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Traffic Injury Prevention, 2016; 17(3):258-263

An estimate of the effectiveness of an in-vehicle automatic collision notification system in reducing road crash fatalities in South Australia

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ABSTRACT

Objectives: The aim of this study was to estimate the potential effectiveness of an in-vehicle automatic collision notification (ACN) system in reducing all road crash fatalities in South Australia (SA). Methods: For the years 2008 to 2009 traffic accident reporting system (TARS) data, emergency medical services (EMS) road crash dispatch data and Coroner's reports were matched and examined. This was done to initially determine the extent to which there was differences between the reported time of a fatal road crash in the mass crash data and the time EMS were notified and dispatched. In the sub-set of fatal crashes where there was a delay, injuries detailed by a forensic pathologist in individual Coroner's reports were examined to determine the likelihood of survival had there not been a delay in emergency medical assistance. Results: In 25% (N=53) of fatalities in SA in the period 2008 to 2009, there was a delay in the notification of the crash event, and hence dispatch of EMS, that exceeded 10 minutes. In the two-year crash period, five people were likely to have survived through more prompt crash notification enabling quicker emergency medical assistance. Additionally three people potentially would have survived if surgical intervention (or emergency medical assistance to sustain life until surgery) occurred more promptly.

Conclusions: The minimum effectiveness rate of an ACN system in SA with full deployment is likely to be in the range of 2.4% to 3.8% of all road crash fatalities involving all vehicle types and all vulnerable road users (pedestrians, cyclists and motorcyclists) in 2008 to 2009. Considering only passenger vehicle occupants the benefit is likely to be 2.6% to 4.6%. These fatality reductions could only have been achieved through earlier notification of each crash and their location to enable a quicker medical response. This might be achievable through a fully deployed in-vehicle automatic collision notification (ACN) system.

KEYWORDS

automatic collision notification, eCall, crash notification delay, emergency medical services

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INTRODUCTION

An automatic collision notification (ACN) system is a technology that automatically activates an emergency medical response with minimal delay after a road crash has occurred. Such systems have gained attention for their potential to improve times-to-treatment and for the claims that have been made regarding their utility in reducing road deaths through the opportunity for more timely treatment (Evanco 1996; Clarke and Cushing 2002; Wu et al. 2013).

In most modern vehicles, sensors used for existing safety systems (airbags, seat-belt pre-tensioners etc.) can be utilized to detect collisions and enable activation of an ACN system. Location information and communication of this information can be carried out through an integrated in-vehicle telematics/GPS system.

The impact of ACN systems is limited by several factors including market penetration (uptake is slow), successful detection of a serious collision, successful transmission of relevant information and establishment of communications.

Phases Of The Emergency Response

Evanco (1996) suggested that the effectiveness of the emergency response to a crash depends on time taken in the various phases that occur between the crash and the treatment of the injured person(s) in an emergency department of a hospital. These include the period between the crash and notification of the EMS, the period between EMS notification and arrival at the crash scene, and the period between EMS arrival at the crash scene and arrival at hospital (summarized in Figure 1). NHTSA (2001) discuss ‘crash notification time’, which incorporates the decision to notify, the time taken to contact and the actual call period to the emergency services (see Figure 1). Additionally, they note that the ‘decision period’ commences at the moment of injury and

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extends to the point of realization that emergency assistance is required. This period according to NHTSA (2001): "… varies greatly and is dependent on a number of factors including time of day, population density, traffic density, and random chance." It is this initial period that is most likely to be altered by an ACN system. Finally, Akella et al. (2003) proposed eight critical event times, which influence the four critical time intervals, shown in Figure 1.

Australian Crash Response - The Australian Emergency Call Service

In Australia there is a nationwide Emergency Call Service (ECS) with a primary emergency service number (000) which can be dialled on all fixed line and mobile telephones. In addition there are two secondary emergency service numbers: 112 (for use on digital mobile phones - particularly when there is no 000 mobile coverage) and 106 for the hearing impaired (Australian Government 2013).

With regard to a serious crash that requires urgent medical attention in SA, the sequence of events that occur in order to dispatch EMS is as follows (SA Ambulance Service 2013a, b):

- *t0* Crash occurrence (Crash Time)
- *t1* Contact made with the Emergency Call Service (000), the call is transferred to the relevant Emergency Service Organisation – in this case, SA Ambulance, Emergency Operations Centre
- *t2* SA Ambulance Emergency Medical Dispatch Support Officer acquires information about the crash and crash location from the emergency caller and transfers this information to:
- *t3* SA Ambulance Emergency Medical Dispatcher who coordinates ambulance resources and dispatches the SA Ambulance services required

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where *t0* to *t3* are defined as they are by Akella et al. (2003).

Previous Research On Potential ACN Effectiveness

A number of studies have examined the potential effectiveness of ACN. Evanco (1996) estimated that an ACN system that would reduce the EMS notification time to one minute would have reduced rural fatalities in the US in 1990 by 11.9%. Lahause et al. (2008) used a variation of Evanco's model to determine the likely effect of ACN on Australian passenger vehicle occupant fatalities and estimated that fatalities would be reduced by 10.5% and 12% in urban and rural areas, respectively. Clarke and Cushing (2002) estimated a fatality reduction in the US of between 1.5% and 6% with ACN and more recently Wu et al. (2013) estimated a 1.8% fatality reduction in the US with earlier crash notification.

A number of studies have also been conducted in Europe, where ACN systems are more commonly referred to as "eCall". The principles of eCall are similar to the ACN systems described above. In the event of a serious crash an emergency call is triggered (or can be manually triggered) and a voice link is established with the closest emergency service anywhere within the European Union. In addition, an emergency message is sent containing a minimum set of data (MDS) including the time, location of the crash and vehicle identifiers (European Parliament 2012).

Sihvola et al. (2009) evaluated the likely effect of an automated emergency call system on crash outcomes in Finland for all road fatalities (including unprotected road users such as motorcyclists, pedestrians and cyclists) and estimated that 3.6% of all fatalities may have been avoided with eCall. When considering only vehicles for which eCall can be fitted (passenger vehicles), 4.4% of vehicle occupant fatalities would probably have been avoided with eCall.

Chauvel and Haviotte (2011) examined crashes involving vehicles that were currently already fitted with eCall in France and related this to the fatalities in France and estimated that eCall, with universal deployment throughout France, may have a benefit of around 2.8% (119 fewer fatalities).

Chauvel and Haviotte (2011) and European Commission (2009) summarise other studies relating to eCall effectiveness. These studies estimated effectiveness in reducing fatal crashes ranging from 1% to 20%. Effectiveness rates for serious injuries are not as well studied, but a summary can be found in a report by the European Commission (2009). Estimates range from a 0.1% increase in injuries (when fatalities change to injuries) to a 7% decrease in serious injuries (shifting to less serious injuries).

AIM

The primary aim of this study was to estimate the potential effectiveness of a fully deployed automatic collision notification system in reducing fatalities in the state of SA. This paper documents the method and procedure used to determine the crash-to-EMS notification and dispatch periods for each fatal crash in SA for the period 2008 to 2009 and to identify crashes where there was a significant delay. Correspondingly, the sub-set of crashes identified as having a significant delay were examined in detail to estimate whether the reduction of the delays in those cases could have prevented deaths.

METHOD

Fatal crashes for the period 2008 to 2009 in SA were examined to determine which fatalities may have been prevented, had quicker medical response occurred through earlier notification of the crash. Three sources of data in SA were used:

- TARS data relating to all fatal crashes for years 2008 to 2009
- South Australian Ambulance Service (EMS) dispatch data relevant to each fatal crash
- Coroner's files pertaining to the sub-set of fatal crashes where there was a delay in crash notification

Determining Crash Notification Delays

Records of fatal crashes in SA were extracted for the period 2008 to 2009. There were 191 fatal crashes in SA in this period: 115 fatal crashes in rural areas resulting in 133 fatalities and 76 fatal crashes in metropolitan Adelaide resulting in 85 fatalities.

The crash times (*t0)* according to TARS were matched with data on dispatch times (*t3)* from the SA Ambulance Service (EMS) based on crash location. EMS dispatch times were used since actual notification times were unavailable for this study. Hence, while it is recognised the crash-to-EMS notification (*t1-t0)* is a critical period of time, this study considered the difference between the dispatch time (*t3)* and the crash time (*t0*). This difference (*t3-t0)* incorporates the crash-to-EMS notification delay (*t1-t0*), the elapsed time that occurs as a result of the acquisition of crash and location information from a caller (*t2-t1)* and the elapsed time before an ambulance can be dispatched (*t3-t2)*.

The period (*t3-t0)* was assumed to be a reasonable proxy for crash notification delays. Note that crash information obtained by the emergency medical dispatch support officers is electronically transferred to the emergency medical dispatchers immediately following, or even prior to the termination of an emergency call. Consequently, the delay (*t2-t1*) is likely to have a negligible effect on EMS dispatch delay. Further, Mayer (1980, p80) found that the "… the interval from the time an ambulance dispatcher is contacted until an emergency unit begins its response [i.e.,

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(*t3*-*t2)*], is typically less than one minute". Hence hereafter the period (*t3*-*t0)* incorporating each of the delays following the crash is referred to as the "EMS notification delay".

The Accuracy Of Recorded Crash Times

When a call is made to the emergency call service (000) in Australia, the caller is prompted with the option of one of three emergency services; police, fire or ambulance. Request for an ambulance is assumed to be the choice for a caller when a severe injury is suspected, and the call is subsequently transferred to the SA Ambulance Service. The emergency medical dispatch support officer retrieves the pertinent information from the caller to facilitate sending immediate assistance, providing first-aid advice and contacting the police and fire/rescue services. The information retrieved from the caller is electronically transferred to the emergency medical dispatchers who co-ordinate and dispatch the emergency medical resources. As a result of this process, EMS are dispatched at a precise time (*t3)*.

The recorded TARS crash times (*t0*) are a best estimate, as there is no means of knowing the precise crash time without an ACN system, a real-time synchronised vehicle event data recorder or an in-car GPS digital video recorder. Generally, for road crashes, crash times are estimates by investigating police officers. Crash times can be refined by major crash police investigators (for fatal crashes) as part of their investigation process and through witness interviews. Due to uncertainties, rounding errors, and the use of witness estimates, there can be some imprecision with crash times. This issue is recognised in other studies including NHTSA (2001) and Akella et al. (2003).

Defining Crash Notification Delays

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For this study the accuracy of the TARS reported crash time was not problematic as the difference between the precise time *t3* and the estimated *t0* served only as a filter to ascertain which fatal crashes had an unequivocal delay, that is, exceeding 10 minutes. The threshold of 10 minutes was selected to allow a level of tolerance for *t0* relating to estimation and rounding errors that may occur during the crash reporting procedure. This is consistent with other studies such as Brodsky (1993) who suggested time groupings of 0 – 4 minutes, 5 – 10 minutes and notification delays in the context of exceeding 10 minutes.

In cases where crash times in TARS were found to be inconsistent with EMS dispatch times due to possible rounding effects or missing/unknown EMS dispatch times, Coroner's files were examined to establish if a more accurate crash time could be estimated or indeed if there was a delay in EMS notification. This involved identification of the origin of the emergency call by examining witness statements made to police as part of a fatal crash investigation.

Generally the emergency call was made via a person who either observed the movements of the vehicle prior to the crash or witnessed the crash itself. In each of these cases, the emergency call was made very soon after the crash and hence it could be verified that there was little/no delay. There were 13 rural crashes and 17 urban crashes that were estimated to have had little or no delay in EMS notification, and while numerical values could not be determined, they were most likely less than five minutes and certainly less than 10 minutes. These were included in the 77 rural and 68 urban fatal crashes that were determined to have an EMS notification delay of less than 10 minutes (see Table 1). Additionally, in this sub-set of crashes, crash times extracted from Coroner's files were compared to the TARS crash times to reconcile any crash time differences.

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For the purpose of this analysis, all fatal crashes with an EMS notification delay exceeding 10 minutes were examined in detail.

Determining The Effect Of Significant Delay

Coroner's files that were available for the fatalities where there was a delay were individually examined. An assessment was made of the extent to which injuries (detailed by a forensic pathologist) were fatal because of any delay in timely medical or surgical intervention. Each fatality was then categorised according to whether ACN would have had a likely benefit, potential benefit or no benefit based on whether there was an EMS notification delay (*t3*-*t0*).

A likely benefit was assumed if the primary medical response team would have been able to adequately address the injuries at the crash site to sustain life and prevent the fatality. A potential benefit was assigned if the fatally injured person would have survived if a higher level of medical treatment was given at the crash site, or if emergency medical assistance might have sustained life until surgical intervention could occur at a hospital. If the fatality was the result of single or multiple injuries that were beyond the capability of medical or surgical intervention, no benefit was assigned. No benefit was also assigned for fatalities with an EMS notification delay of less than 10 minutes.

RESULTS

The distribution of fatal crashes where an EMS notification delay could be calculated is presented in

Figure 2. Fatal crashes where the EMS notification delays were estimated are also shown. The EMS notification delay was less than five minutes in around 32% of fatal rural crashes, less than 10 minutes in 69% of fatal rural crashes, and less that 20 minutes in about 81% of fatal rural

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crashes. In the remaining 18% of fatal rural crashes the EMS notification delays exceeded 20 minutes (Figure 2).

In urban fatal crashes there were fewer crashes with lengthy EMS notification delays. EMS were dispatched in less than five minutes in around 41% of fatal urban crashes, in less than 10 minutes in 89% of the crashes, and in less than 20 minutes for 97% of the crashes (Figure 2). In one crash in the urban sample EMS notification did not occur until several hours after the crash happened.

The 191 fatal crashes examined in this study resulted in 218 fatalities. At the time of the analysis, there were 212 finalised Coroner's files available for examination. Table 1 shows the breakdown of fatal crashes based on EMS notification delay. There were 37 fatal rural crashes with an EMS notification delay exceeding 10 minutes. These resulted in 46 fatalities. There were seven fatal urban crashes with an EMS notification delay exceeding 10 minutes; these resulted in eight fatalities. A Chi-squared test was undertaken to determine whether the differences in number of fatalities by area (rural/urban) and by EMS notification delay (less than 10 minutes/ greater than 10 minutes) were statistically different. It was found that the differences were significant at $p < 0.05$.

In all cases with a delay (except one urban fatal crash where the file was unavailable), Coroner's files were examined. There were two rural and one urban fatality where no EMS contact was made hence there was no EMS dispatch, in these cases a person was injured and alternative transport was used to deliver the injured to a medical treatment facility. These cases were also included in the sample for the analysis. Of the 212 fatalities included in the analysis, 53 fatalities (25%) had a delay between when the crash occurred and the EMS were notified with a majority of these fatalities occurring in rural areas (87%).

Fatalities in SA between 2008 and 2009 were predominantly passenger vehicle occupants (69%), motorcycle riders (14%) and pedestrians (10%). The types of crashes resulting in fatalities were predominantly those involving fixed objects (42%), rollovers (12%) and head-on collisions (11%). Males were involved in 76% of all fatalities, with 16 to 24 year old males making up the highest proportion all fatalities (27%) followed by 30 to 49 year olds males (25%).

In fatal crashes where there was a delay in EMS notification, earlier medical intervention would have been most beneficial for passenger vehicle occupants (the primary reason for the conception of ACN) as opposed to all road user types. The types of injuries sustained that were considered likely to be survivable included airway occlusions, crush injuries, postural asphyxia, fractured ribs, haemothorax, lung injuries, skull fractures with haemorrhages (without brain injury) or mild brain injury. The types of injuries that were considered to be potentially survivable were predominantly internal organ laceration resulting in fatal haemorrhaging. Injuries that were considered non-survivable generally involved single or multiple severe injuries that were beyond the capability of medical or surgical intervention.

ACN was found to be most beneficial in rural areas (Table 2). Three passenger car occupants and one heavy vehicle occupant are likely to have survived if they received earlier medical treatment. Additionally, two passenger car occupants potentially may have survived if their injuries could have been addressed more promptly. In the urban areas one passenger car occupant would likely have survived if they received earlier medical treatment and one passenger car occupant may potentially have survived if their injuries could have been addressed more promptly.

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Effectiveness Rates

Table 3 summarises the estimated effectiveness of ACN by area. The estimated effectiveness of ACN in rural areas (N=131) in reducing all road crash fatalities involving all vehicle types and all vulnerable road users (pedestrians, cyclists and motorcyclists) was in the order of 3.1% (likely benefit) to 4.6% (likely benefit + potential benefit). Considering only passenger vehicle occupant fatalities in rural areas (N=106), the effectiveness of ACN was in the order of 2.8% to 4.7%. For all urban fatalities in the sample (N=81) the overall effectiveness of ACN was estimated to be in the order of 1.2% to 2.4% (Table 3). Considering only passenger vehicle occupant fatalities in urban areas (N=45), the effectiveness of ACN was in the order of 2.2% to 4.4%.

Table 4 shows the aggregated rural/urban effectiveness of ACN for all 212 fatalities in the sample with a Coroner's file. The estimated ACN effectiveness is around 2.4%, but potentially as high as 3.8%. For fatalities that were passenger vehicle occupants the benefits are between 2.6% to 4.6%. This is summarised in Table 4.

DISCUSSION

In this paper we have attempted to estimate the potential benefit of ACN in SA based on a sample of all fatal crashes in the period 2008 to 2009. The majority of fatalities that had EMS notification delays occurred in rural areas (87%) and 67% of these rural fatalities involved a single vehicle. Additionally, more than half of the single-vehicle rural fatalities (58%) occurred late at night or early morning (the period 21:00 to 6:00) when traffic densities were low, which is consistent with NHTSA (2001). The delays in crash notification were always due to a crash going un-noticed for a substantial period of time until a passer-by realised a crash had occurred,

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and it is for these crashes that ACN is beneficial. This issue is ongoing and is unlikely to be resolved without a fully deployed and flawless ACN system.

Of the fatal crashes where there was a delay, an ACN system would have been beneficial in five cases. There were an additional three fatal crashes where there may have been some benefit, but this is on the basis that the ACN system would have facilitated a process allowing immediate surgical intervention or a person to present to a major trauma centre as a viable patient. The benefits of ACN in reducing the time between a crash and notification of EMS relies on an assumption that once notified, the EMS are able to attend the crash site and access the injured promptly and without delay. Although EMS arrival times were unavailable for this study, Coroner's reports were again examined to estimate the arrival times (*t4*) for each of the dispatched EMS. In each case the arrival times of the EMS were consistent with this assumption.

The minimum effectiveness rate of an automatic collision notification system in SA (with full deployment) is likely to be in the range of 2.4% to 3.8% of all fatalities. For passenger vehicle occupants the benefits were are likely to be 2.6% to 4.6%. Hence, it is likely that if it was fully deployed, ACN would have had the potential to save at least two lives but perhaps as many as four lives per year in SA in the 2008 to 2009 period.

According to Bureau of Infrastructure and Transport Economics (2012), 2,925 Australians were killed in road deaths between 2008 and 2009. Assuming the same ACN effectiveness rates for SA could be applied across Australia, a fully deployed ACN system had the potential to save between 35 and 55 lives per year nationwide during that period.

A previous study on the benefit of ACN in Australia by Lahause et al. (2008) estimated a 10.5% fatality reduction in urban areas and a 12% fatality reduction in rural areas for passenger vehicle

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occupant fatalities. This equates to 103.7 lives saved annually in Australia with full deployment of ACN with 95% effectiveness. We believe the estimates by Lahause et al. (2008) are optimistic, particularly given that they rely on an equation derived by Evanco (1996) using US rural fatal crash data from the 1990s. We believe our estimate of the benefit of ACN in SA is more likely to be applicable to Australia generally, as it considers the characteristics of individual fatal crashes that occurred recently. In our study the types of injuries consistent with survival (with earlier medical intervention) were those that involved compromise to airways, such as airway obstructions and postural asphyxia. Quicker medical responses to these types of injuries (facilitated through an ACN system) are those most amenable to survival. This is consistent with Ryan et al. (2004) that found that 1.9% of road fatalities in their sample (3 of 206) may have survived with 'immediate airway intervention' and Ashour et al. (2007) who found 4.8% of their sample (3 of the 62 motor vehicle fatalities) may have been prevented with earlier airway support.

There was evidence to suggest that ACN effectiveness may be limited in SA by network coverage. One fatal case was identified where early emergency medical assistance may have potentially prevented the fatality but there was no network coverage that would have enabled notification of the collision. There was an additional fatality where patchy network coverage affected the ability of the emergency call to be made and influenced the delay in notification. A study by Ponte et al. (2013) examined cellular coverage in Australia and found that depending on mobile network type, in between 4.7% and 29.9% of serious rural crash locations had no cellular coverage and an ACN system would have potentially failed in these cases.

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The benefits of post crash technologies such as ACN, offer a final opportunity to save lives in a serious crash. An ACN system can also resolve issues relating to conveying the precise location of a crash, to enable quicker EMS arrival. This would be particularly beneficial in rural and remote areas or for those unfamiliar with the environment they are in. However, it remains to be seen whether the effectiveness of such a technology will diminish with increasing prevalence of pre-crash technologies such as collision avoidance systems (eg. electronic stability control and autonomous emergency braking).

There is, however, quite a bit of confidence in ACN, particularly in the US, where advanced systems have been developed (AACN) that use vehicle crash characteristics (such as delta-V) to predict the probability of serious injury, to optimise injury triage and emergency resources (see Champion et al. (2004)). Confidence in ACN systems in Europe is also high, with a requirement for eCall to be fitted on all new models of cars and light vans from 31 March 2018 (European Parliament 2015).

A limitation of this study was a reliance on TARS crash times, which as previously discussed, are a best estimate, as there is no means of knowing the precise time of a crash. However, the purpose of comparing TARS crash times to EMS dispatch data was only to identify fatal crashes where there appeared to be a delay between when the crash occurred and when the EMS were notified and dispatched. In this subset of crashes, the delays identified were verified with information from the corresponding Coroner’s file. In the alternate subset of crashes where there were no delays identified, crash times were compared against crash times derived from the Coroner’s reports, and any discrepancies were reconciled.

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There were a considerable number of fatalities with a crash-to-EMS notification delay of less than 10 minutes that were not considered in the analysis. It is possible that some of these shorter delays may have also benefited from ACN, but no benefit was assigned in these cases. Hence the estimates in this study are likely to be conservative.

CONCLUSION

While the benefits of a fully deployed ACN system are modest, there is evidence to suggest that such a system can reduce the number of road crash fatalities. However, the actual benefits of ACN have not yet been determined due to slow deployment and limited prevalence. Material benefits of collision notification systems may not be seen for several years, even in countries with increasing ACN prevalence, until deployment rates have significantly improved.

ACKNOWLEDGEMENTS

This study was funded by the South Australian Department of Planning, Transport and Infrastructure (DPTI) through a Project Grant to the Centre for Automotive Safety Research managed through Matthew Leyson and Frances Doyle.

The Centre for Automotive Safety Research is supported by both the South Australian Department of Planning, Transport and Infrastructure and the South Australian Motor Accident Commission. The views expressed in this paper are those of the authors and do not necessarily represent those of the University of Adelaide or the funding organisations.

The authors would like to acknowledge the assistance of Stephen Bigg from SA Ambulance Service and the SA Ambulance Service for the provision of the ambulance dispatch paging system to The Centre for Automotive Safety Research (CASR) as part of a State Government funded project to conduct in-depth crash investigations in South Australia. The authors would

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also like to thank the Coroner's Court of South Australia for access to the Coroner's investigation files.

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Table 1 A summary of the relevant information pertaining to the fatal crashes with identifiable EMS notification delays.

	Rural			Urban		
EMS Dispatch	Fatal Crashes	Fatalities	Coroner Files	Fatal Crashes	Fatalities	Coroner Files
Greater than 10 minutes	37	46	46	7	8	7
Less than 10 minutes	77	86	84	68	76	73
No EMS notification	1	1	1	1	1	1
Total	115	133	131	76	85	81

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Table 2 A summary of the benefits assigned to rural and urban fatalities examined in Coroner's files by EMS notification delay interval.

	Rural Benefit			**Urban Benefit**			
EMS notification delay	Likely	Potential	None	Likely	Potential	None	Total
Greater than 10 minutes	4	2	40	1	1	5	53
Less than 10 minutes	-	-	84	-	-	73	157
No EMS notification	-	-	1	-	-	1	2
Total	4	2	125	1	1	79	212

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Table 3 All road crash fatalities and passenger vehicle occupant fatality benefits, disaggregated by area.

	Rural Benefit			**Urban Benefit**			
EMS notification delay	Likely	Potential	None	Likely	Potential	None	Total
All road crash fatalities	4	2	125	1	1	79	212
ACN Benefit	3.1%	1.5%	95.4%	1.2%	1.2%	97.5%	
Passenger vehicle occupant fatalities	3	2	101	1	1	43	151
ACN Benefit	2.8%	1.9%	95.3%	2.2%	2.2%	95.6%	

Table 4 State-wide overall benefit of ACN based on sample.

EMS notification delay	Likely	Potential	None	Cases
All road crash fatalities	5	3	204	212
ACN Benefit	2.4%	1.4%	96.2%	
Passenger vehicle occupant fatalities	4	3	144	151
ACN Benefit	2.6%	2.0%	94.1%	

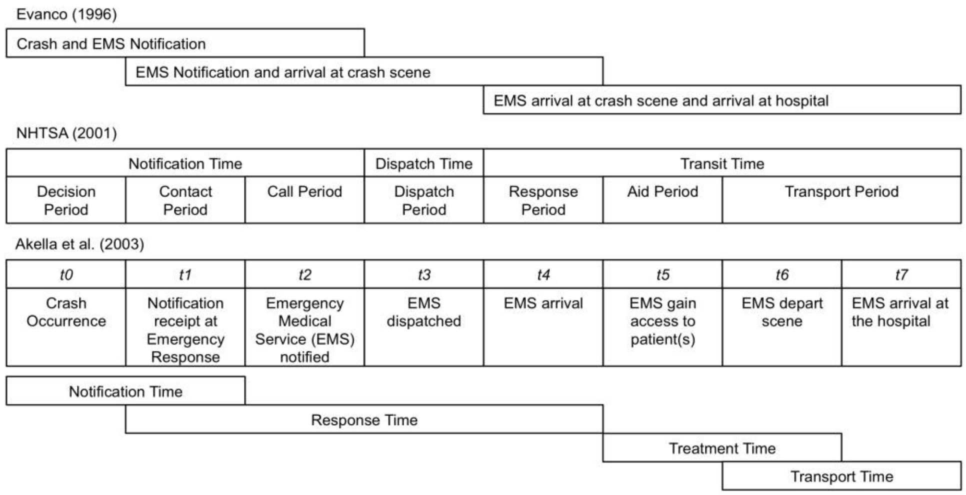

Figure 1 A summary of, and the equivalence between, the critical periods between the occurrence of a crash and delivery of injured to a hospital as described in Evanco (1996), NHTSA (2001) and Akella et al (2003).

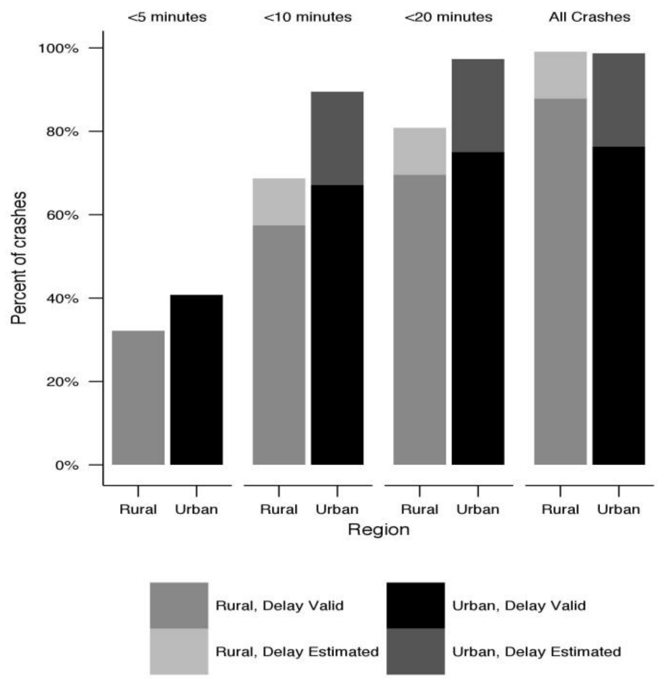

Figure 2 Proportion of rural and urban fatal crashes and the corresponding EMS notification delays.