Eur. Transp. Res. Rev. (2009) 1:99–105
DOI 10.1007/s12544-009-0016-3

ORIGINAL PAPER

In-depth evaluation of the effects of an automatic emergency call system on road fatalities

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Received: 9 April 2009 / Accepted: 8 October 2009 / Published online: 22 October 2009

Abstract
Purpose This study aimed to evaluate the effects of an automatic emergency call system on accident consequences in Finland (ex-ante evaluation). In addition, the effects of the system on emergency response times and the effects of real-time information about the accident location were assessed.
Methods The evaluation utilised in-depth accident reports collected by the road accident investigation teams during the period 2001–2003. The time delay between the accident occurrence and notification of the emergency response centre was estimated from information in the phone log of emergency response centres and from the information provided by the road accident investigation teams. Accuracy and potential errors by emergency callers in defining the accident site, as well as potential problems with rescue units finding the accident site, were examined with a survey sent to emergency response centres.
Results and conclusions The main finding showed that the system could very probably have prevented 3.6% of the road fatalities investigated. In addition, it was assessed that the total preventive effect on road fatalities could be approximately 4–8% if possibly preventable fatalities were taken into account. The system has the greatest potential to save lives in cases where the emergency call would, with no automatic emergency call system, be made more than 5 min after the accident. In conclusion, the system is recommended for immediate and widespread implementation in Finland.

Keywords Automatic emergency call system · eCall · Intelligent transportation systems · Road fatality · Accident consequence

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1 Introduction

Automatic emergency call systems aim to decrease road fatalities and injuries and to improve incident management. Specifically, these systems are designed to detect collisions, dial the emergency response centre, and transmit information such as vehicle position and type and severity of accident. In addition, many systems open a voice connection between the vehicle occupants and the emergency response centre and allow manual dialling.

The expected benefits include improved quality of information for rescue personnel, thereby resulting in faster rescue operations. Furthermore, the benefits are expected to be more substantial in cases where the occupants are unable to call for help, where they cannot identify the site, and where there are no external eyewitnesses, passing drivers and passengers, or patrols (e.g. [13, 15, 17]).

Reinhardt et al. [20] found that, in 70% of road accidents, the emergency call was made by somebody not involved in the accident. When this is the case, substantial delays may be caused, especially on roads with sparse traffic (see also [5, 9]). Moreover, Evanco [9] reported that, in the U.S. in 1990, the notification time covered 46% of the total time from accident occurrence to the arrival of emergency personnel. This finding suggests that there is a lot of room for improvement in emergency call systems, although the fact that cell-phone density is currently much higher in many countries than in the 1990s may already have shortened the notification time.

The first minutes are the most critical for recovery and severity of injuries. Earlier studies show that approximately 50% of fatalities occur within minutes, 30% within a couple of hours and 20% during the following days and weeks [2, 6, 17]. For example, Feero et al. [10] investigated whether out-of-hospital emergency medical service time intervals are associated with unexpected survival and death in cases of urban major trauma. The results suggested that a short overall out-of-hospital time interval may positively affect patient survival in the case of selected urban major trauma patients.

The effects of automatic emergency systems on delays, road fatalities and incident management have been investigated in many countries. For example, Lindholm [18] reported (on the basis of data collected in the 1990s) an almost 50% rescue time improvement in rural areas, with a net gain of almost 10 min. The largest time reduction was found in the communication between the vehicle and emergency call centre, but also a decrease in the time taken to detect and locate the accident was identified.

It has been estimated that the effects of the automatic emergency systems on the number of road fatalities range from 2 to 15% in Europe: 2–4% in Sweden [4], 2% in Great Britain, 5% in Germany, 7% in the Netherlands [14] and 5–15% in 25 member states of the European Union [1, 7, 14]. In the U.S. the estimates range from 1% to 6% [3, 5, 16, 17].

In addition, 3–15% of severe injuries could be reduced to slight injuries [1, 4, 14]. For slight injuries, no positive effect of eCall was foreseen [1, 4, 14]. In addition to direct safety effects, the automatic emergency call system is expected to improve incident management, which might result in avoiding further accidents and congestion [1].

Given the relatively large range of the effect estimates of earlier European studies, this study aimed to evaluate the effects of an automatic emergency call system on accident consequences in Finland (ex-ante evaluation). The evaluation concerned a particular system entitled eCall that has been defined as follows [8]: “The in-vehicle eCall is an emergency call generated either manually by vehicle occupants or automatically via activation of in-vehicle sensors. When activated, the in-vehicle eCall system will establish a voice connection directly with the relevant PSAP (Public Safety Answering Point), this being either a public or a private eCall centre operating under the regulation and/or authorisation of a public body. At the same time, a minimum set of incident data (MSD) will be sent to the eCall operator receiving the voice call.” The MSD includes for instance vehicle location information, time stamp, Vehicle Identification Number (VIN), and other relevant information.

The study aimed to provide an estimate based on local circumstances, such as accident profile, rescue operation procedures etc. Specifically, it is assumed that the profile of fatal road accidents in Finland might emphasise the benefits of the eCall system, because 71% of the accidents that included one or more motor vehicles in the period 2001–2003 occurred in rural areas, while the proportion of single-vehicle accidents was 41% [12]. An even more important motivation for the evaluation was the possibility of utilising in-depth accident reports collected by road accident investigation teams. While earlier studies were based on various statistical models and accident databases, this study was designed to conduct an in-depth evaluation of each fatal road accident that recently occurred in Finland. In addition to the evaluation of potential safety effects, we assessed the effects of the system on emergency response times and the effects of real-time information about the accident location.

Based on the basic functions of the eCall system, it was assumed that faster accident notification and improved location information (1) decrease the number of traffic fatalities (and severity of injuries in general) and (2) improve incident management. In addition, it was assumed that the system does not reduce the total number of accidents, except for a minor potential effect from avoided secondary accidents.

2 Method

2.1 Delays

The principles of the Finnish rescue operation are as follows: The main participating authorities in road accidents include emergency response centres, rescue service providers and police. In addition, private towing service providers are involved in the rescue operation, as well as the Road Administration’s Traffic Information Centre, which collects and conveys information via media to other drivers. Emergency calls are received by an operator in the local emergency response centre. If the caller cannot identify his or her location, the emergency centres currently receive an approximate location of the cellular phone based on the closest tower. Because the accuracy of the location information depends on the density of towers, the location information ranges from tens of metres in urban areas to kilometres in sparsely populated rural areas.

Firstly, the operator assesses the urgency of the case. If the call is assumed to concern a major accident or people are injured, the rescue operation is launched. The operator aims to identify the location of the accident and the number of injured persons. Secondly, on the basis of the received accident information, the required number and quality of rescue units are sent to the site. The first rescue unit is usually alerted within 30–180 s of the start of the emergency call. The rescue units are expected to leave within 1 min of being alerted.

The time delay between the accident occurrence and notification of the emergency response centre was estimated from information in the phone log of the emergency response centres and from the information provided by the road accident investigation teams (see below).

2.2 Accidents

The estimated number of fatalities that could be avoided using the eCall system was based on case reports made by road accident investigation teams in 2001–2003, with almost maximum penetration level of the cellular phone density. The teams investigate each fatal road accident in Finland that results in death within 3 days. The reports include information such as the following [11]: a detailed description of the event, the location and situation-related information, the use of safety devices, information about the users and vehicles, a police report of the accident, description of injuries and the total extent of injuries. Diseases and conditions are documented as well.

The accident data included 1,080 fatal road accidents that occurred in Finland, excluding the Åland Islands, involving 1,192 fatalities, of which 919 were motor-vehicle occupants and 261 were unprotected road users.

For the safety evaluation, the accident data was classified by type of fatally injured person(s): (a) motor-vehicle occupant and (b) unprotected road user. (There were no accidents involving both types of fatalities.) Furthermore, both categories were divided in two sub-categories as follows: The first category involving motor-vehicle occupants was classified by type of vehicle involved: (1) one or more motor vehicles for which eCall has been designed (i.e. cars, vans, lorries and buses) and (2) one or more vehicles for which the current version of eCall has not been designed (i.e. single-vehicle accidents involving motorcycles, mopeds and snowmobiles, as well as accidents involving one of these vehicles and a train or tram). It was assessed that the inclusion of the latter category could provide useful information, even though the results could not be applied as soon as those relating to the first category. The second category involving unprotected road users was classified according to whether any motor vehicle was involved.

2.3 Procedure of the evaluation

It was assumed that eCall would have been installed in each vehicle involved in these accidents, except for bicycles, trams and trains. Case reports made by road accident investigation teams were examined specifically focusing on the injury reports, estimated delays and the possibility of rapid medical treatment such as first aid. The following factors were gathered from reports: time and place of the accident, development of injuries, characteristics of injuries (principal and immediate cause of death), time and place of death, time of the accident based on the police report, time of the beginning of the accident investigation based on the police report, time of notification of police based on the police report, eye witnesses, manner of the request for help, estimated notification delay, and any problems in the determination of the accident site.

Firstly, the patients whose injuries had been fatal regardless of any immediate medical treatment were excluded from the data. Such injuries typically included major head, chest or cardiovascular injuries that resulted in immediate death. In addition, cases with no indication of delays and injuries rated as 6 on the Abbreviated Injury Scale (AIS) were excluded. Secondly, two medical doctors specialised in traffic accident traumatology categorised the remaining cases independently into two groups: (1) eCall could not have prevented the fatality and (2) the impact of eCall had to be examined from the original files of the road accident investigation teams. A case was categorised into the first group only if both doctors agreed. Thirdly, one of the doctors categorised the remaining cases (cases in group 2) based on examination of the original files of the road investigation teams into three groups: (1) eCall could very probably have prevented the fatality, (2) the very probable effect of eCall could not be authenticated, and (3) those with insufficient data (e.g. not enough information about injuries).

2.4 Location information

The survey form with a cover letter requesting voluntary cooperation was sent by e-mail to all emergency response centres in Finland. In total, 20 emergency response centres were involved. Recipients of the forms were requested to deliver one to each operator. The questions dealt with accuracy and potential errors in the definition of the accident site by emergency callers, as well as potential problems with rescue units finding the accident site. However, it is worth noting that the questions concerned all types of severe road accidents, because operators could not know at the time of the emergency call whether the accident resulted in fatalities.

3 Results

3.1 Fatality prevention

Overall, the main results showed that eCall could very probably have prevented 3.6% of the road fatalities (Table 1). However, there were substantial differences by

Table 1 Effects of eCall on the number of fatalities

Effect	Motor vehicle occupants (N)		Unprotected road users (N)		Overall (N)
	eCall designed for vehicle	eCall not designed for vehicle	Motor vehicle involved	No motor vehicle involved	
Very probable prevention	4.4% (39)	10.8% (4)	0.0% (0)	0.0% (0)	3.6% (43)
Very probable prevention could not be authenticated	94.2% (831)	86.5% (32)	100.0% (233)	100.0% (28)	95.2% (1,124)
Insufficient data	1.4% (12)	2.7% (1)	0.0% (0)	0.0 (0)	1.1% (13)
Total	100.0% (882)	100.0% (37)	100.0% (233)	100.0% (28)	100.0% (1,180)

accident type. The system would have been most effective in accidents involving vehicles for which eCall is not designed (i.e. motorcycles, mopeds etc.), followed by accidents involving vehicles for which eCall is designed (i.e. cars, vans, lorries and buses). The very probable effect of eCall could not be authenticated for any fatality resulting from the accidents involving unprotected road users. The proportion of single-vehicle accidents was high among accidents involving vehicles for which the system is not designed.

In addition to the very probable effect of eCall, it was ascertained that there were cases where the system might possibly have prevented the fatality. This proportion was approximately 5% for motor-vehicle occupants and 1% for unprotected road users, which means that the upper limit of the estimate would be roughly 8% ($3.6\% + [(882 + 37)*5\% + (233 + 28)*1\%]/1,180 = 7.7\%$). Consequently, these findings suggest that eCall could have prevented approximately 4–8% of the road fatalities that occurred in Finland during 2001–2003.

Fatalities that could probably have been prevented by eCall typically included the following types of injuries: Firstly hypoxia, frequently caused by drowning. There were cases in which a vehicle had overturned in shallow water or had driven directly into water and passengers were not able to exit the vehicle. Secondly, there were cases involving alcoholic abuse in which an occupant died because the passengers (with or without trauma) were so drunk that they were asleep or unable to recognise the gravity of the situation. Thirdly, sometimes there was no trauma that would have caused death, had help been available within a reasonable time. These cases included fractures to the ribs with slowly proceeding haematoma, and mild initial brain contusions in combination with breathing difficulties, leading to severe brain oedema. Many of the deceased people had had mild heart ischemia or non-traumatic brain bleeding or another severe disease. Finally, there were severe medical attacks in rural areas. It was assessed that in those accidents the occupant could have used a manual emergency button at the first onset of symptoms. In all cases, only those with close enough and realistic treatment resources were included.

3.2 Notification delays

Table 2 shows the estimates for delay between accident occurrence and notification of the emergency response centre.

Overall, more than 80% of emergency calls were made within 5 min of the accident occurrence. However, in 13% of cases the emergency call had been made 5–30 min after the accident occurrence, and in roughly 3% of cases more than 30 min after the accident occurrence. Long delays seem especially typical of accidents involving occupant fatalities in motor vehicles not designed for eCall, with a high proportion of single-vehicle accidents and animal collisions, followed by those involving unprotected road-

Table 2 Notification delays of fatal road accidents

Delay	Accidents involving motor vehicle occupant fatality (N)		Accidents involving unprotected road user fatality (N)		Overall (N)
	eCall designed for vehicle	eCall not designed for vehicle	Motor vehicle involved	No motor vehicle involved	
Less than 5 minutes	79.8% (579)	70.8% (17)	97.3% (215)	77.2% (21)	83.4% (832)
5 to 30 minutes	17.0% (123)	4.2% (1)	1.8% (4)	11.7% (3)	13.2% (131)
More than 30 minutes	3.2% (23)	25.0% (6)	0.9% (2)	11.1% (3)	3.4% (34)
Total	100.0% (725)	100.0% (24)	100.0% (221)	100.0% (27)	100.0% (997)

Table 3 Delays longer than 5 min by average daily traffic volume, time of day and accident type

	Percentage of delays longer than 5 minutes
Average daily traffic volume	
more than 10,000	0
5,000–10,000	2
2,000–4,999	10
500–1,999	21
Fewer than 500	29
Time of day	
23:00–04:59	43
05:00–22:59	10
Accident type	
Single-vehicle accidents	36
Accidents with animal	35
Other accidents	5

user fatalities and no four-wheel vehicle. Overall, the results suggest that eCall would decrease the notification delay in approximately 30% of fatal accidents.

Longer notification delays occurred more frequently on less trafficked roads, at night and in single-vehicle accidents, followed by accidents with animals (Table 3).

3.3 Location information

In total, of the survey forms sent to the emergency response centres 181 were returned, representing 18 of the 20 emergency response centres in Finland. The number of forms completed by individual emergency response centres ranged from two to 20.

The results showed that emergency callers frequently cannot locate the site of the road accident accurately or that they even mislocate the site (Fig. 1). There are also problems finding the accident scene, although these problems occur less frequently than when emergency callers provide inaccurate or insufficient information. Overall, the results suggest that systems such as eCall could improve the location information, and thereby speed up the arrival of rescue units, to an even greater extent than expected on the basis of a decrease in notification delays.

4 Discussion

This study was designed to conduct an in-depth evaluation of the potential safety effects of the eCall system. Specifically, the evaluation was based on in-depth studies of fatal road accidents that occurred in Finland during the period 2001–2003, and it was carried out prior to the implementation of

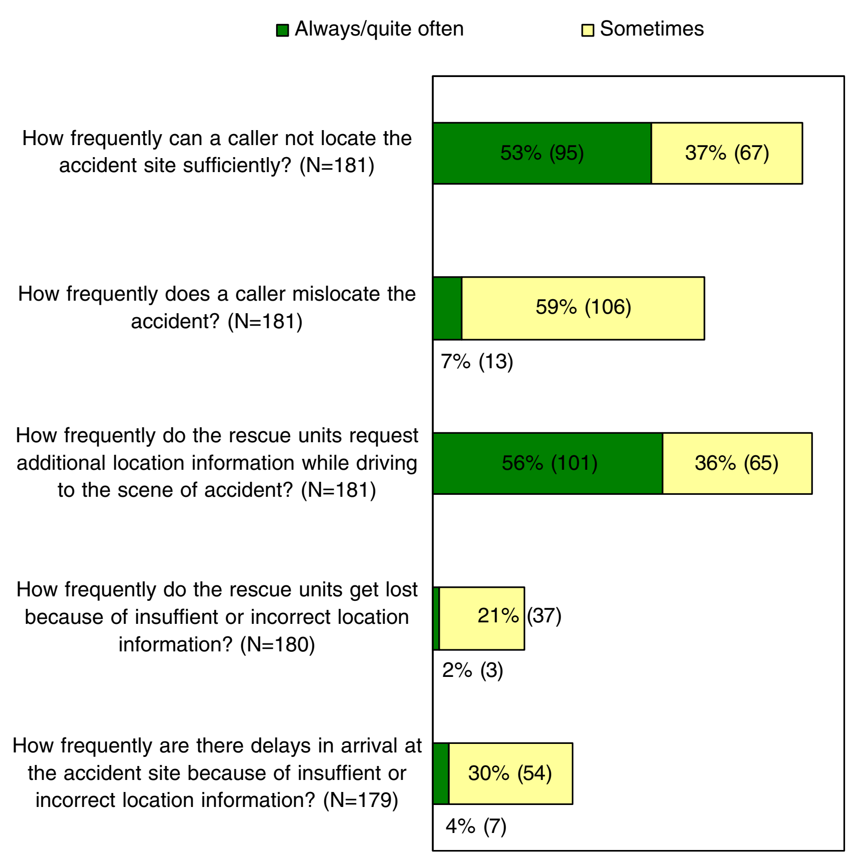

Fig. 1 Assessments by operators of the received location information, requested additional information, and frequency of delays (scale: always, quite often, sometimes, seldom, never)

eCall (ex-ante evaluation). In addition, we assessed the effects of the system on notification delays and the effects of real-time information about the accident location.

The main finding showed that eCall could very probably have prevented 3.6% of the road fatalities investigated. The most substantial safety benefits could be gained in accidents in which there were occupant fatalities involving motor vehicles for which the system is designed (i.e. cars, vans, lorries and buses). Moreover, the results showed that—in relative terms—the system would have been even more effective in accidents involving vehicles for which the system is not designed (i.e. motorcycles and mopeds etc.). The proportion of single-vehicle accidents was high among those accidents. No very probable safety effect was found on the fatalities resulting from accidents involving unprotected road users. In addition, it was assessed that the total preventive effect of eCall on road fatalities would have been roughly 4–8% if possibly preventable fatalities were taken into account.

The magnitude of the obtained effect was very close to the results obtained earlier. Given the differences in research methods, as well as in local road accident profiles, road networks and rescue procedures, it is not possible to analyse the differences in greater detail. However, the results of this study are assumed to be reliable because of the detailed analysis of all fatal road accidents that occurred in Finland over a period of 3 years and the fact that only a minimal proportion of cases had insufficient data. The results can be expected to be valid for similar countries as Finland (sparsely populated with long distances, high level of rescue service, low average annual daily traffic on motorways/main roads/secondary roads, and medium level of traffic management). For densely populated countries the effects are expected to be somewhat smaller.

The results showed that eCall has the greatest potential to save lives in cases where the emergency call would, with no eCall, be made more than 5 min after the accident. Consequently, eCall (equipped with accurate location information such as Global Positioning System, GPS) is expected to have the most substantial effects on minor rural roads, at night-time, and in off-peak traffic.

The answers of operators in the emergency response centres showed that the accident location is sometimes mislocated by the emergency caller, and that quite often the rescue units ask for additional information. eCall could provide accurate location information so that these sorts of problems can be avoided in the future, and rescue operations could proceed faster than is currently the case if caller is located based on the approximate location of the cellular phone. Because the percentage of long delays was substantial in accidents involving only vehicles for which the current system is not designed, it is suggested that eCall for motorcycles, mopeds etc. should be introduced as soon as possible. It seems obvious that the benefits of doing so would be remarkable if the reliability of the system were the same as, or better than, that for four-wheelers.

The effects of eCall depend on the penetration rate of the system (not investigated in this study). For example, if only 50% of the vehicles were equipped with eCall, the benefits would be lower than estimated in this study. However, the benefits do not decrease in linear relation to penetration rate, as in multi-vehicle accidents it is not necessary to have the system in each vehicle. Overall, further research should address these issues.

A comparison with the results of Brodsky [5] shows that the delays reported in the present study were much shorter. It is assumed that the difference is due mainly to the much higher penetration of cellular phones compared with the early 1990s.

In accidents involving a four-wheel motor vehicle and an unprotected road user, the notification delays were shorter than in multi-vehicle accidents. In other words, there is not a great deal of scope for eCall to shorten the delay. However, it is assumed that there might be some benefits in terms of improved location information, as the driver could generate a manual emergency call that is much easier than giving specific location information while in shock from the accident. Overall, the responses of the operators showed that eCall can improve the location information, as the information provided by emergency callers is frequently imperfect. This finding is in line with many other evaluations (e.g. [14]).

In conclusion, on the basis of the main findings of this study, the eCall system is recommended for immediate and widespread implementation in Finland. The measure is more effective than many other road-safety measures. In addition, there is usually no interaction with other measures, which implies that the effectiveness of eCall remains dependent solely on the number of severe road accidents. Finally, implementation of the system has the strong support of Finnish drivers [19].

Acknowledgements Appreciation is extended to the Ministry of Transport and Communications Finland, the Finnish Motor Insurers' Centre and the Emergency Response Centre Administration for support of this research through the AINO programme. The authors wish to thank the following persons and institutes for their assistance with this research: Anu Lamberg and Seppo Öörni of the Ministry of Transport and Communications Finland, Mikko Jääskeläinen of the Ministry of the Interior, Pekka Sulander of the Finnish Motor Insurers' Centre, Timo Ernvall of the Helsinki University of Technology, and Risto Kulmala of the Technical Research Centre of Finland.

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