Post-Crash Care: Technology to Summon Help

**CURTIN-MONASH
ACCIDENT RESEARCH CENTRE**

Faculty of Health Sciences

Curtin University

Hayman Road

Bentley WA 6102

Matthew Govorko; Lynn Meuleners
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Author(s)

Govorko, M., Meuleners, L.

Performing Organisation

Curtin-Monash Accident Research Centre (C-MARC)
Faculty of Health Sciences
Curtin University
Hayman Road
BENTLEY WA 6102

Tel: (08) 9266-9951
Fax: (08) 9266-2958
www.c-marc.curtin.edu.au

Sponsor

Road Safety Commission
Level 1, 151 Royal Street
East Perth WA 6004

Abstract

Time is a critical factor in managing road-related trauma, with the ideal trauma care system minimising the time from injury to definitive care. The aim of this review was to identify current and emerging technology that can support quicker emergency response times following a motor vehicle crash, as well as to identify additional initiatives across the post-crash care spectrum. The key technology identified was that of automatic crash notification (ACN) systems, with the published literature suggesting an estimated 1.5-10.8% fatality reduction with 100% deployment of this technology. This report also documents other post-crash care initiatives such as mandatory first aid training, motorcycle-specific first aid courses, and crash detection smartphone applications.

Keywords

Automatic crash notification; eCall; emergency response; post-crash care

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ACKNOWLEDGEMENTS

The authors would like to acknowledge Dominic Reay and Alan Crossman from the Department of Fire & Emergency Services for sharing their experiences with post-crash response.

ABBREVIATIONS

AACN	Advanced Automatic Collision Notification
ACN	Automatic Collision/Crash Notification
ATSB	Australian Transport Safety Bureau
BITRE	Bureau of Infrastructure, Transport and Regional Economics
EMS	Emergency Medical Services
EU	European Union
FARS	Fatality Analysis Reporting System
KSI	Killed or Seriously Injured
MVC	Motor Vehicle Crash
NHTSA	U.S. National Highway Traffic Safety Administration
RFDS	Royal Flying Doctor Service
RPH	Royal Perth Hospital
SA	South Australia
TRACE	Traffic Accident Causation in Europe
UK	United Kingdom
US	United States of America
WA	Western Australia
WHO	World Health Organization

EXECUTIVE SUMMARY

Introduction

Post-crash care aims to reduce the severity of injury and risk of mortality once a motor vehicle crash has already taken place. Time is a critical factor in managing road-related trauma, with the ideal trauma care system minimising the time from injury to definitive care. In Western Australia (WA), the primary issue relates to the time it takes to get to Royal Perth Hospital (RPH), the designated provider of major trauma services for adults in the state. For instance, it can take approximately 12 hrs from certain regional and remote areas compared to approximately 1hr in metropolitan Perth. However, once someone gets into the trauma system of care, their risk of death decreases (Fatovich et al., 2011). Therefore, the key issue for post-crash care is the initial notification to emergency services that a crash has occurred.

The principal aim of this project was to identify what current technologies are available to reduce response times following a motor vehicle crash, and to review the applicability of these technologies in WA.

The specific objectives of this investigation were to:

1. Identify available technologies that can support quicker post-crash response times;
2. Review the suitability of these technologies for use in the Western Australian context;
3. Review the literature surrounding the potential impact of automated crash notification systems on reducing killed or seriously injured (KSI) in WA, and
4. Identify additional initiatives that address aspects of the post-crash care spectrum, from time of crash to arrival at the hospital of definitive care.

Method

A systematic search of relevant databases, including Google Scholar, PubMed, ScienceDirect, ProQuest, and Scopus, was conducted using “key words” to identify local, national and international technical reports, peer reviewed journal articles, and conference proceedings. The desktop review also involved searching for, and obtaining, grey literature from relevant stakeholder websites. Some keywords used to obtain the literature included *“automatic accident detection systems”*, *“automated crash notification”*, *“automatic collision notification”*, *“eCall”*, *“crash notification delay”*, *“post-crash care”*, *“emergency response”* and *“emergency medical services”*.

Review Findings and Recommendations

The key technology identified was that of automatic crash notification (ACN) systems, which are designed to determine if a crash has taken place, contact and notify emergency services, and transmit pertinent information related to the vehicle type and crash location. As a result, ACN systems can reduce or eliminate delays in crash discovery and notification as well as provide accurate information to emergency services relating to the crash, such as GPS location, in order to improve response times and time to medical treatment.

No published studies were identified that conducted an evaluation of the impact of ACN systems on reducing road crash fatalities post-implementation. The studies identified in the published literature were ex-ante evaluations that estimated the effectiveness of ACN prior to it being implemented. However, no published studies were identified estimating the effectiveness of ACN systems in WA. Overall, two Australian studies were found: Lahausse, Fildes, Page, and Fitzharris (2008) estimated a 10.5% reduction in urban road fatalities and a 12.5% reduction in rural road fatalities due to ACN, and Ponte, Ryan, and Anderson (2016) estimated that full ACN deployment in SA would reduce all road crash fatalities by 2.4 to 3.8%. Furthermore, Ponte et al. (2016) reported that ACN would be most beneficial for crashes in rural areas where it would reduce all road crash fatalities by an estimated 3.1 to 4.6%. Previous studies conducted in Europe and the US estimate that fully deployed ACN or “eCall” systems can reduce road crash fatalities by between 1.5% and 8.6% per year.

The literature suggests that the greatest benefits of an ACN system would be for crashes occurring in regional and remote areas, on roads with low traffic density, at night, and for single-vehicle crashes and run-off-road crashes. However, there are a number of limitations and barriers that prevent the full benefits of ACN from being realised. For instance, the benefits of ACN are limited by market penetration and uptake rate, mobile network coverage, communication technology and emergency services availability, as well as the cost-effectiveness of mandatory installation.

This report also highlighted other post-crash care initiatives including the idea of mandatory completion of a first aid course for learner drivers, which is implemented in over half of EU countries; the requirement for a basic first aid kit to be in every vehicle; promotion and/or requirement for motorcycle riders to complete motorcycle-specific first aid training, such as the

Rider Down program; and the development and implementation of specifically designed smartphone apps as an alternative to in-vehicle ACN devices.

In light of the review, the following recommendations are proposed:

(i) Conduct a Stakeholder consultation to:

- identify areas for improvement and issues with the current post-crash care model.
- Discuss the feasibility and utility of implementing mandatory first aid courses for the following groups:
  - Learner drivers/individuals applying for learner's permit
  - Individuals applying for a motorcycle license
  - Individuals who are renewing a driver's license

Stakeholders should include: Department of Fire and Emergency Services, St John Ambulance (WA), WA Police, State Trauma Committee, Department of Transport and other stakeholders involved in trauma care/post-crash response.

(ii) Estimate the percentage of KSI crashes that occur outside mobile network coverage area in WA. This would provide a greater understanding of the potential effectiveness of in-vehicle ACN technology and/or a suitably developed crash detection smartphone app in the state.

iii) Conduct a trial of ACNs in government fleet vehicles operating in regional/remote areas.

1. INTRODUCTION

1.1 Background to Post-Crash Care

Post-crash response is considered to be the fifth pillar of road safety by the World Health Organization, following road safety management, safer roads and mobility, safer vehicles, and safer road users (World Health Organization [WHO], 2016). Emergency care is at the core of the post-crash response pillar and aims to reduce the severity of injury and risk of mortality once a motor vehicle crash (MVC) has already taken place (Safety Net, 2009; World Health Organization [WHO], 2016). Moreover, post-crash care can be considered in light of the Haddon Matrix where the emphasis during the post-crash phase is on life sustaining measures (see Table 1; Mohan, Tiwari, Khayesi, & Nafukho, 2006).

Table 1: The Haddon matrix.

Phase		Human	Vehicles and equipment	Environment
Pre-crash	Crash prevention	Information Attitudes Impairment Police enforcement	Roadworthiness Lighting Braking Handling Speed management	Road design and road layout Speed limits Pedestrian facilities
Crash	Injury prevention during crash	Use of restraints Impairment	Occupant restraints Other safety devices Crash protective design	Crash protective roadside objects
Post-crash	Life sustaining	First aid skill Access to medics	Ease of access Fire risk	Rescue facilities Congestion

Note. Retrieved from “Road Traffic Injury Prevention Training Manual,” by D. Mohan, G. Tiwari, M. Khayesi, and F.M. Nafukho, 2006, p.24. Copyright 2006 by World Health Organization.

1.1.1 The Phases of Post-Crash Response

Post-crash emergency response is time sensitive and can be broken down into a sub set of activities beginning with discovery of the crash, notification and activation of emergency medical services (EMS), response time, on-scene time, occupant retrieval, pre-hospital medical care, transport, and arrival at hospital (see **Figure 1**; BITRE, 2018; Wall et al., 2014). As such, there are multiple factors that can impact the outcomes of post-crash emergency response, such as discovery and identification of the crash, categorisation of patient injury severity, response times, training of personnel and bystanders, type of treatment at crash scenes, and transport to hospital-based emergency services (Wall, Woolley, Ponte, & Bailey, 2014).

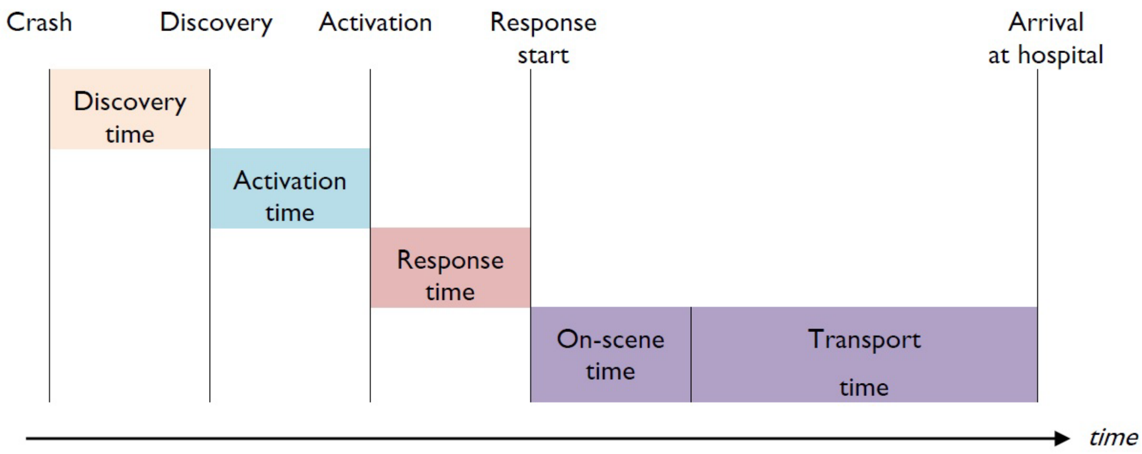

Figure 1: Emergency medical response timeline Gantt chart. Reprinted from "Location and other risk factors in crashes. Information sheet 97," by Bureau of Infrastructure Transport and Regional Economics (BITRE), 2018, p. 4. Copyright 2018 by Commonwealth of Australia.

1.1.2 The Importance of Response Time: 'Time is Traumatic'

Time is a critical factor in the management of trauma patients, such as those involved in motor vehicle crashes (MVC). Research indicates that the ideal system for managing trauma patients is one that minimises the time from injury to definitive care (Fatovich, Phillips, Langford, & Jacobs, 2011). Trauma literature frequently refers to the 'golden hour', which is a term often used "to characterise the urgent need for the care of trauma patients" (Lerner & Moscati, 2001, p. 758). Moreover, the golden hour refers to the first 60 minutes after an injury has occurred where trauma patients have the highest likelihood of better outcomes (i.e., reduced morbidity and mortality) if they are provided definitive care within this time period (Lerner & Moscati, 2001).

However, time from injury to definitive care at a tertiary hospital is prolonged for trauma patients involved in MVCs in regional and remote areas, impacting the applicability of the 'golden hour' principle (Bureau of Infrastructure Transport and Regional Economics (BITRE), 2018; Fatovich et al., 2011). The vastness of the road network throughout regional and remote Australia presents clear problems for post-crash emergency response and trauma management (Croser, 2003; Fatovich et al., 2011). As a result, access to emergency medical treatment following a crash differs between urban and rural areas: emergency response and retrieval times are significantly slower in rural areas, which consequently impacts on crash outcomes (Bureau of Infrastructure Transport and Regional Economics (BITRE), 2018; Fatovich et al., 2011).

Delays until discovery or delays in accessing the trauma system increase the risk of mortality following major trauma. In previous research conducted in WA, Fatovich et al. (2011) found that there was more than double the risk of death from major trauma in regional and remote areas. Using data from the state's Trauma Registries and the Royal Flying Doctor Service (RFDS) database for the period 1 July 1997 to 30 June 2006, 3333 major trauma patients who needed to be transferred to a hospital in Perth were identified. Mean times from major trauma to definitive care were significantly different between metropolitan and rural areas: 59 minutes versus 11.6 hours, respectively (see Table 2 for the differences in time intervals for each group). After adjusting for age and injury severity, the time prior to ambulance arrival was shown to be a significant predictor of the risk of death from major trauma; that is, the risk of death increases the longer it takes for the ambulance to arrive. Once the ambulance arrives, the risk of death decreases. Moreover, mortality outcomes are equivalent to the metropolitan area if rural major trauma patients survive to be retrieved by the RFDS and taken to Perth (Fatovich et al., 2011).

Table 2: The key time variables for each group. Observed time data, reported as geometric mean (95% CIs).

	Metro	Rural	*p*-Value
Time 1	18 min (17–19)	55 min (48–63)	<0.001
Time 2	43 min (41–45)	10.1 h (9.6–10.7)	<0.001
Time 3	59 min (57–61)	11.6 h (11.2–12.1)	<0.001

Time 1: time of trauma to time of first provider input (usually ambulance). Time 2: time of first provider input (usually ambulance) to time of arrival at tertiary hospital. In the Rural group, this time includes prehospital care, rural hospital care and RFDS retrieval care. Time 3: time of trauma to time of arrival at tertiary hospital Emergency Department. Note that time 3 does not equal the sum of times 1 and 2 because of different numbers of missing values.

Note. Retrieved from "A Comparison of Metropolitan vs Rural Major Trauma in Western Australia.," by D.M. Fatovich, M. Phillips, S.A. Langford, and I.G. Jacobs, 2011, *Resuscitation*, 82(7), p. 888. Copyright 2011 by Elsevier Ireland Ltd.

More recently, the Bureau of Infrastructure Transport and Regional Economics (BITRE) (2018) conducted a study looking at the location-specific factors that increase the likelihood of a person involved in a MVC being killed. The study used data from the National Crash Database for the period 2014 to 2016, with the final dataset including 227,566 individuals who were involved in 133,876 MVCs. The results showed higher road-related mortality in rural areas compared with urban areas, and that this was linked to the distance to a "Principal Referral Hospital's" healthcare as well as to the nature of rural areas themselves. Distance to the nearest Principal Referral Hospital can be considered a proxy for both access to pre-hospital emergency medical care and access to hospital care, due to these two types of access being highly correlated. More specifically, mortality increased with increasing distance between where a crash occurred and the nearest Principal Referral Hospital. The probability of mortality for an individual involved in a crash was 0.08% when 0 km from a Principal Referral Hospital and this increased by nearly 2.7% per 100km, or to around 0.09% when 500km from a Principal Referral Hospital. However, it should be noted that the results do not indicate whether it is access to hospital care or access to other emergency health care (i.e., first responders and other pre-hospital care) that is the primary cause of improved survival (BITRE, 2018).

Similar findings have been reported in the US. Previous research has found that occupants outside of a 60-minute coverage area had significantly greater odds of fatality as a result of a MVC, compared with those who were within a 45-min coverage area (National Highway Traffic Safety Administration, 2012). In particular, Wu, Craig, and Longthorne (2015) stated that there is a strong need to improve EMS arrival times in rural areas given that the rate of EMS arrival within 15 minutes is 20% lower in rural areas compared with urban areas and that over half of fatalities (approximately 61%) occurred in rural areas. As such, timely emergency care and earlier hospitalisation as a result of earlier crash notification may play a significant role in mitigating the impact of injuries sustained in a MVC (Wu, Craig, & Longthorne, 2015).

1.1.3 Post-Crash Care in Western Australia

Western Australia (WA) is the largest state in Australia, covering over 2.5 million square kilometres, with distances up to 2400km needing to be covered should an individual require treatment at a Level 1 Trauma Centre (Gupta & Rao, 2003). Consequently, the primary issue in WA relates to the time it takes to get to Royal Perth Hospital (RPH), the designated provider of major trauma services for adults in the State (a Level 1 Trauma Centre)(Gupta & Rao, 2003); for instance, it can take approximately 12 hrs from certain regional and remote areas compared to approximately 1hr in metropolitan Perth (Table 2). However, once someone gets into the trauma system of care, their risk of death decreases (Fatovich et al., 2011). Therefore, the key issue for post-crash care is the initial notification to emergency services that a crash has occurred.

However, post-crash response does not feature in the current Western Australian road safety strategy for 2008-2020 (Office of Road Safety, 2008). In a review of post-crash response arrangements in Australia and other countries, it was stated that the current road safety strategy documents from Australian jurisdictions rarely discussed the post-crash phase and, on the occasions where it was included, there was often limited detail (Wall et al., 2014). Currently, South Australia and New South Wales are the only Australian jurisdictions that include a discussion on post-crash response (Wall et al., 2014). Therefore, WA is looking to feature post-crash care in the post-2020 State road safety strategy. One of the key elements of this will be the integration of new and emerging technology that can improve emergency response times following a crash as well as the identification of other post-crash care initiatives.

1.2 Aims and Objectives

The principal aim of this project was to identify what current technologies are available to reduce response times following a motor vehicle crash, and to review the applicability of these technologies in Western Australia (WA).

The specific objectives of this investigation were to:

1. Identify available technologies that can support quicker post-crash response times;
2. Review the suitability of these technologies for use in the Western Australian context;
3. Review the literature surrounding the potential impact of automated crash notification systems on reducing killed or seriously injured (KSI) in WA, and
4. Identify additional initiatives that address aspects of the post-crash care spectrum, from time of crash to arrival at the hospital of definitive care.

1.3 Significance

This project aligns with the Safe Vehicles cornerstone of the Towards Zero strategy through identifying emerging in-vehicle technologies, which could be used to improve the safety of the WA vehicle fleet. In particular, identification and adoption of this technology could play an important role in reducing response times and possibly improving survivability following crashes occurring in regional and remote WA. Moreover, post-crash care is likely to feature in the post-2020 State strategy, with implementation of such in-vehicle technology to support quicker response times being a possible factor.

2. METHOD

2.1 Ethics Statement

This project did not require ethics approval from the Curtin University Human Research Ethics Committee. The project only uses publicly available information and did not require the collection and/or use of data.

2.2 Literature Search and Retrieval

A systematic search of relevant internet databases, including Google Scholar, Medline, PubMed, ScienceDirect, ProQuest, and Scopus, was conducted using 'key words' to identify local, national and international technical reports, peer reviewed journal articles and conference proceedings examining in-vehicle technologies that notify emergency medical services of crashes as well as other post-crash response initiatives.

The desktop review also involved searching for and obtaining 'grey' or non-peer reviewed literature from relevant stakeholder and road organisation websites; that is, from various Australian state road and transport authorities, and from commercial companies involved in the design, manufacture and implementation of the identified technologies. Reference lists of the publications were reviewed for additional relevant literature.

Some key search terms used to identify and obtain the relevant literature included the following: '*automatic accident detection systems*', '*automated crash notification*', '*automatic collision notification*', '*advanced automatic collision notification*', '*eCall*', '*crash notification delay*', '*post-crash care*', '*post-crash response*' and '*emergency medical services*'.

The literature search primarily covered the period from the year 2000 onwards, and it only included publications available in English.

3. LITERATURE REVIEW PART 1: TECHNOLOGY TO SUMMON HELP

This section addresses objective 1: To identify available technologies that can support quicker post-crash response times.

3.1 Automatic Crash Notification (ACN) Systems

As defined by Ponte, Ryan, and Anderson (2016, p. 258), an automatic crash notification (ACN) system is “a technology that automatically activates an emergency medical response with minimal delay after a road crash has occurred.” These systems can go by various other names: e-Call devices, automatic accident detection systems and automatic collision notification (NB: for readability, the term ‘ACN’ will be used throughout this document and encompasses these and related terms). The primary goal of ACN systems is to improve emergency medical response times and times to medical treatment in an attempt to save lives and reduce disabilities from injuries. This is done through technology that automatically notifies EMS of a crash, thereby reducing – or even eliminating – delays in crash discovery and EMS notification.

ACN systems are designed to determine if a crash has taken place, contact and notify emergency response personnel of the crash, and transmit information related to the vehicle type and crash location (see Figure 2)(Bachman & Preziotti, 2001). Further to this, some systems allow manual dialling or can open a voice connection between the vehicle occupants and the emergency response centre (Bachman & Preziotti, 2001; Sihvola, Luoma, Schirokoff, Salo, & Karkola, 2009). More specifically, ACN systems are typically comprised of four main components: 1) sensors, which are generally at the front and sides of the vehicle; 2) the Sensing Diagnostic Module (SDM), which includes an accelerometer and event data recorder; 3) the Vehicle Communication and Interface Module, and 4) a cellular antenna (Lahausse et al., 2008). Sensors that are already present in most modern cars and used for safety systems, such as airbags and seatbelts, can also be used to detect if a crash has occurred and then trigger activation of an ACN system. In-vehicle telematics and Global Positioning System (GPS) can then be used to transmit pertinent location information to emergency services (Ponte et al., 2016). As such, the benefits of ACN are limited to faster notification times as the system only transmits vehicle (crash) location and identification information (Lee et al., 2017).

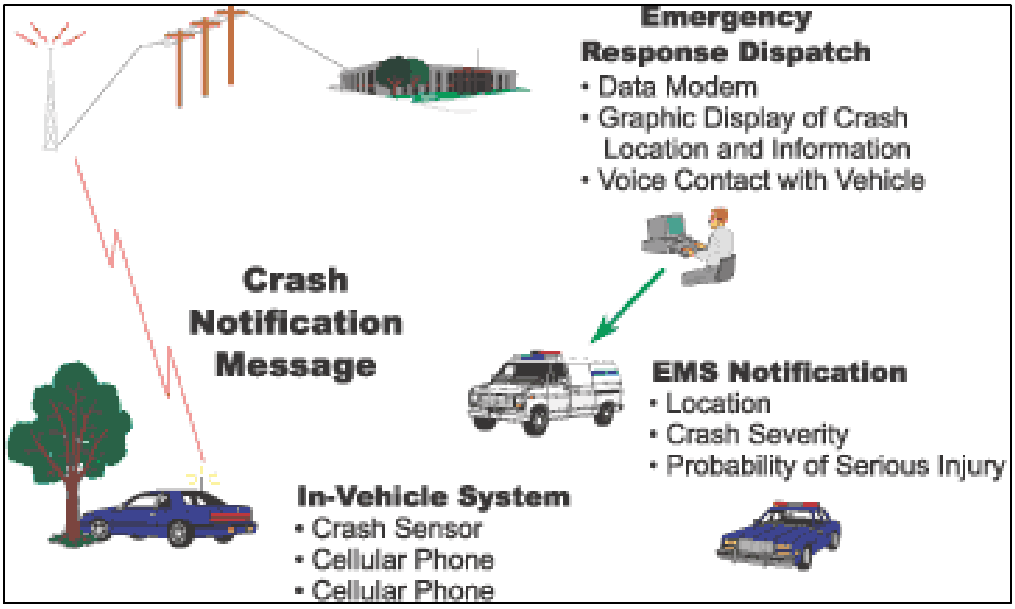

Figure 2: Example of ACN System. Reprinted from "Automated Collision Notification (ACN) Field Operational Test Evaluation Report," by L.R. Bachman and G.R. Preziotti, 2001, p. 21. Copyright 2001 by U.S. Department of Transportation, National Highway Traffic Safety Administration (NHTSA).

Further to the standard ACN technology, there has emerged the development of advanced automatic collision notification (AACN) systems. In addition to being able to execute the basic functions of an ACN system, an AACN system has the ability to calculate and transmit more detailed data, which relate to vehicle identification information (make, model, colour), the current vehicle location and a severe injury risk prediction (Lee, Wu, Kang, & Craig, 2017). AACN systems can improve the ability of first responders to identify the crash location and can provide an injury prediction that helps EMS to make more informed decisions about how and where to transport the trauma patient (Lee et al., 2017). Therefore, there are two principal ways in which AACN can potentially reduce the fatality risk of those involved in a crash: 1) by shortening the notification time and 2) by estimating injury severity (Jonsson, Lubbe, Strandroth, & Thomson, 2015).

3.2 Availability of In-Vehicle Crash Notification Systems

ACN technology has been available from some vehicle manufacturers since the late 1990s (Bachman & Preziotti, 2001; Wu et al., 2015), for example, OnStar by General Motors has been operating for over 20 years in the United States (US). However, there has been limited availability and uptake of this technology in Australia, but there are indications that this is changing. For example, Holden is planning to introduce OnStar into Australia during 2019, which offers automatic crash response (Poppitt, 2017). Similarly, Ford currently offers SYNC® Emergency Assistance with certain models that can make calls to emergency services through a paired phone within mobile network range if a crash causes the airbags to be activated or the fuel pump to shutdown (Ford Motor Company of Australia, 2018). A list of manufacturers offering in-built emergency call or ACN technology is presented in Table 3.

In particular, IMR Technologies, a Perth-based technology company, has designed the IMR Sentinel, which is an ACN device that can be fitted to new vehicles or retrofitted aftermarket. The device is certified for use in the European Union (EU) and complies with EU regulations. The company website states that it is easily installed and works in nearly any make or model. Key features of the IMR Sentinel include that it is a fully autonomous system that does not require the use of any other in-vehicle computers; can send automatic or manual emergency alerts to 000, 911 or 112 emergency services; records and transmits details pertaining to the location, vehicle, fire, immersion and hazmat; transmits data via satellite and GSM/GPRS (Global System for Mobile communications/General Packet Radio Service), and is constructed with an impact resistant glass fibre reinforced polycarbonate casing (IMR Technologies, n.d.). It is anticipated that the IMR Sentinel will be released to the Australian market in 2019.

Other aftermarket eCall devices have also been developed in Europe and the US that comply with the EU eCall deployment legislation. For instance, "**split**secnd" has been developed in the US and has been designed to plug into any vehicle's 12-volt outlet. The device includes an impact sensor, backup battery, internal GPS, help button, cellular module and speaker. **split**secnd uses the same type of sensor that triggers airbags in order to detect a crash. During crash testing, the device transmitted crash force data and GPS location to emergency services in 0.46 seconds, with two-way voice connection established in 7 seconds. The service requires a monthly subscription fee. Although it is claimed on their website that the device works anywhere in the world, no information could be located regarding its availability and capabilities in Australia (splitsecnd, 2017)

Table 3: List of select crash detection and emergency call technologies.

Product	Manufacturer	Available in Australia	Notes
IMR Sentinel	IMR Technologies	Planned	Can be fitted to new vehicles or retrofitted aftermarket.
OnStar	General Motors	Planned	Holden is planning to introduce OnStar (including automatic crash response) in Australia in 2019
Intelligent Emergency Call	BMW	Yes	System automatically detects vehicle position, if airbags have been deployed and if other damage has been sustained. Notifies BMW and information immediately sent to emergency services.
SYNC® Emergency Assistance	Ford	Yes	Makes an emergency call through a properly connected and compatible mobile phone. No subscription fee. Can set emergency contacts. Must be within mobile coverage.
mbrace	Mercedes-Benz	No	
On Call	Volvo	No	

3.3 Potential Impact of ACN Technologies in Western Australia

This section addresses objective 3: To review the literature surrounding the potential impact of automated crash notification systems on reducing KSI in WA. This section also summarises the crash and injury types that are most likely to benefit from ACN deployment.

Several studies have been conducted that provide estimates of the number of lives that could potentially be saved with full deployment of ACN or AACN systems in the passenger vehicle fleet. Although the potential benefits of ACN or AACN are most probably country dependent, due to the differences between countries (and even within countries) regarding their EMS operations, multiple studies support the potential effectiveness of these systems in terms of road crash fatality reductions. However, no studies were found that evaluated the effect of ACN on reducing KSI after implementation and no studies have been published examining the potential impact of

ACN in WA. The results of the most recent Australian and international studies from each country or jurisdiction are discussed below and summarised in Table 4.

3.3.1 Australian Studies

Only two studies were identified that have estimated the potential benefit of a fully deployed ACN system on reducing road fatalities in Australia as a result of improved crash-to-EMS notification times. The first of these predictive studies was conducted by Lahausse et al. (2008) as part of the European Framework TRACE (**Tr**affic **A**ccident **C**ausation in **E**urope) project.

Lahausse et al. (2008) obtained Australian road fatality data for the years 2001 to 2004 from the Australian Transport Safety Bureau (ATSB) and VicRoads and used mean response time data from a US study conducted by Evanco (1999). Assuming the deployment of an ACN system in all registered passenger vehicles in Australia, the authors calculated a 10.5% reduction in urban road fatalities and a 12.5% reduction in rural road fatalities due to ACN. This equates to approximately 104 road fatalities (Urban=40.7, Rural=63) saved each year by ACN in Australia, which would result in HARM fatality savings of $194,126,400 per year.

Further to this, Lahausse et al. (2008) evaluated the cost-effectiveness associated with installing ACN systems across the entire fleet of passenger vehicles in Australia. Based on their calculated benefit-cost-ratios, ACN would need to cost approximately $120 for a 15-year vehicle lifespan or $140 for a 25-year vehicle lifespan in order for ACN deployment across the entire passenger vehicle fleet to be cost-effective in Australia. This cost is very low and considered to be infeasible. Therefore, the authors concluded that ACN does not appear to be a cost-effective option for mandatory installation in newly registered passenger vehicles across Australia unless there was substantial government subsidization (Lahausse et al., 2008).

Nevertheless, it was predicted that ACN could prevent 10.8% of all passenger vehicle occupant fatalities in Australia due to improved crash-to-EMS notification times, with the greatest benefits estimated for road fatality crashes in rural areas. Therefore, if ACN systems are proven to be cost-effective in the future, then ACN should be mandated and the necessary infrastructure put in place in order for the full benefits to be realized (Lahausse et al., 2008).

The second Australian study was conducted by Ponte et al. (2016) who aimed to "estimate the potential effectiveness of a fully deployed automatic collision notification system in reducing fatalities in the state of SA" (p.259). Data were obtained from the traffic accident reporting system (TARS), coroner's reports and EMS road crash dispatch data for the period 2008 to 2009.

During the period 2008-2009, there was an EMS notification delay greater than 10 minutes for 25% (n=53/212) of road crash fatalities in SA. The majority of fatalities that had EMS notification delays occurred in rural areas (87%). More specifically, of the 53 fatalities with notification delays exceeding 10 minutes, 46 fatalities occurred from 37 crashes in rural areas and eight fatalities were the result of seven crashes in urban areas. Furthermore, two-thirds of the rural fatalities involved a single vehicle (67%), and more than half of the single-vehicle rural fatalities (58%) occurred late at night or early in the morning (i.e., between 9:00 p.m. and 6:00 a.m.), which is when traffic densities are low. The crash notification delays were always the result of the crash going unnoticed for a significant period of time until a passer-by realized a crash had taken place and notified authorities (Ponte et al., 2016).

Based on the forensic pathologist's details of sustained injuries provided in the coroner's reports, the authors also determined the likelihood of survival if there had been no delay in receiving EMS treatment for a subset of fatal crashes where there had been a delay. During the study period, five people were deemed as "likely" to have survived with earlier crash notification and quicker EMS assistance and three people "potentially" would have survived if surgical intervention or EMS assistance occurred more promptly (Ponte et al., 2016).

Overall, full ACN deployment in SA was estimated to reduce all road crash fatalities (i.e., including all vulnerable road user groups and all vehicle types) by 2.4 to 3.8%. The benefit is likely to be greater for passenger vehicle occupants with an estimated 2.6 to 4.6% fatality reduction. Furthermore, Ponte et al. (2016) reported that ACN would be most beneficial for crashes in rural areas where it would reduce all road crash fatalities by an estimated 3.1 to 4.6% and, more specifically, it would reduce passenger vehicle occupant fatalities by an estimated 2.8 to 4.7%. In contrast, ACN would reduce all road crash fatalities in urban areas by an estimated 1.2% to 2.4%, with effectiveness increasing to 2.2 to 4.4% when considering only passenger vehicle occupant fatalities. As such, if ACN was fully deployed in SA, then it would have potentially prevented two fatalities, and as many as four fatalities, each year during the study period, 2008-2009. Further, if the effectiveness rate was applied nationwide, then a fully deployed ACN system had the potential to prevent 35 to 55 fatalities annually in Australia during the same period (Ponte et al., 2016).

In summary, ACN was estimated to be most beneficial in rural areas and, specifically, for single-vehicle crashes and crashes occurring late at night or early in the morning when there are likely to be no witnesses to notify EMS. Ponte et al. (2016) noted that their estimates are likely to be conservative, but the evidence suggests that ACN systems would be beneficial and decrease the number of road crash fatalities. Despite this, the real benefits of ACN are yet to be determined and evaluated due to limited uptake and slow deployment of the technology. The authors also noted that it is unknown if the effectiveness of ACN technology will be reduced as a result of the increasing uptake of pre-crash systems in passenger vehicles, such as autonomous emergency braking and electronic stability control, which can prevent or reduce the severity of a crash (Ponte et al., 2016).

3.3.2 International Studies

There are a greater number of studies estimating the effectiveness of ACN, AACN or “eCall” systems when looking to those conducted outside of Australia. In particular, a range of studies were conducted in Europe that led to the passing of the eCall deployment legislation in 2015 making it mandatory for all newly registered passenger and light commercial vehicles in the EU to have GPS-enabled automated eCall emergency devices as of 31 March 2018 (European Parliament, 2018). Further to this, a number of studies have been conducted by the NHTSA in the U.S. The most recent studies from these regions are summarised below.

3.3.2.1 United States

Lee et al. (2017) aimed to determine the number of lives which could potentially be saved with full implementation of AACN across the U.S. vehicle fleet and to identify the target population who would most benefit from the system's deployment. To do this, Lee et al. (2017) used data from the Fatality Analysis Reporting System (FARS), 2009-2015 and National Automotive Sampling System-Crashworthiness Data System (NASS-CDS), 2000-2015. Based on these data, it was estimated that between 360 and 721 lives could potentially be saved each year in the U.S. with full deployment of AACN and universal cell coverage. Moreover, this represents an estimated fatality reduction rate of 1.6 to 3.3% annually (Lee et al., 2017).

Previously**,** based on FARS data for 2009 to 2012, Wu et al. (2015) estimated that earlier crash notification associated with ACN would result in a 1.5 to 2% fatality reduction annually (or approximately 177 to 244 fewer deaths) in the U.S. Moreover, notification times between 1 to 2 minutes were found to be most helpful for saving lives; later notification of greater than 2 minutes was associated with a relatively higher fatality hazard (up to 4% higher). Wu et al. (2015) stated that there is a strong need to improve EMS arrival times in rural areas given that the rate of EMS arrival within 15 minutes is 20% lower in rural areas compared with urban areas and that over half of fatalities (approximately 61%) occurred in rural areas. The authors also noted that, of the fatalities that occur within 6 hours of the crash taking place, the greater majority (86.6%) of drivers and passengers die within 0 to 100 minutes and nearly two-thirds (61%) die within 40 minutes of the crash, which emphasises the need for timely EMS notification and arrival. As such, crash survivability could be significantly improved as a result of earlier crash notification associated with ACN (i.e., less than 1-2 minutes) and the subsequent earlier EMS arrival times (Wu et al., 2015).

This is similar to earlier estimates based on FARS data from 2005 to 2009, in which Wu, Subramanian, Craig, Starnes, and Longthorne (2013) estimated that there would be an approximate 1.8% fatality reduction if ACN systems were present and used in passenger vehicles, light trucks and vans to notify EMS earlier. Likewise, Clark and Cushing (2002) used 1997 FARS data to estimate that there would be between a 1.5 to 6% reduction in annual road crash fatalities (or between 421 and 1676 fewer deaths) with full deployment of an ACN system in the U.S. Again, the findings suggest that ACN would have the greatest benefit for crashes in rural areas where there are longer EMS notification and response/arrival times (Clark & Cushing, 2002).

3.3.2.2 Europe

In Sweden, Jonsson et al. (2015) used data from the Swedish Traffic Accident Data Acquisition database for the period 2006 to 2014 and in-depth studies of fatal crashes to estimate the effectives of AACN in reducing road crash fatalities. It was estimated that there would be an 8.6% (95% CI = -0.3, 16.4) reduction in road crash fatalities with AACN use in Sweden (Jonsson et al., 2015).

Chauvel and Haviotte (2011) conducted *a posteriori* benefit evaluation of eCall in France, which included 418 occupants (drivers and passengers) involved in 202 crashes that occurred between 2004 and 2011. Based on 100% uptake of eCall in passenger vehicles only, Chauvel and Haviotte (2011) estimated a 2.8% reduction in fatalities. In particular, eCall was judged as being more “useful” when only considering single-vehicle crashes, with benefits increasing to 15.8%. Moreover, the benefits of the eCall system were reported to be the greatest for crashes occurring at night, in rural areas, and only involving a single vehicle (Chauvel & Haviotte, 2011).

In Finland, Sihvola et al. (2009) investigated road crash fatality data for the period 2001-2003, which included 1,080 fatal road crashes resulting in 1,192 fatalities. The results indicated that the notification delay could have been reduced in 30% of the fatal crashes if eCall was available. Delays in notification most frequently occurred for crashes on less trafficked roads (i.e., roads with low traffic density), at night, involving a single vehicle, and those involving animals. The authors reported that 3.6% of fatalities could “very probably” have been prevented with fully deployed eCall. If “possibly” preventable fatalities were taken into consideration, then approximately 4-8% of road fatalities may have been prevented. ACN systems were considered to have the greatest potential benefit for crashes where the call to emergency services would be made more than five minutes after the crash if such systems were not installed. There were substantial differences in the estimated effectiveness of eCall based on crash type; the system was estimated to be most effective for vehicles that eCall has not been designed for, such as motorcycles. Nevertheless, the example of Finland emphasises the benefits of an ACN system given the high percentage of crashes that occurred in rural areas (71%) during the study period (Sihvola et al., 2009).

In a report prepared for the European Commission, Francsics et al. (2008) summarised the results of 10 studies (i.e., eIMPACT, TRACE, AINO, SEiSS, SBD, Dutch eCall study, Austrian eCall study, ADAC study, E-MERGE review and Austrian eCall study) that evaluated the potential impact of eCall in countries across the European Union (EU). The estimated impact of eCall on reducing road crash fatalities varied between countries and studies; for example, 3% reduction in the UK, 3 to 9% in the Czech Republic, 2 to 4% in Sweden, and 4 to 8% in Finland. Results of the eIMPACT Project suggested that eCall would reduce road crash fatalities in EU-25 countries by 5.8% (3.6 – 7.6%), provided that there was 100% penetration of eCall across the European passenger vehicle fleet. Furthermore, there was an estimated 5 to 15% road crash fatality reduction across EU-25 countries in the SEISS study and a 5-10% reduction across EU-15 countries in the E-MERGE project (Francsics et al., 2008).

Table 4: Summary of estimated occupant fatality reductions associated with full deployment of ACN or AACN systems.

Location	Study Period	Type of System (ACN or AACN)	Estimated Effectiveness (i.e., % Fatality Reduction)	Reference
National				
Australia	2001-2004	ACN	10.8% reduction (passenger vehicle occupant fatalities)	(Lahausse et al., 2008)
South Australia	2008-2009	ACN	2.4-3.8% reduction (*all* fatalities) 2.6-4.6% reduction (only passenger vehicle occupants)	(Ponte et al., 2016)
International				
Sweden	2006-2014	AACN	8.6% reduction (95% CI = -0.3, 16.4%)	(Jonsson et al., 2015)
France	2004-2011	ACN/eCall	2.8% benefit	(Chauvel & Haviotte, 2011)
Finland	2001-2003	ACN/eCall	3.6% reduction (total preventive effect on road fatalities approx. 4%-8%)	(Sihvola et al., 2009)
USA	2009-2015 / 2000-2015	AACN	1.6-3.3% reduction	(Lee et al., 2017)
USA	2009-2012	ACN	1.5-2.0% reduction	(Wu et al., 2015)
USA	2005-2009	ACN	1.8% reduction	(Wu et al., 2013)
USA	1997	ACN	1.5-6.0% reduction	(Clark & Cushing, 2002)

3.3.3 Crash Types Most Likely to Benefit from ACN Technologies

A summary of the crashes for which ACN is likely to have the most substantial benefits is presented in Figure 3. The greatest benefits from ACN technologies are likely to be seen for drivers and occupants who are involved in crashes in regional and remote locations. Moreover, those involved in single-vehicle crashes and run-off-road crashes are likely to benefit from ACN, which are also the crash types that are characteristic of regional and remote areas. Crashes with no witnesses, no visuals (i.e., vehicle is not visible from the road), or reduced visibility (e.g., at night time) are also likely to benefit from ACN due to these crashes potentially going unnoticed or undetected from passers-by, thereby delaying crash discovery and notification if ACN is not equipped (Chauvel & Haviotte, 2011; Ponte et al., 2016; Sihvola et al., 2009).

In addition, the types of injuries most amenable to survival as a result of quicker emergency medical response due to ACN include those involving compromise to airways, for example, postural asphyxia and airway obstructions (Ponte et al., 2016). Furthermore, occupants who have any time sensitive trauma (e.g., brain haemorrhage or aorta laceration), an incapacitating injury where they are trapped in the vehicle, or are seriously or fatally injured (e.g., unconscious, internal bleeding, amputation or injuries to the vital organs) could also benefit from the quicker emergency response and medical treatment associated with ACN (Chauvel & Haviotte, 2011; Lee et al., 2017; Wu et al., 2015). Conversely, ACN technology is unlikely to benefit occupants who die on impact or within a few minutes of the crash occurring (Clark & Cushing, 2002; Wu et al., 2015).

It is expected that the benefits of ACN systems will also include improved quality of information for EMS personnel, which would result in quicker emergency response and arrival times. This is particularly the case for crashes where witnesses or those involved do not know or cannot identify the exact location where the crash occurred (Ponte et al., 2016; Sihvola et al., 2009). For instance, Sihvola et al. (2009) reported that emergency callers often mislocate or cannot identify the site of the crash. Furthermore, during preliminary discussions with the Department of Fire and Emergency Services (DFES), there was support for ACN due to the ability for the GPS location provided by the devices to guide fire and emergency response crews to the scene of the crash. It is common for vehicle occupants and/or bystanders who call emergency services to be unable to give the precise location of a crash, which can delay fire crews in extricating the casualties from the vehicles and subsequently delay the ability of paramedics to administer the required emergency medical care. Therefore, GPS-enabled ACN systems could resolve issues relating to communicating the precise location of a crash, which would be especially beneficial for those unfamiliar with their surroundings and in regional and remote areas (Ponte et al., 2016). As a result, it may be the accurate GPS location that facilitates quicker EMS arrival times to a greater extent than the reduction or elimination of notification delays (Sihvola et al., 2009).

Figure 3: Summary of crashes most likely to benefit from ACN technology.

Location

- Regional and remote
- Locations with no witnesses
- Involves occupants who do not know or cannot identify the location where the crash has occurred

Type of crash

- Single-vehicle crashes
- Run-off-road crashes

Conditions

- Reduced visibility (e.g., night time)
- No visuals (i.e., vehicle is not visible from the road)
- Low traffic density

Injury

- Time sensitive trauma (e.g., brain haemorrhage or aorta laceration)
- Compromise to airways (e.g., airway obstructions and postural asphyxia)
- Occupants seriously or fatally injured (e.g., unconscious, internal bleeding, amputation, injuries to the vital organs)
- Occupants incapacitated and/or stuck in the vehicle

3.4 Limitations and Barriers

This section addresses objective 2: To review the suitability of these technologies for use in the Western Australian context.

Despite the strong evidence for the positive impact ACN systems are predicted to have on reducing road crash fatalities, there are certain limitations of the aforementioned studies and barriers to implementing ACN in WA that need to be considered. The most notable limitations and assumptions include the following:

1. *Full deployment or 100% uptake of ACN or AACN systems across the vehicle fleet*

The market penetration rate of the system is a crucial factor in determining the effects of ACN. The studies assume an uptake or deployment rate of 100% (e.g., Chauvel & Haviotte, 2011; Lahausse et al., 2008; Sihvola et al., 2009). However, if a smaller percentage of vehicles are equipped with ACN (e.g., 50%), then the benefits would be much less than estimated in these studies (Sihvola et al., 2009). Ponte et al. (2016) note that market penetration is currently slow, and that this is a barrier to realising the full benefits from ACN technology. As discussed in Section 3.2, this may change alongside improvement to the availability of the technologies together with the required infrastructure.

2. *Only fatal crashes are considered*

The studies only considered fatal crashes and therefore did not assess the potential impact of ACN on serious injury crashes (e.g., Lahausse et al., 2008; Lee et al., 2017; Sihvola et al., 2009). For instance, Lahausse et al. (2008) noted that a limitation of their study was that it didn't consider the injury mitigation benefits that could be associated with improved emergency responses times due to automatic notification. Although, the major benefit of ACN/eCall systems relates to whether or not the casualty survives, which is captured in these studies.

3. *Universal mobile network coverage*

The majority of studies assume that there is universal cell coverage availability, even in regional and remote areas (e.g., Lee et al., 2017; Ponte et al., 2016). However, mobile coverage is very limited in certain regional and remote areas of WA; the areas that could see the greatest benefit from ACN deployment if the required infrastructure was in place. In the study conducted by Ponte et al. (2016), evidence was found to suggest that the network coverage could limit the effectiveness of ACN in SA. There was at least one fatality identified in their data set who may have survived if they received early medical treatment, however, the crash occurred in an area with no network coverage and therefore no automatic notification would have been sent (Ponte et al., 2016). Furthermore, Ponte, Ryan, and Anderson (2013) reported that during the period 2006 and 2011, between 4.8 and 30.6% of fatal and serious injury crashes in rural SA occurred in locations that did not have cellular coverage (depending on the type of mobile network). Consequently, an ACN system may have failed to notify emergency services of the crash in these instances.

It is currently unknown what proportion of KSI crashes occur outside the mobile network coverage area in WA and thus would not be able to utilize current ACN technology to alert emergency services. Therefore, it is recommended that a study be conducted investigating the percentage of KSI crashes that occur outside the current mobile network coverage area in WA.

4. *Communication technology & availability of EMS*

Similar to assuming 100% uptake of ACN and universal cellular coverage, the studies also assume that all emergency response centres have the necessary communication technology to receive the automatic notifications and that there is successful transmission of relevant information, such as crash location and vehicular information. Furthermore, the estimates of ACN in reducing response times are based on the assumption that, once notified, EMS are readily available to respond to each notification and attend to the crash without delay (Ponte et al., 2016). Additionally, an assumption is made that prehospital care providers fully utilise the information received from an ACN or AACN device (Lee et al., 2017).

5. *Subscription services*

A further potential barrier to market penetration is that some services require a subscription or annual fee, such as OnStar in the US.

6. *Cost-effectiveness of mandatory installation across the WA vehicle fleet*

Lastly, the cost-effectiveness of mandatory installation across the WA vehicle fleet could be a barrier to implementation. For instance, Lahausse et al. (2008) concluded that, based on their benefit-cost-ratio, ACN does not appear to be a cost-effective option for mandatory installation in all registered passenger vehicles across Australia unless there was substantial government subsidization. As stated in section 3.3.1, ACN would need to cost approximately $120 for a 15-year vehicle lifespan or $140 for a 25-year vehicle lifespan in order for ACN deployment across the entire passenger vehicle fleet to be cost-effective in Australia.

However, according to the European Commission (2018), eCall is not expensive and is estimated to cost less than € 100 per car. Moreover, they expect the cost to decrease due to economy of scale (i.e., all new cars registered in the EU as well as in certain neighbouring countries will be equipped with eCall) and that the cost of electronic components will decrease (European Commission, 2018).

Figure 4: Summary of limitations and barriers.

1. Benefits estimated based on full deployment or 100% uptake of ACN systems across the vehicle fleet
2. Only fatal crashes were considered in the evaluations of estimated effectiveness
3. Universal network coverage – however, mobile coverage is very limited in certain regional & remote areas of WA
4. Communication technology & availability of emergency medical services
5. Subscription services – for example, *OnStar* by General Motors requires an annual subscription fee in the U.S.
6. Cost-effectiveness of mandatory installation across the WA vehicle fleet

4. LITERATURE REVIEW PART 2: OTHER POST-CRASH CARE INITIATIVES

In addition to ACN systems, other post-crash care initiatives are beginning to be explored, developed and implemented in Australia and elsewhere. This section addresses objective 4: To identify additional initiatives that address aspects of the post-crash care spectrum, from time of crash to arrival at the hospital of definitive care.

4.1 Mandatory First Aid Certification & First Aid Kits

It is recognised that road traffic crashes and injuries are an important public health issue that requires both primary prevention initiatives and post-crash response initiatives (LeCornu, 2014; World Health Organization [WHO], 2016). Previously, St John Ambulance Australia (SJAA) has expressed concerns that "there is still no initiative to prevent the loss of life and serious injury between when an accident occurs and the arrival of emergency services" (LeCornu, 2014, p. 1). Furthermore, LeCornu (2014) stated that "current road safety initiatives do not prepare road users to act to save lives and reduce injury during an emergency–first aid does."

First aid is a crucial first step in providing an effective post-crash emergency response and can be critical for limiting the consequences of a crash for those involved (LeCornu, 2014; St John Ambulance Australia [SJAA], 2017). The first 3-5 minutes following a road traffic crash are crucial as it takes only minutes for an injured person to sustain an irreversible brain injury, or to die from severe bleeding or an obstructed airway if left untreated. However, the median response time for ambulance services to arrive at the scene is 8 minutes in Australia (St John Ambulance Australia [SJAA], 2017). As such, bystanders can play a significant role in delivering first aid prior to the arrival of emergency services, particularly in situations where there may be significant delays in the arrival times of EMS, such as crashes occurring in regional and remote WA.

Therefore, another post-crash care initiative is to make first aid certification a mandatory prerequisite for obtaining a driver's licence (D. Fatovich, personal communication, November 27, 2018). The Rural and Regional Affairs and Transport References Committee (2016, p. 51) has previously recommended that state and territory driver licensing authorities consider introducing mandatory first aid training as a prerequisite for receiving a learner's permit or renewing a driver’s licence. Mandatory first aid training could be delivered either online or in-person. Although it is optimal to deliver first aid training face to face, online courses are the next best option and have the added advantage of being easily and highly accessible. It is thought that a 30-minute online training course would not be too burdensome for those obtaining a learner’s permit or renewing a driver’s licence, but it could significantly increase safety on Australian roads (Rural and Regional Affairs and Transport References Committee, 2016). Furthermore, St. John Ambulance Australia has since released a position statement in full support of the implementation of compulsory first aid training for new drivers (St John Ambulance Australia [SJAA], 2017).

There already exists two web-based training courses: *Clicktosave* (www.clicktosave.com.au) run by St John Ambulance (Western Australia) and *First@Scene* (www.firstatscene.com.au) run by St John Ambulance (Northern Territory). These e-learning initiatives aim to reduce death and serious injury related to road traffic crashes by teaching the basic concepts and skills required to apply first aid at the scene of a crash. Each course takes approximately half an hour to complete and are provided for free. Notably, e-learning initiatives such as these can be developed at relatively low cost, are simple to administer and can be delivered en masse (LeCornu, 2014; Rural and Regional Affairs and Transport References Committee, 2016). It is possible that such e-learning courses could be adopted or used as a model for developing a mandatory first aid course for new drivers in WA.

First aid certification prior to receiving a driver’s licence has become mandatory in over half of the countries throughout the European Union (EU), for instance, in Austria, Germany, Hungary and Switzerland. Moreover, this prerequisite to receiving a driver’s licence has been in place in Austria since 1973 (International Federation of Red Cross and Red Cross Societies [IFRC], 2009). It is estimated that approximately 2.5 million learner drivers across Europe participate in mandatory first aid training each year, with an annual cost that is estimated to exceed 160 million Euros (Adelborg, Thim, Secher, Grove, & Løfgren, 2011).

However, there is a paucity of evidence supporting the courses. In an evaluation of the effects of mandatory first aid and basic life support course for learner drivers in

Europe, Adelborg et al. (2011) found that completion of the course improved participants' knowledge and self-assessed first aid skills. More specifically, 95% or more of the participants knew how to relieve a foreign body airway obstruction, knew the recommended compression-ventilation ratio during cardiopulmonary resuscitation (CPR), and were able to prioritise the treatment of several casualties (Adelborg et al., 2011). To the best of our knowledge, no evaluations of the impact of mandatory first aid on morbidity and mortality from road traffic crashes have been conducted or could be located in the peer-reviewed literature.

In addition to mandatory first aid, many European countries require all drivers to carry basic first aid supplies in order to increase the safety of road users (United Nations Economic Commission for Europe, 2010; World Health Organization [WHO], 2016). Generally, it is recommended that the first aid kit should be simple, appropriate and safe to use; affordable; easily replenished locally, including the inclusion of a limited number of products with expiry dates; and adapted to local practices and conditions (United Nations Economic Commission for Europe, 2010, p. 50). Although the requirements vary between countries for what specific items should make up the first aid kit, it is recommended that the kits should contain items that can do the following: remind the individual how to assist casualties (e.g., an information booklet with emergency numbers and instructions); protect the casualty from cold or heat (e.g., isothermal rescue blanket); control external bleeding (e.g., gloves, compress, and gauze); care for skin wounds (e.g., antiseptic protective barriers to prevent or limit infection); stabilise bone and/or joint trauma (e.g., triangular bandage); artificial respiration (e.g., face mask), and other miscellaneous items (e.g., pocket torch or flashlight to illuminate the scene)(United Nations Economic Commission for Europe, 2010). The requirement for each vehicle to be equipped with a basic first aid kit is an idea that could be considered for implementation in WA. However, no evidence could be found for the effectiveness of mandatory first aid kits in cars.

An alternative to mandatory first aid training is to run community awareness programs regarding first aid and basic life support at the scene of the crash. A possibility is an advertisement campaign/mass media campaign targeting bystanders at the scene of a crash that touches on the basics of life support and their important role. For instance, in preliminary discussions with DFES, it was stated that bystanders at the scene of a crash should look to (1) open obstructed airways, which often can be as simple as raising/tilting a slumped head back to an upright position, and (2) control any bleeding. It was noted that two of the most common, and sometimes treatable, causes of death relate to asphyxia and haemorrhaging (which can lead to cardiac arrest); however, many bystanders do not know how to address these issues. Furthermore, it was emphasised that community members should be aware of the dangers of dragging or extricating casualties from a vehicle prior to emergency services arriving.

4.2 Motorcycle-Specific First Aid Programs: Rider Down

Motorcyclists are only protected by their clothing, related protective gear and helmet, and therefore are at high risk of injury and mortality in the event of a crash. Consequently, motorcycle riders are largely considered to be a vulnerable road user group (Bureau of Infrastructure Transport and Regional Economics (BITRE), 2017; Christie, 2014; Motorcycle Safety Review Group, 2015). Furthermore, motorcycle riding exposure in Australia has increased significantly during the previous decade, with motorcycle registrations increasing by nearly 5% annually while there has also been a 4% per annum increase in the estimated kilometres travelled (BITRE, 2017).

For the ten-year period, 2007-2016, there was an estimated trend reduction in motorcycle fatalities in WA of 1.5% per annum (Bureau of Infrastructure Transport and Regional Economics (BITRE), 2017). Despite this, motorcyclist fatalities increased in 2016 (BITRE, 2017) and motorcyclists continue to be overrepresented in crash fatality statistics; for instance, in 2016, motorcyclist fatalities comprised 21% of road deaths in WA despite constituting only 5.8% of all registered vehicles in the state (i.e., 128,619 registered motorcycles and 2,208,812 total motor vehicle registrations)(Australian Bureau of Statistics, 2017; Road Safety Commission, 2018b).

Based on data from the Ambulance Clinical Information System and the State Trauma Registry for the period 1 July 2005 to 30 June 2010, the median response time from crash notification to arrival of the ambulance at the scene of a motorcycle crash resulting in major trauma was 16 minutes in Victoria. The place of injury and the time of call were major factors contributing to response times, with significantly shorter response times for motorcycle crashes occurring in metropolitan Melbourne. Furthermore, the median time from injury to arrival at the hospital of definitive care was 2 hours for motorcycle-related major trauma cases. Inter-hospital transfer was the strongest predictor of time to definitive care; there was an 8-fold increase in the mean time to definitive care for cases requiring inter-hospital transfer. Additionally, transport by air ambulance and crashes occurring in regional areas were associated with longer times to definitive care (Boufous et al., 2012).

Therefore, it is important that motorcycle-specific post-crash care initiatives be developed and implemented in the community in order to reduce motorcycle-related road trauma. An example is first aid programs tailored to motorcyclists. There has been growing support for first aid programs for motorcyclists as first-responders across Australia, UK and US. However, there is currently a lack of rigorous evaluations of these courses with respect to their effectiveness in improving emergency response and injury outcomes for motorcyclists who have been involved in a crash (Boufous et al., 2012). Nevertheless, it appears that these program have been well received among the motorcycling community, with anecdotal evidence that the training has been used in crash situations (Boufous et al., 2012).

A specific example of first aid training for motorcyclists is Rider Down™, which was established in response to the increasing number of motorcyclist fatalities in Australia. Rider Down™ is a WA-based organisation that offers nationally recognised training in First Aid and Emergency Response that is tailored specifically to motorcyclists/motorcycle rider injuries. It offers two motorcycle-specific courses: First Aid for the Motorcyclist (8 hour Provide First Aid course) and Fast Aid for the Motorcyclist (4½ hour workshop) (Rider Down, 2018). To the best of our knowledge there has been no rigorous evaluation of the program regarding its effectiveness in reducing motorcycle-related fatalities and injury outcomes; this is something that should be considered for future research. Despite this, it appears the program is well received among motorcycle riders and is recommended by those who have completed a course.

4.3 Smartphone Applications

As most people own a smartphone that includes an accelerometer, gyroscope and a GPS function, a suitably developed smartphone application (app) could achieve a similar result and be an alternative to in-vehicle ACN devices (D. Fatovich, personal communication, November 27, 2018). This idea has been explored and implemented in other countries, such as the UK and Canada, where the apps have specifically targeted motorcycle riders. Smartphone apps are an ideal platform for motorcycle riders because many of the ACN systems and eCall devices are yet to be adapted for use on motorcycles.

For instance, the REALRIDER® app offers a crash detection service across the UK (including England, Scotland, Wales, and Northern Ireland) and Canada, and it is available on both the iOS and Android platforms. REALRIDER® works by monitoring key sensors in the smartphone in order to detect changes that occur during a crash; for instance, rapid deceleration and tumbling motion followed by a period of no movement. If the app detects a crash, then it triggers an alert containing the motorcyclist's location, medical and contact details and sends it to emergency services via 999. If no emergency services are needed, then the app gives the rider 120 seconds to deactivate the main crash alert and no call will be made to 999; failure to deactivate the 120 second countdown will result in the call being placed. However, the app will only be able to send the alert if there is a network connection and mobile signal. Furthermore, this is a paid subscription service (approximately £3.99 per month)(Realsafe Technologies, 2017).

No evaluations of the effectiveness of crash detection smartphone apps on improving emergency response were identified in the published literature.

This is an idea that could potentially be explored for implementation in WA, especially when considering that motorcycle crashes in regional areas are more likely to result in a fatality and often involve a single motorcycle losing control (Motorcycle Safety Review Group, 2015); the types of crashes that are most likely to benefit from automatic notification technologies. However, similar to the barriers to in-vehicle ACN systems, mobile network coverage is very limited in regional and remote areas of WA. Therefore, network coverage would need to be improved in these areas if the full benefits of a specifically designed smartphone application were to be developed and deployed across WA.

5. CONCLUSIONS AND RECOMMENDATIONS

Post-crash care aims to reduce the severity of injury and risk of mortality once a motor vehicle crash has already taken place. Time is a critical factor in managing road-related trauma, with the ideal trauma care system minimising the time from injury to definitive care. This report identified and reviewed current and emerging technology that can support quicker response times following a motor vehicle crash as well as identified additional initiatives across the post-crash care spectrum.

The key technology identified was that of ACN and AACN systems, which have been deployed in other regions, such as the European Union. ACN systems are designed to determine if a crash has taken place, contact and notify emergency response personnel of the crash, and transmit information related to the vehicle type and crash location. As a result, ACN systems can reduce or eliminate delays in crash discovery and notification as well as provide accurate information to emergency services relating to the crash, such as GPS location, in order to improve response times and time to medical treatment.

There is currently limited availability and a low penetration rate of ACN technology in Australia. This is despite ACN technology having been available in certain overseas markets for over 20 years (e.g., U.S.) and it being made mandatory for all newly registered passenger and light commercial vehicles in the EU from 31 March 2018. However, there are indications that this may change in Australia with Ford providing SYNC® Emergency Assistance in certain models and Holden Australia announcing a planned introduction of General Motor’s OnStar in 2019. Notably, a Perth-based technology company, IMR Technologies, is planning to release the IMR Sentinel in Australia, which can be fitted to new cars or retrofitted aftermarket.

No published studies were identified that conducted an evaluation of the impact of ACN and associated systems on reducing road crash fatalities post-implementation. The studies identified in the published literature were ex-ante evaluations that estimated the potential benefits of ACN prior to it being implemented. However, no published studies were identified estimating the effectiveness of ACN systems in WA. Overall, two Australian studies were found: Lahausse et al. (2008) estimated a 10.5% reduction in urban road fatalities and a 12.5% reduction in rural road fatalities due to

ACN, and Ponte et al. (2016) estimated that full ACN deployment in SA would reduce all road crash fatalities by 2.4 to 3.8%. Furthermore, Ponte et al. (2016) reported that ACN would be most beneficial for crashes in rural areas where it would reduce all road crash fatalities by an estimated 3.1 to 4.6%. Previous studies conducted in Europe and the US estimate that fully deployed ACN or "eCall" systems can reduce road crash fatalities by between 1.5% and 8.6% per year (Chauvel & Haviotte, 2011; Clark & Cushing, 2002; Jonsson et al., 2015; Lee et al., 2017; Sihvola et al., 2009; Wu et al., 2015; Wu et al., 2013).

According to the Road Safety Commission (2018a), 161 individuals were killed in motor vehicle crashes on Western Australian roads in 2017. Assuming that the same ACN effectiveness rates could be applied to WA, approximately 2 to 17 lives could have been saved on WA roads in 2017 if an ACN system was fully deployed across the vehicle fleet. The literature suggests that the greatest benefits of an ACN system would be for crashes occurring in regional and remote areas, on roads with low traffic density, at night, and for single-vehicle crashes and run-off-road crashes.

However, there are a number of limitations and barriers that prevent the full benefits of ACN from being realised. For instance, the benefits of ACN are limited by market penetration and uptake rate, mobile network coverage, communication technology and emergency services availability, as well as the cost-effectiveness of mandatory installation.

In addition to ACN systems, this report highlighted other post-crash care initiatives that have been or could be explored, developed and implemented in Australia and elsewhere. These included the idea of mandatory completion of a first aid course for learner drivers, which is implemented in over half of EU countries; the requirement for a basic first aid kit to be in every vehicle; promotion and/or requirement for motorcycle riders to complete motorcycle-specific first aid training, such as the Rider Down program; and the development and implementation of specifically designed smartphone apps as an alternative to in-vehicle ACN devices.

5.1 Recommendations and Further Research Opportunities

In light of the above, the following recommendations are proposed:

(i) Conduct a Stakeholder consultation to:

- identify areas for improvement and issues with the current post-crash care model.
- Discuss the feasibility and utility of implementing mandatory first aid courses for the following groups:
  - Learner drivers/individuals applying for learner's permit
  - Individuals applying for a motorcycle license
  - Individuals who are renewing a driver's license

Stakeholders should include: Department of Fire and Emergency Services, St John Ambulance (WA), WA Police, State Trauma Committee, Department of Transport and other stakeholders involved in trauma care/post-crash response.

(ii) Estimate the percentage of KSI crashes that occur outside mobile network coverage area in WA. This would provide a greater understanding of the potential effectiveness of in-vehicle ACN technology and/or a suitably developed crash detection smartphone app in the state.

iii) Conduct a trial of ACNs in government fleet vehicles operating in regional/remote areas.

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