TRAFFIC INJURY PREVENTION
2016, VOL. 17, NO. 3, 278–283
http://dx.doi.org/10.1080/15389588.2015.1062885

Taylor & Francis
Taylor & Francis Group

TECHNICAL NOTE

A new approach to road accident rescue

Alejandro Morales[a], Diego González-Aguilera[b], Alfonso I. López[c], and Miguel A. Gutiérrez[c]

[a]Departamento de Informática y Automática, Universidad de Salamanca, Salamanca, Spain; [b]Departamento de Ingeniería Cartográfica y del Terreno, Universidad de Salamanca, Ávila, Spain; [c]Departamento Tecnológico, Universidad Católica de Ávila, Ávila, Spain

ABSTRACT

Objective: This article develops and validates a new methodology and tool for rescue assistance in traffic accidents, with the aim of improving its efficiency and safety in the evacuation of people, reducing the number of victims in road accidents.

Method: Different tests supported by professionals and experts have been designed under different circumstances and with different categories of damaged vehicles coming from real accidents and simulated trapped victims in order to calibrate and refine the proposed methodology and tool.

Results: To validate this new approach, a tool called *App_Rescue* has been developed. This tool is based on the use of a computer system that allows an efficient access to the technical information of the vehicle and sanitary information of the common passengers. The time spent during rescue using the standard protocol and the proposed method was compared.

Conclusion: This rescue assistance system allows us to make vital information accessible in posttrauma care services, improving the effectiveness of interventions by the emergency services, reducing the rescue time and therefore minimizing the consequences involved and the number of victims. This could often mean saving lives. In the different simulated rescue operations, the rescue time has been reduced an average of 14%.

ARTICLE HISTORY
Received 30 October 2014
Accepted 12 June 2015

KEYWORDS
rescue time; road accident rescue; rescue sheet; QR code; golden hour; firefighters; health care services

Introduction

If passengers survive a road accident, the time taken to extricate them is, in most cases, vital for their survival. Sánchez-Mangas et al. (2010) analyzed to what extent a reduction in the time interval between a road accident and the arrival of the emergency services to the accident scene is related to a lower probability of death. Their results suggest that a 10-min reduction in medical response time can be statistically associated with an average decrease in the probability of death by one third, on both motorways and conventional roads. In fact, the well-known golden hour that encloses the 60 min after the road accident is critical with regard to health care to keep a victim alive (Sukegawa and Sekino 2011).

Due to the advances concerning safety in vehicles and the different propulsion systems, it is becoming increasingly necessary to have relevant information to perform quick and safe rescue of trapped victims. The new security elements of vehicles entail risk and difficulty when victims are trapped inside and they have to be extricated, so technical information about vehicles and their passengers could be crucial in order to optimize the rescue process. Although there are some studies about new extrication techniques, such as those by Wik et al. (2004) for frontal and side crashes and, more recently, specific measures for emergency rescue teams (Yu 2013) to ensure the safety of rescuers in secondary rear-end accidents, the possibilities offered by the new technologies have not been fully harnessed by emergency services as a support tool in traffic accident interventions. Therefore, it seems clear that the rescue time depends directly on the knowledge of certain information.

In order to reduce rescue time, the Allgemeiner Deutscher Automobil Club (ADAC) proposed the creation of a rescue sheet (RS) in 2009. It is a standardized record at the European level with technical information and security systems of the vehicle provided by the manufacturers, which must be considered by firefighters when performing rescue operations in order to reduce their response times. This sheet is the size of an A4, and it transforms all of the basic technical information into a graphical framework (that allows quick interpretation). Complementary to this, this sheet uses several colors and graphical symbols in order to represent the different security elements.

There is a gap in this context because the information provided by the paper-based RS is not easily accessible and the information provided is limited. In particular, the ADAC proposal is that drivers download and print the RS of their car on an A4 sheet and place it on the sun visor of the driver's seat. They must also place a sticker on the windshield indicating that the car carries the RS. Thus, in case of an accident firefighters know that the vehicle contains the RS and will try to locate the sun visor. Therefore, the analogic format and the location (inside the vehicle) of the proposed ADAC's RS often prevent its access. In addition, this sheet (which is printed on paper) can be lost or

CONTACT Diego González-Aguilera daguilera@usal.es Departamento de Ingeniería Cartográfica y del Terreno, Universidad de Salamanca, C\ Hornos Caleros 50, 05003 Ávila, Spain.

Associate Editor Richard Frampton oversaw the review of this article.
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/gcpi.

deteriorate. On the other hand, the proposed rescue sheet does not consider all of the relevant information (technical and biomedical) needed, which in many cases can be important.

Based on these gaps, we consider that better access and knowledge of certain information in road accidents could contribute to minimize rescue time and thus save lives. Focused on reducing the rescue time in traffic accidents, the present article aims to solve these drawbacks—that is to improve the accessibility and the quality of the information provided. For the former, quick response codes (hereafter QR) placed on strategic areas of the car were designed. Scientific studies using QR in this industry are not very common. Some authors such as Moharil et al. (2012) have used QR to provide an efficient approach to automatic number plate recognition but not for accessing RSs. For the latter, advanced technical information on the vehicle and biomedical information on the common occupants could be useful in supporting the rescue.

This article has been organized as follows: the following section describes the experiments designed to address the access to information and the reduction in rescue time. The next section presents the different tools developed and the experimental results conducted on several simulated cases in order to validate the new rescue approach and thus the reduction in time. The following section discusses the significance of our discovery, discussing how it accepts, rejects, or expands on existing discoveries. The article ends with future perspectives on the new approach proposed in the field of road safety.

Methods

In order to fill the gap noted in the Introduction, 2 different hypotheses have been taken into account:

Hypothesis 1: Analyze the format and location of the RS proposed by ADAC (sun visor of the driver's seat) in order to determine its suitability to guarantee the best accessibility. To this end, a study using 204 crashed vehicles provided by MAPFRE insurance company was carried out with the aim of finding out about the degree of accessibility. After this study, it seems clear that the access to information could be improved.

Hypothesis 2: Determine whether the information provided by the paper-based RS is enough for emergency services and, if not, how it could be improved. Firefighters from different communities in Spain (Cuenca, Tarragona, Toledo, Valladolid, and Avila), the Spanish Traffic Accidents Rescue Professional Association, and medical services specialist in road accidents were consulted. As a result of the feedback provided, relevant and useful technical and biomedical information was proposed to complement the RS.

Based on the hypotheses above and with the aim of minimizing rescue time, a computer system was developed to provide efficient access to technical information on the vehicle and sanitary information on the common passengers. Mobiles devices such as tablets or smartphones were used to yield better usability. To access information, QR codes were used because these codes provide quick access to information even when they are damaged, providing a clear advantage versus the paper-based RS. Despite the QR codes' simplicity, 3 key aspects have been analyzed for QR codes in order to optimize and calibrate the performance of the proposed system:

- The first aspect (Test 1) was to determine the minimum number of QR codes needed per vehicle and where they should be placed. These properties are key, because the QR codes give access to the information, taking to read at least one code (regardless of the accident conditions). For this reason a wide set of photos (437 photos in 142 interventions), taken by Avila's Firefighters, have been analyzed. In addition, 204 vehicles, provided by MAPFRE, were used to evaluate the optimum locations where the QR code could be placed. In all simulated situations, the least damaged areas were analyzed as well as the least affected zones, depending on the type of accident (frontal, lateral, spill, rear, etc.).
- The second aspect was to design a way of encoding the information enclosed by the QR code, establishing a numerical format that optimizes the storage capacity and the response time and avoiding that this information was accessible for other QR-based applications. (This aspect did not require a specific test.)
- The third aspect (Test 2) was to analyze its readability under real situations. To this end, several tests were performed after the accident and in nonideal situations (e.g. poor lighting conditions, partial loss of the QR code, etc.). This second test was used to determine the optimum properties of these codes, considering the ISO/IEC 18004:2006 guidelines:
  - The QR code size and the maximum distance from which this code can be read.
  - The resolution or number of readable points in the QR code. This determines the amount of storable data. Higher resolution implies more difficulty in reading.
  - Redundancy: The ability to restore information when the QR code is damaged. There are 4 classification levels (L, M, Q, and H) that include different restoration levels; for level H (the highest level), 30% of the information can be restored.

Finally the robustness and efficiency of the proposed approach was performed with a third test (Test 3) based on 8 drills (simulated accidents) designed in collaboration with firefighters and MAPFRE insurance company. To ensure objectivity in the results, 4 groups were established within the 8 drills, establishing 2 comparative studies: standard rescue vs. new rescue approach. In each one, 2 modern vehicles (less than 8 years old) were used with similar properties: (1) category; (2) number of doors; (3) similar damage; (4) final position; (5) security elements (airbags, protection sidebar, structural reinforcements, pretensioners, etc.); and (6) number of victims.

Results

The main result of our study has been the development of a computer system (Figure 1), *App_Rescue*, that improves accessibility and quality of information in road accident rescue. This system involves the development of 2 different modules: the first one, called *aWebRescue*, is a web application that allows the user to generate and print QR codes, including advanced technical information on the vehicle and sanitary information on the

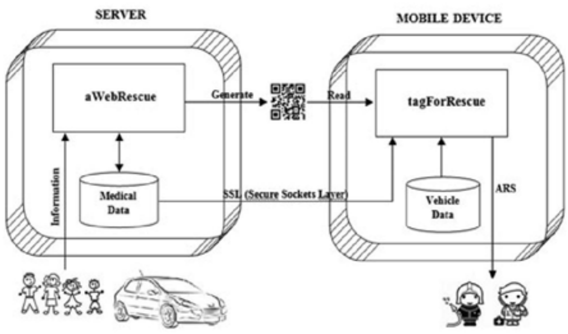

Figure 1. General diagram of the computer system, *App_Rescue*.

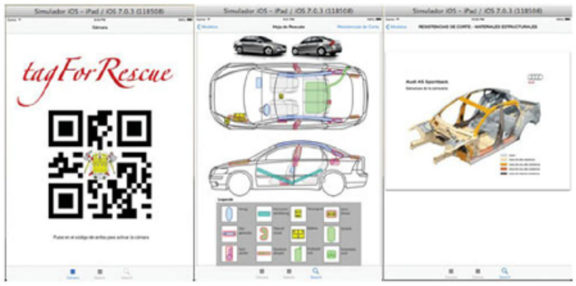

Figure 2. *tagForRescue* tool for reading and accessing RS and ARS information.

common passengers. The second component, called *tagForRescue*, is an application for smartphones and tablet devices that can only be used by emergency services.

The information provided by the computer system to emergency services is a key element to guarantee speed and reliability inroadaccident rescue. For this reason, and after Hypothesis 2 described previously, we found that there is technical and biomedical information that is not currently being shown by the paper-based RS to rescue services that couldbe useful to reduce rescue time and thus improve safety. In particular, the following information has been added to the RS:

- The type of fuel used by the vehicle.
- A 3D model of the vehicle chassis, including the manufacturing materials (e.g., steel, aluminum, magnesium, etc.) and their shear strengths.
- Additional security elements of the vehicle (e.g., armored windows, antiroll bars, panoramic roof, etc.).
- Relevant health information for the usual occupants to cover a first medical intervention. Specifically: blood type, chronic illnesses, medications, treatments, and allergies.

Based on this information we have created an *advanced rescue sheet* (hereafter ARS).

Regarding Hypothesis 1, a computer system with 2 different tools was developed (Figure 1):

- *aWebRescue*: A Web application programmed in PHP that allows drivers to generate and print their own QR codes encoding the ARS. Its friendly and ease-to-use interface is supported by a database that contains advanced technical information on the vehicle and sanitary information on the common passengers. The database connection is made through a safety protocol that guarantees data security and complies with the Spanish Organic Law on Data Protection (LOPD, 15/1999) . The information stored in the QR code that generates the application is also encoded by a numerical system, thus ensuring that personal information cannot be read by third-party apps. The open source library “PHP QR Code” was used to generate QR codes.
- *tagForRescue*: An app developed for smartphones and tablet devices and guarantees robustness, speed, and reliability in accessing advanced vehicle technical information and sanitary information on the passengers. This app was developed using object-oriented programming techniques and a model–view–controller architectural pattern for implementing the user interface. In particular, *tagForRescue* has been created for IOS and Android operating systems using XCode IDE and Studio 1.0 IDE, respectively. It makes use of 2 databases: a local database from which the technical information on the vehicle is obtained and a remote database from which the relevant health information on the common occupants is obtained. Thanks to the local database, minimal access (no Internet connection) to technical information is guaranteed. The connection to the remote database is done following a secure protocol to ensure confidentiality and data protection.

The application *tagForRescue* provides the following features to the user (Figure 2):

- By scanning the QR code using the camera of the mobile device: The application extracts numerical data from the QR code and makes a query to the local database and another query to the remote database in order to obtain health information on the common occupants. This advanced information (ARS) is shown structured in different screens, making management of the app easier.
- By reading a QR code from a picture stored on a mobile device: This option was designed in case the police or a witness arrived at the scene before emergency services. They could photograph the QR code and send it to emergency services. The application is able to read the code from a picture and performs the sequence of steps described in the previous option.
- By manually accessing the RS (without reading the QR code) from the brand and model of the vehicle or by a car model search system: This option is intended for the case in which it is not possible to read any of the vehicle's QR codes.

As mentioned in the Methods section, the number, location, encoding, and readability of QR codes are crucial factors for success with the computer system proposed. The following paragraphs describe in detail the different parameters proposed for these factors.

Based on the results of the first test (Test 1), the ideal number of QR codes to be used is 3, and the most suitable places to put them are as follows (Figure 3):

- The top corner of the windscreen (opposite to the cap of the fuel tank side), which is laminated and even when it cracks it does not break.
- Inside the protective door of the fuel tank, which protects the code when overturned.
- Next the rear plate.

Figure 3. Strategic QR codes' location in the vehicle: door of the fuel tank (top left), top corner of the windscreen (right) and next to the rear plate (bottom left).

The second test (Test 2) evaluated the possibility of incorporating different QR code types (size, resolution, and redundancy). The different sizes used were 5 cm wide (to be read from up to 1.5 m), 3.5 cm wide (with a reading distance of 0.85 m), and 2.5 cm wide (to be read from up to 0.50 m). Considering density as the variable, different QR codes were tested with the following values: 21 rows × 21 columns (QR-1), 25 rows × 25 columns (QR-2), and 41 rows × 41 columns (QR-6). Regarding the redundancy, all of the QR codes tested had an H class redundancy (allowing a high rate of correct reading if the QR code is damaged).

The codes were placed into 3 different positions:

- The first QR code was placed on the windshield (top corner), considering a total of 75 samples (damaged cars with different degrees of windshield fracture; Figure 3). These samples were distributed in 3 groups: (1) day samples (with natural lighting conditions); (2) sunset samples (with poorer lighting conditions); and (3) night samples (complemented with the use of a lantern, similar to those used by rescue professionals).

  As a result of the 75 different samples (Table 1), the best solution, with success rates of 88% (during the day and at sunset) and 83% (at night), seems to be the QR code with a 5-cm-wide, QR-2 density of points (25 rows × 25 columns) and H class.
- The second QR code was located at the back of the vehicle (next to the rear registration plate) in 37 rear-end accident vehicles with different degrees of damage.

As shown in Table 1, the best results were obtained from the QR-2 density of points, with a size of 5 cm wide and a level of redundancy of H. The identification was successful in 29 of the 37 cases. In the 8 remaining vehicles, the reading was not possible due to their level of damage.

The third QR code was placed inside the fuel tank door in 51 side-damaged cars. In this case, only 1 of the 51 tested vehicles had lost the fuel tank door, so the reading was successful in 98% of cases.

After Test 2 was conducted, it was confirmed that the most suitable features for reading the QR codes are a QR-2 density of points (25 rows × 25 columns), a size of 5 cm wide, and a level of redundancy of H. Likewise, it was confirmed that reading at least one of the 3 QR codes was possible in all of the analyzed crashed vehicles.

Finally, Test 3 allowed us to check the efficiency, robustness, and reliability of the computer system with regard to rescue time. To this end, vehicles of different brands and categories (ranging from compact utility cars to the largest executive cars, classic sedans, 4-wheel drive vehicles, and family cars) were analyzed with the tools proposed and compared with the standard protocol. Specifically, the following vehicle models were tested: Toyota Yaris, Peugeot 207, Volkswagen Golf, Seat Leon, Nissan Qashqai, Volkswagen Tiguan, Audi A4, and BMW 3 Series.

All rescues were carried out by the same team of firefighters, including 1 in charge of coordination and command and 5 effective rescuers. In addition, all tests were performed at the same time of day and with the same set of tools, so issues such as visibility, team experience, or fatigue of the members was not an influencing factor of final results.

Before starting the drills, a meeting was held to explain the operation of the developed system to the firefighters (location of the codes and the management of the *tagForRescue* application on an IPad 2). In order to make the drills as realistic as possible, firefighters were not allowed to see the conditions of the vehicles and were not guided on how to proceed with the rescues before the drills began.

In all case studies, the same procedure was followed. Firstly, the position of the vehicle was determined (complete rollover, side dump on all 4 wheels, etc.). Then, the number of trapped victims and the type of trapping was determined. Afterwards, the QR codes were generated with *aWebRescue* according to the parameters established in Tests 1 and 2 and fixed to the vehicles. Subsequently, the vehicle was placed in the chosen position and the simulated victims (firefighters) was introduced into the car. All vehicles were from real accidents, allowing the tests to be as reliable as possible.

Finally, firefighters performed the rescue while a witness timed and controlled the tasks taken by each firefighter at each different rescue stage.

In order to conduct a comparative study between the time spent on a standard rescue (protocol without RS) and the proposed one (*tagforRescue* protocol with ARS), 4 groups were established within the 8 drills. Each group includes 2 vehicles with very similar characteristics involved in the same type of accident.

- The first drill was performed with a Toyota Yaris (year 2010) and a Peugeot 207 (year 2008), both 3-door versions and from rollover accidents. A rollover accident with a conscious single victim (the driver) was simulated without trapped limbs. In both cases the extraction was performed by the tailgate of the vehicle.
- Both vehicles had a driver airbag, passenger airbag, side and curtain airbags, door reinforcing structures, and seat belt pretensioners. The Peugeot 207 had column reinforcements at the base and the top of the A-pillar, and the pillar and B-pillar ring were central, whereas the Toyota did not. Additionally, the Toyota Yaris had knee and head airbags, whereas the Peugeot 207 did not.
- The second drill was performed with a Volkswagen Golf VI (year 2009) and a Seat Leon (year 2010), both 5-door

Table 1. Satisfactory results (%) for the reading of QR codes with different densities and sizes, placed at the top corner of the windscreen and next to the rear plate.

	QR-1			QR-2			QR-6		
	5 cm	3.5 cm	2.5 cm	5 cm	3.5 cm	2.5 cm	5 cm	3.5 cm	2.5 cm
				Top corner of the windscreen					
Morning	68	73	83	64	72	88	57	60	71
Sunset	65	71	81	65	71	87	56	59	69
Night	68	73	83	64	72	88	57	60	71
				Next to the rear plate					
Morning	62	70	76	62	73	78	57	62	70
Sunset	57	65	70	57	70	76	57	59	68
Night	62	70	76	62	73	78	57	62	70

versions and from side impact collisions on the passenger side, being overturned onto the driver's side. A driver's side overturned accident with a conscious single victim (the driver) was simulated without trapped limbs. In both cases the extrication was performed by removing the vehicle's roof.

- Both vehicles had a driver airbag, passenger airbag, side and curtain airbags, door reinforcing structures, and seat belt pretensioners. The Volkswagen Golf had knee airbags and the Seat Leon did not.
- The third drill was performed with a Nissan Qashqai (year 2010) and a Volkswagen Tiguan (year 2010), both 5-door versions and from multiple-vehicle collisions with front-to-rear crashes. Thus, an accident with serious damage to both the rear and front with 2 victims (the driver and a passenger) was simulated. The driver was unconscious and trapped by the lower limbs. The passenger was conscious and without any trapped limbs. The rescue could not be performed by the tailgate due to the damage to the vehicles so it was carried out by removing the doors and the driver side's central pillar.
- Both vehicles had a driver airbag, passenger airbag, side and curtain airbags, door reinforcing structures, and seat belt pretensioners. The Volkswagen Tiguan had column reinforcements at the A and B pillars, whereas the Nissan Qashqai did not.
- The forth drill was performed with an Audi A4 (year 2010) and a BMW 3 Series E90 (year 2009), both 5-door versions and from front-passenger side collisions. Thus, an accident with serious damage to both the front and passenger side with 2 victims (the driver and a passenger) was simulated. Both victims were conscious and only the passenger was trapped by the lower limbs. The rescue was performed by the side of the vehicles.
- Both vehicles had a driver airbag, passenger airbag, side and curtain airbags, door reinforcing structures, and seat belt pretensioners. The Audi A4 had structural reinforcements in the post, the B-pillar, and the lower horizontal crossbar, whereas the BMW 3 Series E90 did not.

All analyzed drills were timed for each phase and task, for both the standard protocol (without RS) and the proposed one (*tagforRescue* with ARS). Table 2 shows the results for each of the drills.

The total rescue time was reduced by 16.8% using the proposed system in the first rescue, 28.7% in the second, 14.8% in the third, and 13.2% in the fourth. The average rescue time was reduced by 14% by using the proposed system.

Discussion

The importance of the new approach proposed for road accident rescue is that thanks to the information provided, ARS, and the computer system developed, *App-Rescue*, more lives can be saved. In addition, the proposed system solves the problems noted for the paper-based RS, because the information can be accessed more efficiently and quicker in any type of accident. In particular, the ADAC initiative to design a standardized record at the European level called RS has 2 major limitations: (1) a certain lack of technical information on the vehicle and health information on the common occupants and (2) no guarantee effective accessibility under real and complex situations. There

Table 2. Time required to put into practice various task of the rescues using standard and proposed protocols.

	Task	Standard protocol	Proposed protocol
		Toyota Yaris	Peugeot 207
First Rescue	Location and reading QR code	0 s	9 s
	Control and removal of risks	6 min 28 s	2 min 42 s
	Open hole to extrication	2 min 39 s	3 min 2 s
	Victim release	0 s	0 s
	Total time	17 min 25 s	14 min 29 s
		Volkswagen Golf	Seat León
Second Rescue	Location and reading QR code	0 s	12 s
	Control and removal of risks	6 min 52 s	2 min 18 s
	Open hole to extrication	8 min 34 s	3 min 48 s
	Victim release	0 s	0 s
	Total time	21 min 43 s	15 min 29 s
		Volkswagen Tiguan	Nissan Qashqai
Third Rescue	Location and reading QR code	0 s	8 s
	Control and removal of risks	5 min 41 s	2 min 52 s
	Open hole to extrication	10 min 23 s	7 min 50 s
	Victim release	5 min 10 s	3 min 14 s
	Total time	23 min 27 s	19 min 58 s
		Audi A4	BMW Series 3
Fourth Rescue	Location and reading QR code	0 s	9 s
	Control and removal of risks	4 min 10 s	2 min 15 s
	Open hole to extrication	11 min 53 s	8 min 59 s
	Victim release	5 min 56 s	6 min 26 s
	Total time	25 min 12 s	21 min 52 s

are several specific publications for firefighters (Morris 2004; Sweet 2011) that describe protocols, techniques, and tools to be used in rescue work. They focus on information about moving to the accident site, security steps, management of the accident, potential hazards, extrication techniques, etc., but the RS is not considered as a support document. Though these publications represent an essential tool in the specific training of rescue services members in terms of management tools, protocols definition, preparing rescue plans, etc., experience has shown that having specific information on each vehicle and its common occupants on the scene is crucial to ensuring the safety and improves the efficiency of rescue. In this sense, it can be stated that the proposed system works correctly based on the tests performed. The information provided has been useful, reliable, and complete for emergency services. Last but not least, the rescue times achieved with the new system were reduced in all simulated rescues.

Based on the tests and results obtained, we can conclude that the computer system developed constitutes a useful tool for emergency services in road accident rescues. This system is able to provide information to rescue teams that was not available before, in particular, advance technical and medical information about the vehicle and its occupants, which is crucial for saving lives. The information included in the ARS has been proposed by professionals and experts, which supports its usefulness and completeness. In addition, the system has been designed so that the information is easily configurable and accessible. The reliability and response time of the system have been demonstrated in the tests conducted. In all tests the information has been accessed through at least one of the QR codes placed in the vehicle, which means that both the location and the characteristics chosen (size, density, and redundancy) were appropriate. Last but not least, rescue times have been reduced (by 14% on average) in all tests performed, which will contribute to minimizing injury to occupants and save lives.

We would like to emphasize that the proposed information system does not affect standard rescue protocols followed by emergency services; in contrast, it would serve as an important support tool to aid in decision making. Moreover, as Calland (2005) pointed out, a perfect coordination between health services and firefighters in rescues is necessary, and new applications would help improve that coordination.

Implementation of the proposed system is easy, because the use of the application does not require training, and it is low cost, because it would only involve the creation, printing, and placement of QR codes, which can be done by vehicle owners, car dealerships, or Inspección Técnica de Vehículos (ITV) stations.

The following are proposals for the future:

- Adapting the proposed system to larger, heavier, and more complex vehicles (trucks, buses, trains) or even those carrying dangerous goods.
- The use of an electronic tag with a radio frequency identification system to store the encoded information on the vehicle and the occupants, instead of QR codes, or in addition to these. This way it could always be placed in the same location in all vehicles and allow reading simply by approaching the vehicle with the device.
- Developing an expert system for decisions based on the information provided by the current system helps firefighters implement the evacuation protocol and improve the victim's extrication. This could be relevant if the firefighters conduct a 3D scan of the damaged vehicle with a mobile device and based on the theoretical 3D shape of the vehicle and its current form, the system, given the characteristics of the car, may advise regarding the best way to perform the extrication.

Acknowledgments

The authors thank the Fire Department of Avila as well as the MAPFRE Centre for Road Traffic Safety and Research (Spain) for the assistance given during the tests.

Funding

This research was supported by the Security Science Institute "CISE" from the University of Salamanca.

References

Calland V. Extrication of the seriously injured road crash victim. *Emerg Med J*. 2005;22:817–821.

Information Technology Automatic Identification and Data Capture Techniques. QR Code 2005 Bar Code Symbology Specification. ISO/IEC 18004. Geneva, Switzerland; 2006.

Ley Orgánica de Protección de Datos. 1999;298:43088–43099.

Moharil B, Ghadge V, Gokhale C, Tambvekar P. An efficient approach for automatic number plate recognition system using quick response codes. *International Journal of Computer Science and Information Technologies*. 2012;3:5108–5115.

Morris B. *Holmatro's Vehicle Extrication Techniques*. Lille, France: Icone Graphic; 2004.

Sánchez-Mangas R, García-Ferrrer A, de Juan A, Arroyo A. The probability of death in road traffic accidents. How important is a quick medical response? *Accid Anal Prev*. 2010;42:1048–1056.

Sukegawa Y, Sekino M. Analysis of rescue operations of injured vehicle occupants by fire fighters. Paper presented at: 22nd Enhanced Safety of Vehicles Conference (ESV); June 2011; Washington, DC.

Sweet D. *Vehicle Extrication Levels I & II: Principles and Practice*. Burlington, MA: Jones & Bartlett Learning, National Fire Protection Association, International Association of Fire Chiefs; 2011.

Wik L, Hansen T, Kjensli K, Steen P. Rapid extrication from a car wreck. *Injury*. 2004;35:739–745.

Yu Q. Causes and prevention measures of secondary rear-end accidents in the rescue of highway traffic accidents. *Procedia Eng*. 2013;52:571–577.