing market

Lack of consumer information. Not informing the public about the usefulness of the technologies in an effective way. Lack of customer knowledge about technology. Greater consumer awareness required.

Regulatory impediments – the way regulations are written may prohibit some systems

Other government regulation, eg. emission standards which are traditionally more important than safety

ACN – interaction between vehicle and OOO operator

Driver perception that control is being taken away, that the system is complex and require extra expense for maintenance

Driver distraction – audio and visual warnings

Driver inexperience with system – difficult to 'test' the safety system

First generation technology – consumers nervous about adopting it. Early adoption – limited to levels of development, many technologies still under development

Higher repair costs may be an issue (eg. partial AEB systems where damage can be caused to the radar in the bumper bar)

Insurance – needs to be more affordable

Looking far into the future – what safety technologies would you see being introduced in 20 to 30 years time that might have a significant effect on road deaths and injuries?

Autonomous vehicles (may be no need to control vehicle speed, only steering input). Improved accident avoidance rates and survival rates in collisions that do occur.

Communication between all vehicles

Automatic driving systems, V2V and V2I will have a big impact

Improvements in tyre technology, suspension technology, steering

Uncrashable vehicles

Increased separation of traffic, particularly for vulnerable road users

Car travel will diminish

Effectively no people will be killed on the roads. 80% of avoidable collisions will be removed.

More integrated technologies, better maps provide micro information available to cars

Stronger linkage between driving and insurance premiums

Personal mobility systems – travelling less than 6km/h

Are you involved in any unpublished safety technology evaluations that are currently taking place, and are you able to share any results?

Insurance – beginning to work on pay as you drive system. Currently in data collection phase.

Internal testing on the effectiveness of ultrasonic sensor warnings. No data available.

Study on following distance and connected vehicles. No data available.

Injury algorithm for AACN systems. No data available

Do you have any other thoughts you would like to share?

Cars are moving to be networked.

Cars will be connected to the internet, this is positive for road safety but can also distract.

Drivers need to be mindful of technology and endure still focus on driving not solely relying on car

Needs to be more road safety leadership at a national level.



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