Emerging vehicle safety technologies and their potential benefits: Discussion of expert opinions

Daniel Searson[a], Giulio Ponte[a], T Paul Hutchinson[a], Robert Anderson[a] and Mary Lydon[a]

[a] Centre for Automotive Safety Research, The University of Adelaide

Abstract

The aim of this study was to consult experts from Australia and overseas about their views on emerging technologies, the likely uptake of these technologies and their potential to reduce the number of crashes or crash severity. Interviews were conducted with a cross-section of vehicle and road safety experts. The topics discussed included the most promising technologies, implementation issues, time frame, limitations, and opinions on future technologies, 20 - 30 years from now. In total, 16 interviews were conducted, with nine Australian-based experts and seven international experts. The experts' responses are discussed in the context of research literature on the technologies. The experts suggested that the most important emerging vehicle safety technologies are primary safety systems that provide increasing levels of automation. Autonomous Emergency Braking (AEB) was consistently identified as having the most potential in the near future, and this was confirmed in the literature. Early introduction of vehicle safety systems that are effective at preventing injury crashes will result in significant and cumulative financial and societal savings. This paper provides a brief overview of the more promising vehicle safety technologies, a summary of the opinions of the experts interviewed and potential mechanisms for accelerating uptake of vehicle safety technologies.

Introduction

As new light vehicle safety technologies continue to be developed and deployed through the registered fleet, a need arises to gain a better understanding of their potential impact on road trauma. A research project was undertaken by the Centre for Automotive Safety Research on behalf of The Royal Automobile Club of Victoria, to examine the impact new safety technologies are likely to have in Australia, on a time scale of about 2 to 30 years (see Searson et al., 2014). A component of the project involved consulting a number of vehicle safety experts from both Australia and overseas, about their opinions on emerging vehicle safety technologies, their uptake and their potential benefits. This paper provides a brief literature review of a number of vehicle safety technologies, discusses the method used in the expert consultation, and presents the results of the consultation with some interpretation by the present authors.

Literature review

There are several vehicle safety technologies that have the potential to reduce road trauma and a brief review of the key technologies are presented here.

Autonomous emergency braking (AEB) systems allow a vehicle to detect an obstacle in its path and, without intervention by the driver, brake as strongly as possible. 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. Anderson et al. (2012) estimated that an optimised AEB system could reduce fatal crashes by 39% and injury crashes by 48% (including pedestrian crashes). Rosén et al. (2010) suggested a reduction of 40 - 44% in pedestrian fatalities and 27 - 33% of serious injuries dependent on the system field of view. Vehicles with an AEB system may also have other systems, such as warning of the driver, strengthening of an application of the brake made by the driver, autonomous weak braking, or autonomous emergency steering.

A distinction is often made between low speed AEB, that may be effective at reducing the number of crashes and injuries in a city environment, and high speed AEB, which may reduce impact speed in higher speed environments. As the risk of a fatal injury increases at higher impact speeds (Rosén et al., 2010) an AEB that reduces impact speed in higher speed environments may save lives, while low-speed autonomy will be a convenience to the driver and will probably have some safety benefit particularly in reducing crashes involving vulnerable road users.

Connected vehicle technologies use dedicated short-range communication devices (DSRC) to allow vehicles to connect to and communicate with each other *vehicle-to-vehicle* (V2V) and/or connect to the surrounding compatible infrastructure (*vehicle-to-infrastructure* or V2I). With V2V, equipped vehicles exchange information regarding their position, speed and other vehicle specific information, and hence any emergency information regarding potential conflicts. This is distinct from V2I technology, which allows compatible road infrastructure to send messages to nearby vehicles regarding traffic signals, speed limits, intersections, stop signs, road conditions and possibly traffic flow. To date, little safety data has been published regarding these technologies. However Doecke and Anderson (2014) estimated that V2V in combination with AEB had the potential to further reduce serious injury crashes by 14 - 18 % and fatal crashes by 7 - 12 %, dependent on AEB system type.

Interlock systems are connected to the ignition of a vehicle and are designed to prevent starting and the operation of a vehicle, based on an in-vehicle assessment system. An alcohol interlock system measures and assesses driver breath-alcohol before allowing vehicle operation to commence, with intermittent tests while driving. Similarly, seat-belt interlock system assesses vehicle seat occupancy and allows vehicle operation only after seat belts are buckled. There is much optimism about interlocks, if fully deployed. 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.

Following distance warning systems monitor both distance and relative speed to other objects/road users in the vehicle’s forward travel path, and the driver is alerted if the safe following distance, relative to the vehicle’s travelling speed is breached. Adaptive cruise control systems utilise this information to maintain and regulate a vehicle’s set speed including automatic brake application in order to maintain a safe following distance. 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.

Lane change warning systems and blind spot detection systems can determine whether or not the driver of a vehicle is intentionally changing lanes or merging into traffic, and alerts (audible or visual) are presented if potential conflicts with other road users are detected. Similarly, lane departure warning systems monitor vehicle lane positioning and warn the driver when significant deviation is detected due to unintended lane departure. Warnings can be audible, visual and/or tactile so corrective action can be undertaken. More advanced systems may apply counter-steer to maintain vehicle lane positioning. Anderson et al. (2011) estimated fatality reductions of 7% (100 fatalities) and 4,177 non-fatal injury reductions for lane departure warning systems.

Fatigue warning systems 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 by monitoring eyelid movements of a driver, monitoring and assess steering wheel movements and speed of steering movements. A 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%.

Automatic collision notification (ACN) systems detect that a collision has occurred and automatically notify emergency medical services (EMS) with a precise location of the incident, thereby optimising EMS response. Such a system has been estimated at reducing fatalities by varying amounts: 1.8%, 2.4% and 2.8% (Wu et al., 2013, Ponte et al., 2015 and Chauvel and Haviotte, 2011 respectively).

Night vision systems use forward facing infra-red sensors to enhance driver vision at night, either by projecting detected images on a secondary monitor or a heads-up display, Paine et al. (2008) judged that this technology might lead to a trauma reduction of 0.4%. Reverse visibility systems utilise 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. Advanced systems have the potential to autonomously brake when obstructions are detected in a reverse manoeuvre. Little data exists on the effectiveness of such systems, however, NHTSA (2014) estimate that with full deployment of a reverse visibility system (expected by 2054) compliant with the Federal Motor Vehicle Safety Standard for Rear Visibility up to 69 lives per annum might be saved in the US.

Methods

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. Three of the experts were from the vehicle manufacturing industry, two from automotive safety technology and parts supply, two from automotive communications, two from consumer testing programs, two from government institutions, two from automotive insurance, and three from research institutions.

Content of the interview

The interviews were semi-structured, in the sense that questions were standardised but discussion about the technologies were not asked in a way that encouraged precise answers, being generally open-ended and informal in tone. The questions are given below:

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?

Results - the experts' responses

Overview of safety technologies in 5 to 10 years

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), and were perceived to have the greatest likely impact on road deaths and injuries. The responses were wide-ranging, and there was significant variation of opinion regarding which technologies were the most important and their timeframe for introduction. Table 1 lists the twelve categories of technologies that were mentioned by more than one expert and the nine types of technologies that were identified only by a single expert as having a potential for significant impact.

Table 1. Categories of technology identified by the experts as having a potential for significant impact on road deaths and serious injuries.

Technologies mentioned more than once
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
Technologies mentioned only once
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 technologies identified by the experts as having a significant road safety potential are consistent with those examined in the eIMPACT project (Assing et al., 2006) although electronic stability control (expected to have a significant road safety benefit in the eIMPACT project) was considered to be at almost full deployment in new vehicles in Australia in 2014, and hence the experts in our study no longer considered this an emerging vehicle technology. Interestingly, alcohol and seatbelt interlocks were not highlighted in the eIMPACT project, but the experts in the present study considered these technologies important.

Time frame

Time until a "measurable benefit" was referred to in the questions, and was interpreted differently by various experts. One expert stated that the benefits of safety technologies were immediate for the owner of a vehicle with that technology, another believed that market penetration of technologies such as airbags and electronic stability control might be a guide to future benefit of emerging vehicle technologies. 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)".

Australian experts also acknowledged 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 extending AEB to vehicle reversing manoeuvres, to prevent back-over collisions, was also mentioned several times by experts.

Vehicle-to-vehicle (V2V) technologies were also 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.

Accelerating the 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). The experts 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. Financial incentives were also highlighted as a potential method to accelerate the introduction of technologies. This could be achieved by comprehensive insurance premium reductions or reductions in registration fees. Insurance discounting was identified by many experts (including those in the insurance industry) as a way of encouraging greater adoption of technologies.

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". 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).

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.

Limitations and potential negative impacts of technology

A number of the respondents indicated 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 (e.g., 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.

Regarding human limitations, drowsiness, fatigue, lack of alertness, and inattention are behaviours that are complex to predict and monitor hence 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". 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 (i.e. risk homeostasis). The authors of this paper would like investigate these issues in future research. 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.

Issues relating to liability and litigation were also highlighted, particularly for vehicle technologies that might be imperfect or not working as intended. An 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”.

Infrastructure requirements

Generally it was thought that few modifications to infrastructure would be required except in the case of V2I and V2V communication, where infrastructure was highlighted as being very important. Road infrastructure systems will need to be able to broadcast information to, and receive information from vehicles within the road network [this is compared to I2V that might be broadcast only]. 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”.

Some safety technologies rely upon ideal conditions, and infrastructure changes to compensate for non-ideal conditions (e.g. improved lighting, enhancing of road edges) were considered important, particularly for vehicle guidance systems such as lane keep assist and lane departure warning. 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 need standard and consistent information to function correctly.

Impediments to adoption

The cost of new technologies was seen as an important barrier to their introduction. It was suggested that new technologies are often only found on higher specification or prestige/luxury models of vehicles and are not accessible to society in general. It was acknowledged however, that some safety systems in Australia are available in low cost vehicles, but often as an optional extra. One expert considered there are too many makes, models, and variants of models available in Australia, that the market in Australia is very price sensitive, and that safety features are often removed for economic reasons.

One of the impediments identified regarding 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, which would need to be improved in order for these systems to work effectively.

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”. 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.

Safety technologies in the longer term

The experts were asked about the technologies that they thought would be available in new vehicles on a time scale of 20 to 30 years. The technology most mentioned was autonomous driving technology (both fully and 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.

Other points raised by the experts included:

- 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. For example, drivers that regularly drive over the speed limit may be charged higher insurance premiums.
- The whole system of vehicle ownership may change, for example through car sharing systems.
- There are some technologies that adapt to the characteristics of a person (e.g., seatbelts for the elderly or children).

Discussion

The literature suggests that there are several vehicle safety technologies that have the potential to reduce road trauma. The experts varied considerably in their opinions, but nevertheless there were some common themes. 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.

Australian experts had high levels of optimism about 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 7% of new light vehicles were sold in 2014 with a pre-crash/collision safety system standard, with a further 11% as optional (POLK, Oct-Dec 2014) compared to Japan and Sweden where experts indicated deployment rates of around 50% of new vehicles sold.

The authors of this paper share the optimism regarding AEB and connected vehicle technologies, because even if crashes are not completely prevented, the reductions in impact speed may be sufficient to prevent death and serious injury. Moore (1970) suggested that a 1 per cent reduction in impact speed is likely to lead to a 2.5 per cent reduction in fatality risk. AEB that can shorten reaction time by 0.1 sec and decelerate a vehicle at 8 m/sec/sec will theoretically reduce impact speed by 0.8 m/sec. A collision that might have occurred at 60 km/h (16.7 m/sec) under this scenario, would have been reduced by 4.8 per cent, suggesting a 12 per cent reduction in fatality risk. 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.

Other technologies about which there was optimism include technologies to combat driver drowsiness, distraction, or failure of concentration, alcohol interlocks, adaptive cruise control, warnings (lane change assist, blind spot detection, ISA), advanced lighting systems, AEB when reversing, ACN, V2P (*vehicle-to-pedestrian* communication systems), and night vision. The experts did differ between themselves with many technologies being mentioned by only one person, however these technologies may be very effective for a particular subset of crashes.

No expert identified the 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.

A number of experts did highlight the fact that the average age of vehicles in Australia is quite old (greater than 10 years) and retrofitting interventional safety technologies was not considered feasible. However, no expert mentioned the potential for compatibility issues between newer vehicles with autonomous collision avoidance technologies and advanced braking systems being deployed into a registered fleet of older vehicles reliant on driver ability and fallibility.

We acknowledge a number of limitations when consulting experts about future technologies, particularly because it is difficult to make predictions about the future. An attempt was made to interview a cross section of experts, however their opinions may be biased, depending on their expertise. Our focus was Australia, and the great majority of motor vehicle deaths occur in developing countries, Additionally, most vehicle technologies deployed in Australian vehicles are available as a by-product of international requirements or needs. Hence research and development and instalment of these technologies initially is focused predominantly outside of Australia.

It is important to evaluate safety technologies in real world situations so that the expected potential safety benefits are substantiated, and evaluations such as in EuroFOT (Malta et al., 2012) have indicated that for safety technologies they investigated (most of which were mentioned by the experts in the present study) there were indeed positive benefits.

We believe that a strong policy intervention would be justifiable for an effective vehicle safety technology. Consider a technology that is 20 per cent 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 per cent of the annual crash costs. Crash costs in Australia are roughly 25 billion dollars per year, and thus each year of delay in introducing such a technology will cost around five billion dollars.

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References

Anderson, R. W. G., Hutchinson, T. P., Linke, B. J., & Ponte, G. (2011). Analysis of crash data to estimate the benefits of emerging vehicle technology (CASR094). Adelaide: Centre for Automotive Safety Research.

Anderson, R. W. G., Doecke, S. D., Mackenzie, J. R. R., Ponte, G., Paine, D., & Paine, M. (2012). Potential benefits of forward collision avoidance technology (CASR106). Adelaide: Centre for Automotive Safety Research.

Assing, K., Baum, H., Bühne, J., Geißler, T., Grawengoff, S., Peters, H., Schulz, W. H., & Westerkamp, U. (2006). Socio-economic impact assessment of stand-alone and co-operative intelligent vehicle safety systems (IVSS) in Europe (Deliverable D3). Delft, The Netherlands: eImpact Consortium. Viewed online, August 2015, from: http://www.eimpact.info/download/eIMPACT_Deliverable_D3_V10_061214.pdf

Austroads (2013). Vehicle Positioning for C-ITS in Australia (Background Document) (AP-R431-13). Sydney: Austroads.

Chauvel, C., & Haviotte, C. (2011). eCall System; French A Posteriori Efficiency Evaluation. Proceedings of the Twenty Third International Conference on Enhanced Safety of Vehicles. Washington DC: National Highway Traffic Safety Administration.

COWI (2006). Cost-benefit assessment and prioritisation of vehicle safety technologies (Report No. TREN-ECON2-002). Germany: European Commission Directorate General Energy and Transport.

Doecke, S. D., & Anderson, R. W. G. (2014). The safety potential of connected vehicles. Australasian Road Safety Research, Policing and Education Conference, Melbourne, Victoria, 12-14 November 2014.

Malta, L., Aust. M., Faber, F., Metz, B., Pierre, G., Benmimoun, M., Schäfer, R. (2012). Final results: Impacts on traffic safety (Deliverable 6.4). Aachen, Germany: European large-Scale Field Operational Tests on In-Vehicle Systems. Viewed online, August 2015, from: http://www.eurofot-ip.eu/download/library/deliverables/eurofotsp620121121v11dld64_final_results_impacts_on_traffic_safety.pdf

Moore, D. F. (1970). Minimization of occupant injury by optimum front-end design. Paper No. 700416, Society of Automotive Engineers.

NHTSA (2014). Federal Motor Vehicle Safety Standards; Rear Visibilty. 79 FR 19177. Retrieved April, 2014, from https://www.federalregister.gov/articles/2014/04/07/2014-07469/federal-motor-vehicle-safety-standards-rear-visibility#h-43

NRMA (2014). Two thirds of Australian drivers don’t know what ABS is [press release]. Retrieved 22 April, 2014, from http://www.nrma.com.au/two-thirds-australian-drivers-don’t-know-what-abs

Paine, M., Healy, D., Passmore, J., Truong, J., & Faulks, I. (2008). In-vehicle safety technologies - Picking future winners. In R Anderson (Editor), Proceedings of the Australasian Road Safety Research, Policing and Education Conference, pp. 378-394. Walkerville, South Australia: Department for Transport, Energy and Infrastructure.

R. L. Polk Australia Pty Ltd (2014). South Australian Safety Report: April-June. Melbourne: R. L. Polk Australia Pty Ltd.

Ponte, G., Ryan, G. A., & Anderson, R. W. G. (2015). An estimate of the effectiveness of an in-vehicle automatic collision notification system in reducing road crash fatalities in South Australia. Traffic Injury Prevention, iFirst.

Rosén, E., Källhammer, J., Eriksson, D., Nentwich, M., Fredriksson, R., & Smith, K. (2010). Pedestrian injury mitigation by autonomous braking. Accident Analysis and Prevention, 42(6), 1949-1957.

Searson, D. J., & Anderson, R. W. G. (2013). Potential effectiveness of seat belt interlocks. 2013 Road Safety Research, Policing and Education Conference, Brisbane, 28-30 August 2013. Retrieved online, January, 2014, from http://acrs.org.au/publications/conference-papers/database/

Searson D. J., Ponte, G, Hutchinson T. P, Anderson R. W. G., Lydon, M. (2014). Emerging vehicle safety technology. Research Report 14/03, Royal Automobile Club of Victoria (RACV) Ltd, Nobel Park North, Victoria.

Wu, J., Subramanian, R., Craig, M., Starnes, M., & Longthorne, A. (2013). The Effect of Earlier or Automatic Collision Notification on Traffic Mortality by Survival Analysis. Traffic Injury Prevention, 14(sup1), S50-S57.