AN INNOVATIVE SYSTEM FOR GUIDING TRAVELLERS THROUGH MOBILE PHONE IN TRANSPORTATION HUBS UNDER EMERGENCIES

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ABSTRACT

Physical catastrophes and their imminent effects (e.g. earthquakes, fires, etc.) as well as accidents and terrorist attacks in public transport terminals and infrastructures are unfortunately not rare phenomena of our times. Guiding and safe evacuation of affected people in such large travellers concentration areas is not an easy task, while timing is a crucial parameter for saving their lives. A novel system has been developed within SAVE ME European research project that gives generic (through vision panels) as well as individualistic guidance to travellers. Step-by-step guidance is provided through the mobile phones of the users. Emphasis has been given in the needs of most vulnerable users, such as elderly and mobility-impaired people. Lab-based evaluation of the developed system has been carried out with 24 users, and results are provided in this paper.

Keywords: transportation hub, evacuation, mobile phone, emergency, disabled, elderly, traveller

INTRODUCTION

Some of the most severe accidents in the world have occurred in transportation infrastructures. Over 200 people have died in Europe as a result of tunnel accidents in the last decade (GES accident database). In addition, transportation hubs and stations are often

targets of terrorist attacks due to mass concentration and easy access and escape for the terrorists. Among the attacks, highly selected targets are subways/trains and other public transport terminals, but also bridges and tunnels, namely (Jenkins B.M., 2007):

- Buses (32%), tourist and school buses (8%) and bus terminals (7%) = 47%.
- Subways and trains (26%), stations (12%), and rails (8%) = 46%.
- Bridges and tunnels (5%) and other (2%) = 7%.

The Global terrorism database (GTD) provides information on terrorism incidents from 1970 to 2008. The following picture illustrates the terrorism incidents along Europe reported between 1970 and 2008. The search has been limited to bombings/explosions or facilities/infrastructures attacks involving transportation means:

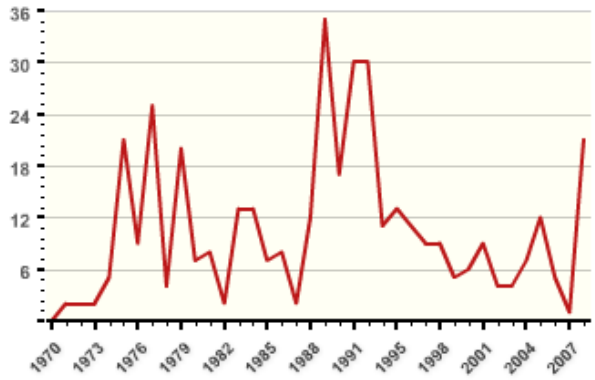

Figure 1: Terrorism incidents in Europe involving transportation means (Global Terrorism database)

SAVE ME is a research project, co-funded by the European Commission that developed an innovative and holistic system in order to support travellers in transportation hubs in case of emergency events due to accidents, physical or man-made disasters. The developed system is a holistic solution, covering detection of event, notification of emergency center, guidance to the rescue personnel to reach trapped people and evacuation guidance to the trapped people. It supports quick and optimal mass evacuation guidance, to save the lives of the general public and the rescuers, giving particular emphasis to the vulnerable travellers (i.e. children, elderly and disabled).

To achieve this, SAVE ME developed a common ontological framework for hazard recognition, classification and mitigation, innovative algorithms on human behaviour under stress, panic and strong emotions, standardised interface elements for intuitive human guidance, a holistic disaster mitigation strategy and intelligent agents algorithms for guidance personalisation. It employed a Wireless Sensor Network for emergency detection, environmental awareness and travellers' position and movements monitoring, as well as a fault tolerant communication network infrastructure.

Furthermore, it integrated simulator model data with real time data from these sensors, to reach enhanced crowd behaviour models and uses them in a Decision Support System, to

supervise the overall disaster mitigation operation. Thus, it supports the infrastructure operator, guides the rescue team through PDA and the trapped travellers. It also developed appropriate training curricula, content and tools for operators, rescuers and the general public; guidelines to the infrastructure / vehicle operators and designers and standardisation proposals to the policy makers. All project developments were thoroughly and iteratively tested and optimised by lab tests as well as two real pilot sites, at a metro station in Newcastle (UK) and the Colle Capretto tunnel (Italy).

The trapped crowd is guided through environmental displays and audio systems (placed at key points in the area), as well as personalised guidance in their mobile phone to the nearest safe and free exit, taking into account their profile (i.e. disability, agility, language, etc.). Generic guidance ensures that all travellers are guided, even those that do not possess a mobile phone. Traditional visual and vocal messages are used for the generic guidance module, which are adapted to suit the needs of elderly. The personalised guidance is important mainly for vulnerable people, as their needs in emergencies are higher in comparison to the rest people. The elderly are slow to react, slow in their movements and get easily disoriented. The elderly are among the most frequent users of public transport. There are also a number of situations requiring a different approach by emergency planners (Disaster Handbook, 1998). People who use wheelchairs, or are otherwise mobility impaired, need special rescue techniques and information regarding evacuation routes that are accessible for them.

This paper presents the personalised guidance system for the travellers, which is offered through the mobile phone, along with evaluation results.

THE MOBILE PHONE-BASED GUIDANCE SYSTEM

Methodology

User needs

The actual problems and needs of all travellers have been investigated. Interesting studies (Drury, J., Cocking, C., & Reicher, S., 2009) show that panic is not always the main reaction of crowds during emergency situations. It seems that far from mass panic occurring, being in an emergency can create a common identity amongst those affected. A consequence of this is that people are cooperative and altruistic towards others - even when amongst strangers, and/or in life-threatening situations. This analysis has direct implications for how the rescue services manage mass evacuations. In line with earlier critiques, the concept of mass panic is considered to be a myth unsupported by existing evidence. Crowds in emergencies can be trusted to behave in more social ways than previously expected by some involved in emergency planning.

In addition, a questionnaire-based study performed in the project, with 32 participants (including people with light mobility problems, i.e. slow walking), revealed that despite that most of the participants stated not to know how to proceed in an emergency situation, half of them recognized that they don't pay attention to emergency signals within transport infrastructures. If they were involved in an incident/disaster, their most probable reaction would be, in this order, the following (Panou M. et al., 2010):

- Look for emergency exits: they would use their personal intuition to get to a safe place, to seek a way out.
- Start running where the rest of people run.
- Follow the signalling: try to find information to follow, follow the announcements, look and listen, etc.
- Try to stay calm: not to panic, try to be calm and encourage others to do the same.
- Help others: advices colleagues, help injured people, help children, etc.
- Panic
- Other: orientate their selves, look where the danger is, call the emergency number, etc.

The probable problems/difficulties reported by travellers in case of evacuation from an incident/disaster situation in a metro station, tunnel or bridge are the low visibility for signals either by smoke or by the crowd that covers them, the difficultness to find the path to arrive at a secure exit and moreover and the fact that people will start escaping into the wrong direction.

Travellers were asked to report their problems and needs regarding the emergency signals and messages that are provided currently in transport environments. The summary of their comments is shown below:

<u>Problems reported and comments:</u>

- In case of panic and chaos nobody would care to read the signs.
- Audio messages are not always easy to hear/understand.
- Usually there are very few signals and they are too little.
- Emergency instructions are sometimes written only in the local language.
- The emergency signalling is noticed only when there is an emergency situation. People are not willing to spend time beforehand learning how or where they can reach a safe place, because they will probably forget it during the incident. Therefore, they need simple and explicit messages of what to do during the emergency.

<u>Appearance and content of signals and messages:</u>

Indications for possible ways to improve the signalling so that travellers would pay more attention to them follow below:

- Messages should be short and simple, clear and easy to understand for all.
- More visual messages, pictures, videos/animations and even cartoons explaining how to manage the emergency situation would help.
- Messages need to be updated frequently.
- Higher volume of audio messages.

The questionnaires explored the possibility of providing information to users through mobile phones. The main advantages reported by the participants are:

- People can receive the info in real time.
- Mobile phones are easy to use, they might be updated through internet.
- Easy, fast and practical means of receiving information.
- Nowadays, mobile phone is a personal device and people carry mobile phones with them all the time.
- Some people like to read the info on their mobile rather than on other devices, they can see the info clearly.
- If people can access this info on their mobile, they will feel more confident and independent.

All the above show that there is a need for an accurate, easy to use evacuation guidance system, that provides real time step-by-step instructions to the travellers.

User interface

Human interaction in emergency condition and critical visual, chemical and noise environment has been addressed in SAVE ME, in order to be able to provide valuable escape instruction to the travellers at need, for a fast and safe evacuation. The same questionnaire survey mentioned above, investigated the information needed during an incident. Through the analysis of questionnaires, it was found that the need of information is a critical matter for all the travellers, especially when talking about emergency situations. Travellers are aware that a quick reaction in these cases would be decisive for their safety. Here, the most important issues that they would like to be informed about (ordered from highest to lowest priority) are summarised:

- *Nearest emergency exits:*
    - Where is the nearest and securest exit
    - Where the safe places are, how travellers can get to them
    - Instructions on where to go

- *How to react:*
  - Escape or stay?
  - What to do so that fear does not affect all the people
  - Instructions on where to go
  - What to do in order not to cause any more trouble and to help others
- *Kind of situation:*
  - Origin, type of emergency
  - Where danger comes from: especially smoke or gases
  - Up-to-date information and the likely duration of the incident
  - What to do in order not to cause any more trouble and to help others
- *Where not to run:*
  - Where is the no-go-area
  - Where exactly the accident is (so to run in the opposite way)

Thus, a user-centered approach has been developed in SAVE ME, resulting in a common user interface and warning strategy which constitutes intuitive and adaptive interfaces for travellers guidance. Specific user interaction elements were commonly used for different types of smartphones (Android, Symbian, iPhone).

System functionality

The emergency support strategies depend (among others) upon the following parameters:

- Type of emergency (earthquake, terrorist attack,…).
- Type of the environment (tunnel, bridge, bus station, metro station, train, metro,…).
- Topology of the location (i.e. linear or almost linear like vessels/trains, 2D like open terminals, 3D like multilevel terminals, networks like tunnels/metro or rail terminals,…).
- Travellers type (i.e. young, old, wheelchair users, child, deaf, blind, tourist/foreigners,…).
- Situation criticality (i.e. monitoring, drill, imminent emergency, ongoing emergency, post emergency support).
- Device type (personal or infrastructure-based).

Different types of interaction are considered on the personal device:

- Simple visual sign (direction signal).
- Complex visual sign (written text, map-based guidance).
- Simple audio (direction signals).

- Complex audio (voice-based route guidance).
- Tactual (i.e. vibrations based).

A decision support system receives input from sensors in the affected areas and calculates the optimal (the safest and nearest possible exit) escape route based on the user profile and the area characteristics (exit paths, stairs, elevators, etc. that have not been affected); different evacuation routes are provided for travellers with different mobility needs. More precisely, real time, fast and reliable route planning is achieved by optimization algorithms that take into account multiple optimization criteria such as nearest exit point, subject-related attributes (such as age, possible mobility and/or other impairments) and infrastructure related data that are stored in advance (accessibility attributes, corridor capacity, sensorial and user interface capabilities for messaging) but also real time changes of the compound attributes such as escape route availability, structural integrity, etc. The system operation lies on its own local network and is not affected by the mobile telecom network, which is very important as it may be disrupted during an emergency event.

SAVE ME mobile phone guidance system is available for devices supporting Symbian, iPhone and Android platforms. This is of great importance, as not all people possess advanced mobile devices (this is even more valid for elderly persons).

When the user starts using the application for the first time, he/she has to insert information about his/her profile, based on which the information type will be decided by the system. The parameters that define a user's profile are the levels of mobility, vision and hearing impairments, as well as his/her age and the existence of cognitive impairment. The following figure shows screenshots of the PC emulators for the three mobile platforms supported.

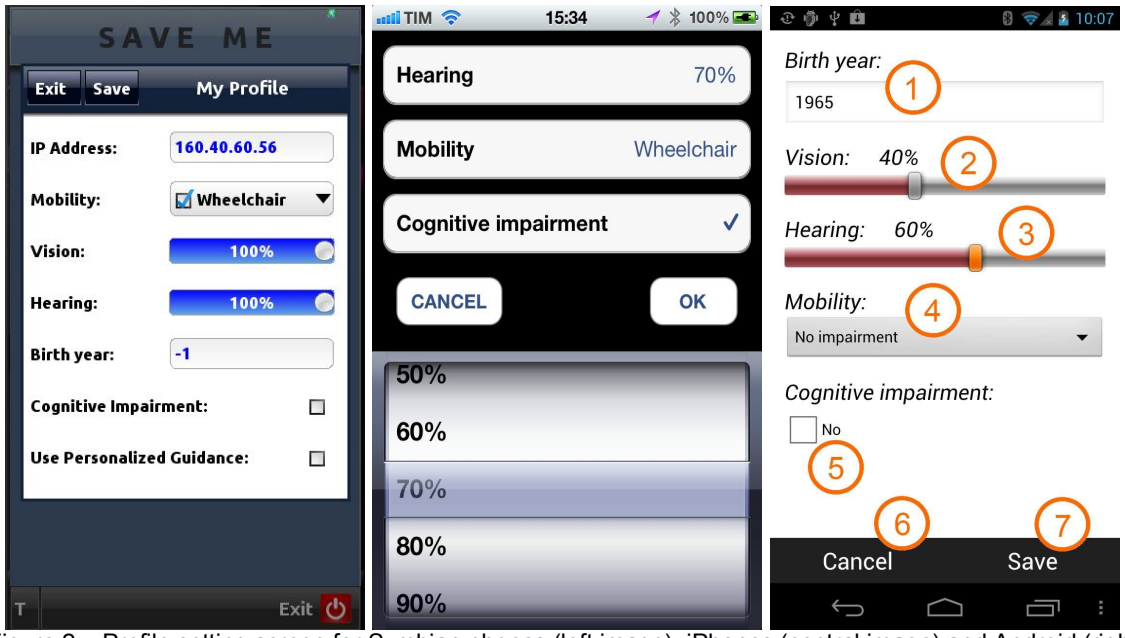

Figure 2 – Profile setting screen for Symbian phones (left image), iPhones (central image) and Android (right image)

Depending on the type of the emergency, the colour of the background could vary, giving three possibilities:

- Blue: Low severity emergency
- Green: Medium severity emergency
- Red: High severity emergency

As shown in Figure 3, there are two buttons on the screen, with the following functionalities:

- Hazard info: By pressing this button, the user can get a summary of the emergency, (emergency type, the place of the emergency or some general advices).
- Escape info: The user should press the "Escape info" button in order to get information and directions about the route he/she should follow in order to evacuate the area with safety.

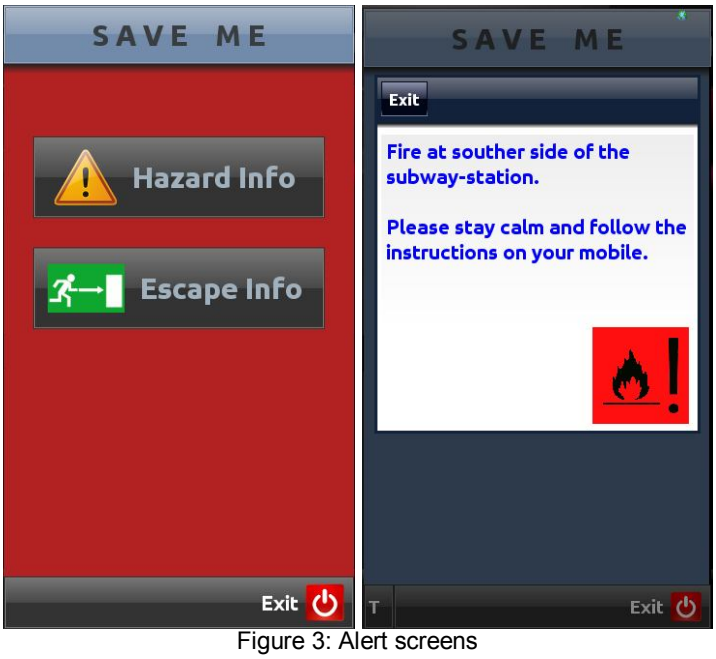

Figure 3: Alert screens

The user can get information about the route he/she should follow in order to reach a safe place, in case of an emergency. This safe place can be outside the building or a safe room inside the building. The evacuation information that is provided to each user may vary, as it is based on the user profile. Thus, a personalised escape route is drawn, reflecting the specific needs of each type of traveller. For example, mobility impaired travellers are guided to the accessible escape routes, i.e. routes with no escalators, or with emergency lifts (in case they operate), or with ramps; vision impaired users are warned with vibrations on the incident and are guided acoustically, while people with hearing problems (elderly might fall in this category) are warned firstly with vibrations and then get step-by-step visual guidance based on maps; finally, travellers with light cognitive problems receive simple guidance optical instructions that are easy to understand and follow (such as a labyrinth view).

The user gets exact directions as shown in the next figure (Figure 4). The blue arrow indicates the current position (yellow dot) of the traveller and the red arrow shows the exit point. The blue line is the escape route which is drawn on the map; it is the shortest and safest route (found by the system) that the traveller should follow in order to reach a safe place.

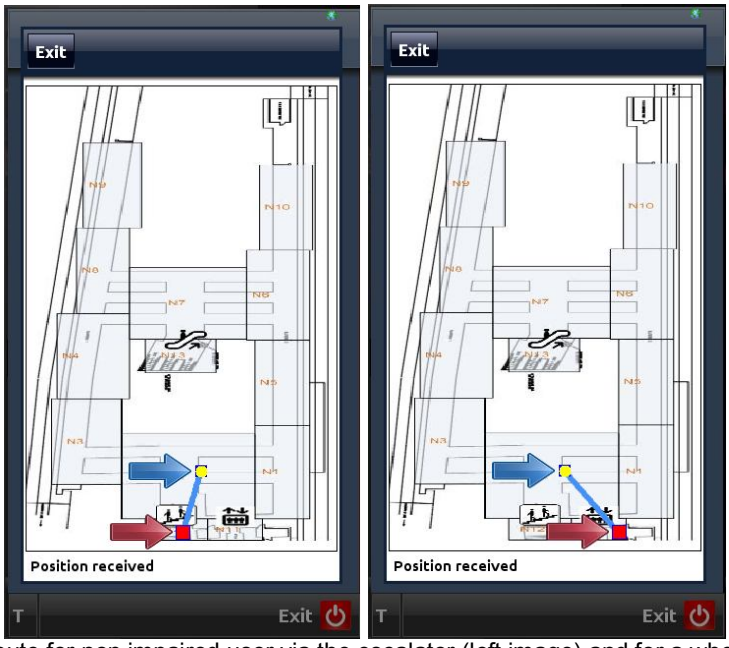

Figure 4: Escape route for non impaired user via the escalator (left image) and for a wheelchair user via the elevator (right image).

EVALUATION RESULTS

A subjective evaluation was carried out with 24 users (elderly, wheelchair users and commuters), aiming at investigating the usability, easiness to use, comprehensibility, appropriateness and accessibility of the developed application. The tests were carried out at the premises of the Hellenic Institute of Transport. This iterative testing procedure was based on several questionnaires, tasks completion success rating, facilitator's notes, a standardised scale for assessing acceptance and quantification of 'think aloud processes'.
Functionalities tested were divided in tasks to be completed by users, as follows:

- Create a user profile
- Receive the flashing hazard message
- Description of type of emergency (e.g. fire)
- Understanding of a metro map and evacuation route

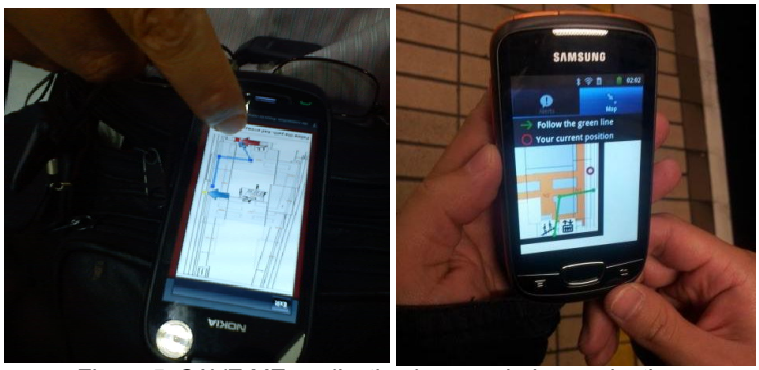

Figure 5: SAVE ME application images during evaluation

It should be noted that these verification tests were used as a proof of concept, while large scale tests are planned for the industrialised phase of SAVE ME application, where a good statistical significance will be achieved. Specific use cases were defined early in the system design, including variables and parameters that determine the success of each use case. These variables are to be evaluated in the large-scale tests.

Easiness to use/learn

Participants found the SAVE ME application very interesting, helpful and innovative. Most participants mentioned that they would use it in a case of emergency and benefit from it. For most elderly and commuters, it was found straightforward and easy to learn how to use the application. On the other hand, for wheelchair users, it appeared not to be such an easy process, mostly because they considered it quite difficult for them to navigate through the system. Results are presented per traveller group and therefore only numbers of users are reported in graphs and no percentages.

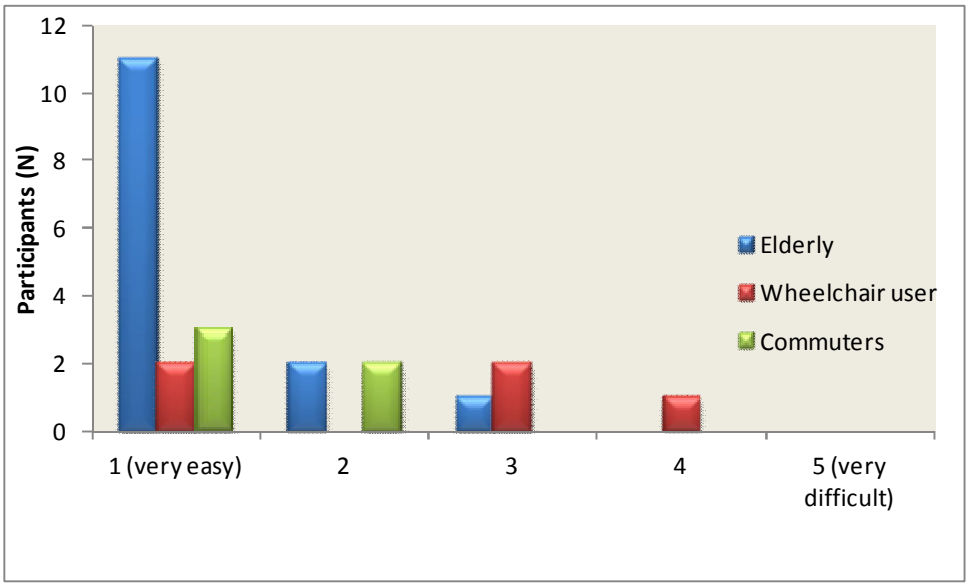

Figure 6: Easiness to use the Route and Guidance system

Both graphs (Figure 6 and Figure 7) reflect the easiness in interaction for the elderly and commuters. Wheelchair users did not report difficulty in learning to use the system but they believed that an amount of effort was necessary.

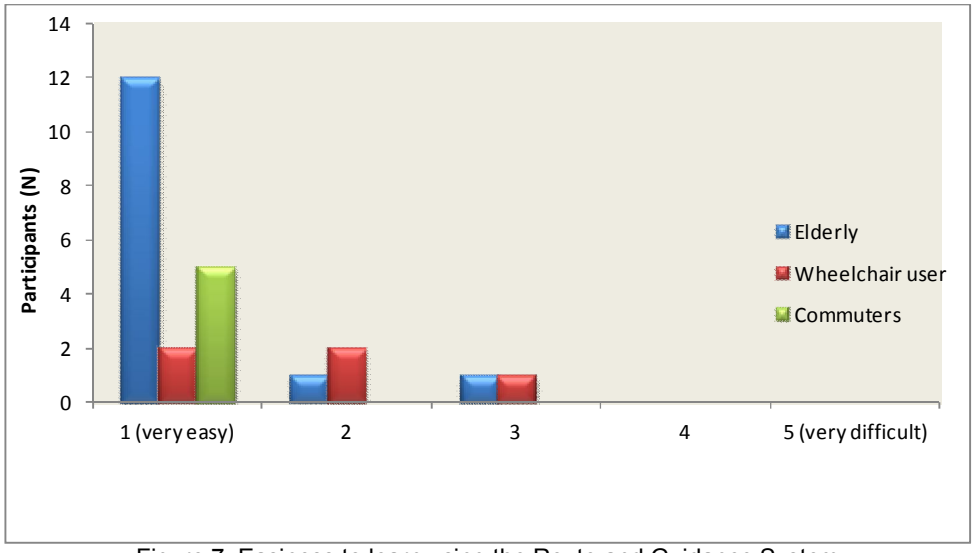

Figure 7: Easiness to learn using the Route and Guidance System

Hence, initial interaction with the system was accomplished fairly easily for all groups with no extra hindrances. This finding is strongly supported by all traveller groups that the application was used without assistance (and not needing any) by technical staff nor the facilitators. Almost all participants agreed they did not have problems accessing the system at all times during the trials.

User interface

On the whole, users were satisfied by the layout of the graphical interface.

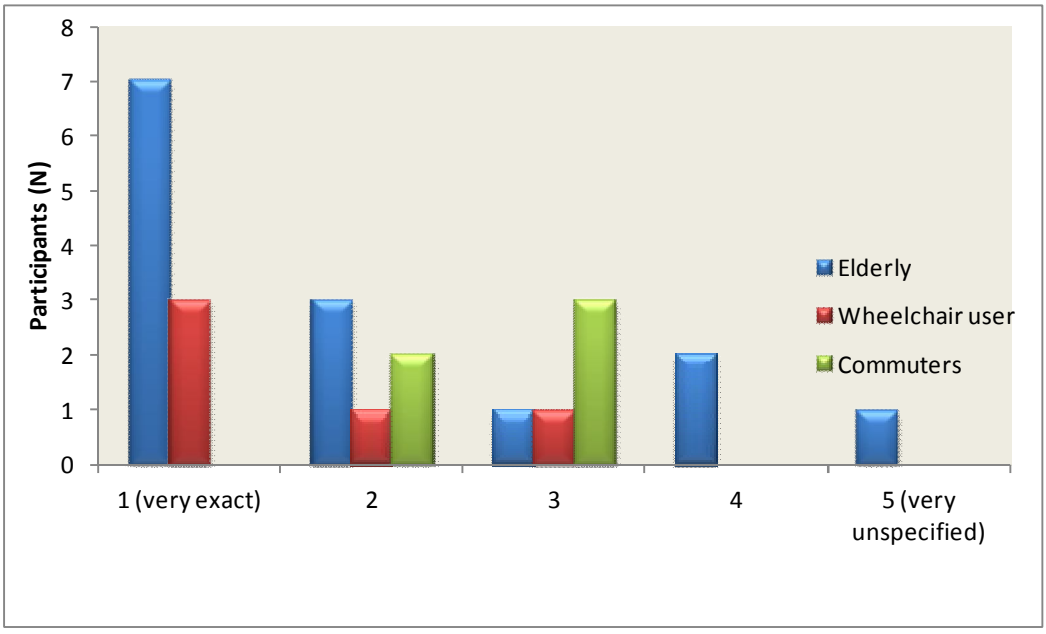

Figure 8: Exactness of graphical interface

Commuters were averagely satisfied by the graphical interface, probably because most participants were young and very ICT literate users and, thus, more demanding with regards to both appearance and content. Elder users reported high clarity of fonts used for this application. On the other hand, both commuters and wheelchair users were satisfied by the font size but suggested to include personalisation possibility for the zoom level and the font size increase, whenever available (since some features are not available to all types of devices/mobiles phones used). Commuters suggested more backrounds available and they indicated that maps should be flashing for both localisation and exits.

Content

Participants evaluated the content used (e.g. map details, text used) in the application. Most participants (19/24) reported that the information received was correct and sufficient. However, the users suggested giving either more details (e.g. verbal instructions) about the exit or providing a more detailed map. There should be an option for enlarging the map and potentially offering more details regarding the route that must be followed.

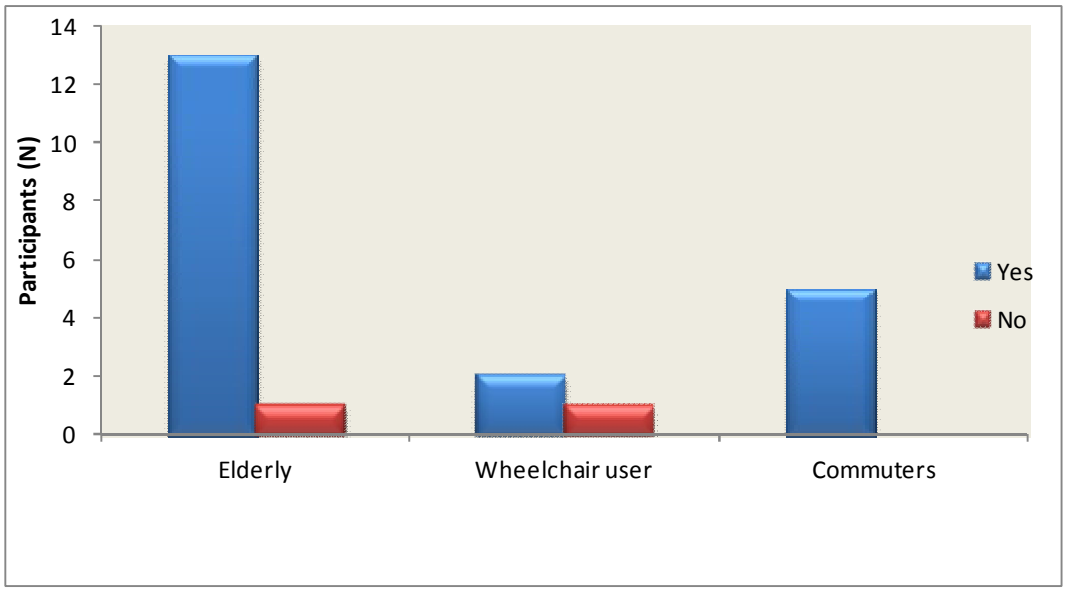

Figure 9: Correctness of provided information (based on requested)

All elderly participants were satisfied by the information provided and rated it as adequate and sufficient. On the other hand, most wheelchair users and commuters stated that content was rather limited and more information should be added in order to make mapping, routing, and exiting a building/station/or other premise efficient and safe. In particular, information about the type of emergency might be unecessary and potentially distressing in the evacuation process, however, users should receive constant relief and support via both verbal and visual messages. For example, they should be constantly reassured that they are on the right track/route and that help will be available when they manage to get to the marked exit point. In addition, the type of help should be defined (e.g. paramedics).

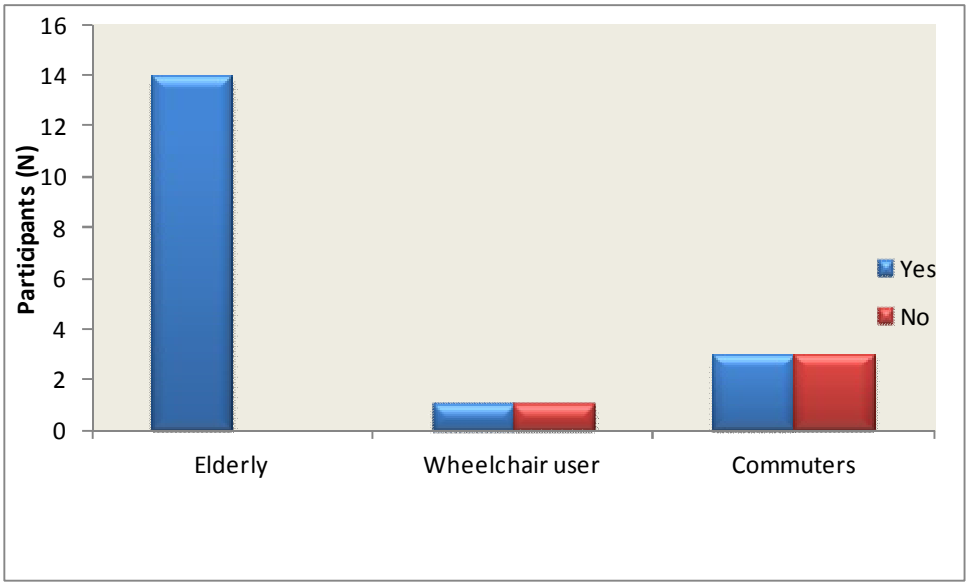

Figure 10: Sufficiency of presented information

Overall usefulness

Route guidance was perceived as useful, assistive, and desirable by all traveller groups. Almost all users mentioned that the system is raising their alertness which is an important element for using it in case of emergency. Suggestions for improvement involve the use of flashing messages and vibrant colours in order to catch users' attention. However, this alternative would also potentially increase their stress levels. Also, all users agreed that the system would be effective in case of emergency in navigating travellers to a safe exit.

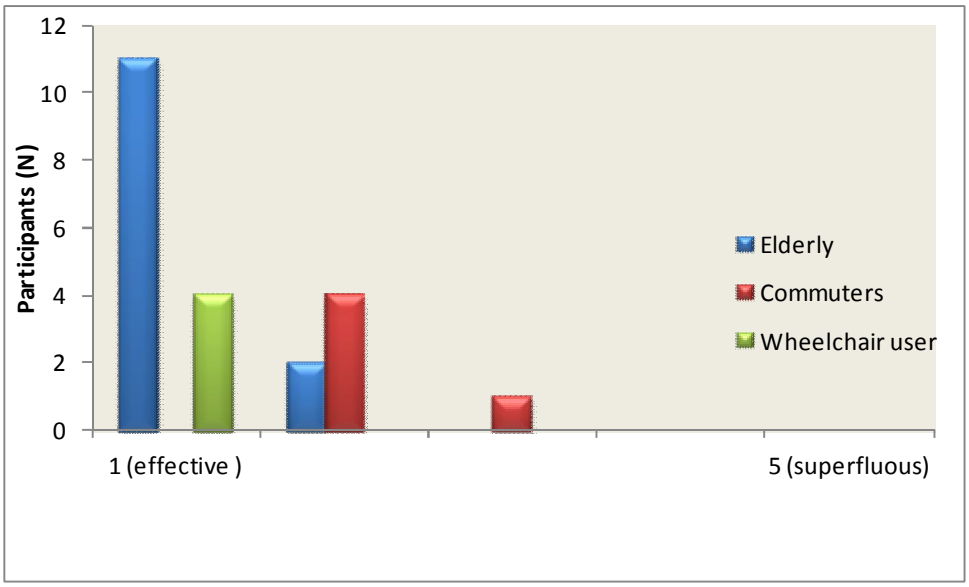

Figure 11: Perceived system effectiveness

Overally, the system was perceived as very useful for emergencies. The idea was descrided as innovative and research on this is of great value for diverse types of stakeholder groups. Users mentioned the necessity to approach governmental bodies responsible for disaster

and emergency control in order to create a standardisated protocol of use and implementation.

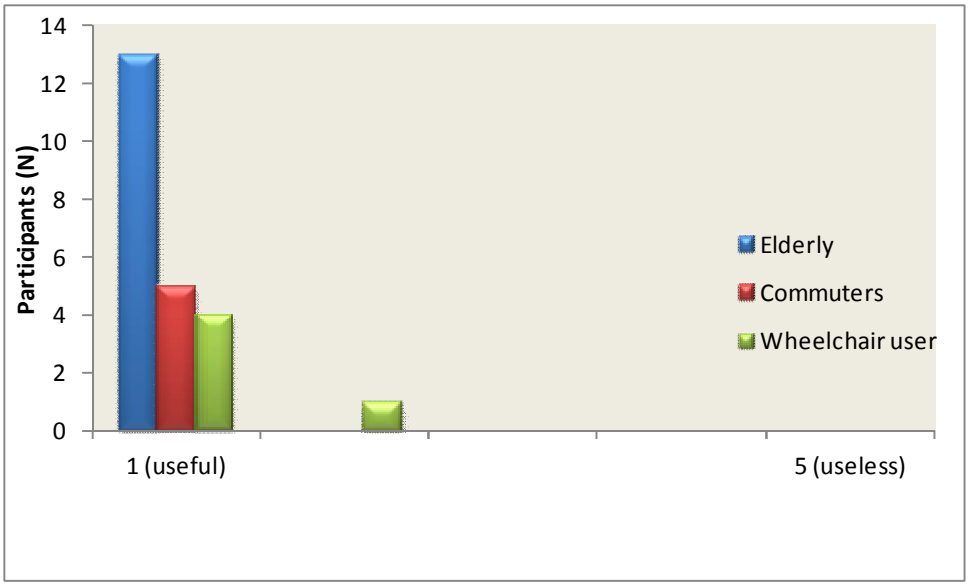

Figure 12: Overall system usefulness

As all the aforementioned results are based on the well-known and standardised acceptance scale (9-item Likert scale) created by Van der Laan, Heino, & De Waard (1997), their overall scoring –for all participating traveller groups– showed very high mean usability (1.86) and very high user mean satisfaction (1.77) for the whole group of participants. As the acceptance scale was administered for the purposes of iterative testing, no pre and post acceptance scores were calculated, hence, the scores presented here are only after-measurement scores.

CONCLUSIONS

SAVE ME mobile-based travellers guidance system innovation lies on the critical issue of disaster mitigation and mass evacuation. One of the success factors of this development is the simplicity of the application and its user interface, since the application is designed to be used in cases of emergency, where the user may be under psychological stress or confusion. Overall, results suggest that the application was found very interesting, helpful and innovative by the participants, with the majority of them giving a positive feedback on the content (maps, route guidance info). Most participants mentioned that they would use it in case of an emergency and benefit from it.

SAVE ME is expected to have major impact in the area of evacuation systems considering, among other, the innovation of the individualised (thanks to mobile phone) info to each involved traveller. Also, SAVE ME contributes greatly to the research and policy developments (by standardised icons, earcons and haptic elements).

Through the ontological framework for hazard recognition, classification and mitigation that has been developed in the project, different types of emergency situations (fire, flood, explosion, etc.) are taken into account, along with their parameters. These disaster types are also included in the design of the system architecture and communication network and the detection sensors are reassessed in case one or more nodes are lost due to the disaster, thus the local communication network is not affected. Thus, SAVE ME is able to provide support and evacuation guidance under different disaster types.

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