Human-machine Interactions in Future Police Vehicles: Applying Speech User Interface and RFID Technology

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Abstract**—**A modern police vehicle is a very complicated combination of different technologies. A single vehicle contains dozens different human-machine interfaces (HMIs) and carries a lot of equipment; for example, Finnish police cars are equipped with an average of about 40 different HMIs and 100 different types of equipment. It is extremely important to be sure that all needed tools are available in field operations. From operational, safety and ergonomic reasons, there is a need to cut down the number of HMIs and make the systems easier and safer to use. This paper presents results from the MOBI project (http://mobi.laurea.fi) with regard to human-machine interactions in future police vehicles. The findings show the significance of the early user feedback for the design work of HMIs. The results also show that a remote identification applying RFID technology enables the police to make the inventory of their vehicles' equipment three times faster than by hand. Based on our study, there is a global need for a standard in the HMI design for emergency service vehicle development.

Keywords**—** Field testing, human-machine interactions, law enforcement, police car, RFID-technology.

I. Introduction

LAW enforcement authorities (LEAs) need to operate multiple equipment in different and difficult circumstances. These circumstances include, for example, driving at high speeds, unstable environment, varying light and temperature conditions. The amount of different technical devices and stand-alone systems has increased dramatically over the years, creating both space and safety issues for police vehicles. In the near future, information and communications technology (ICT) applications and digital services play a more and more important role [1]. All these systems have their own human-machine interface (HMI) and today's Finnish police cars have about 40 HMIs (for radio, navigation, field command systems, radar, alarms and emergency lights etc.) on the deck beyond cars' own user interfaces, as shown in Fig. 1. This problem is noted globally.

Fig. 1 A typical deck of a Finnish police car

Besides lights and other electrical devices, police use different ICT systems, such as the field command system, navigation and different databases. A HMI could also be used to control other devices in the vehicles. Challenge is that the same HMI should be used in vans, trucks, motorbikes or other types of vehicles, and should be able to be taken with the officer when leaving the vehicle. Requirements for usability are critical, since the circumstances where the systems are used are sometimes stressful, and often officers work under high risk situations. The user needs to perform quick and precise actions and access to the information plays a key role. All information related to the situation should be available within a single look.

A modern police vehicle carries a lot of equipment [2]. It is extremely important to be sure that all needed tools are available in field operations [3]. Police vehicles have to be ready to service on 24/7 basis. Preventive maintenance acts vital role to guarantee emergency service vehicle operation preparedness, but maintenance procedures during and after working sift are important, too.

Also, other first responders, such as emergency medical services and rescue operations, have similar needs. Ministry of the Interior of Finland and the National Police Board are planning to acquire a common field command system (KEJO) for police, emergency services, social services and health care, defense forces, border guard and customs [4]. At the moment, the procurement procedure has in the process.

The Mobile Object Bus Interaction (MOBI) research project has been launched by Laurea University of Applied sciences together with co-operative partners [5]. The target of the MOBI project is to create a common ICT hardware and software infrastructure for all emergency service vehicles. This infrastructure includes devices for voice and data

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communications, computers, screens, printers, antennas, cablings, and additionally, interlinking with factory-equipped vehicles' ICT systems is researched [5]. The MOBI research project generates research data for parallel industrial and procurement projects by researching and documenting the needs and requirements of the users, power generating and supplying and specifying existing solutions [6]. The aim of this case study analysis is to provide an improved understanding of the human-machine interactions in future police vehicles. The study also examines how the operational safety and usability of emergency service vehicles can be improved. The sub-task of the study is to analyze the suitability of RFID technology in law enforcement field operations, such as the locating, detecting and identifying of equipment in the police vehicles.

II. The State-of-the-art

A. *Standards for HMIs*

A safer working environment for first responders will be achieved integrating multiple devices and operations under one HMI. The approach for answering this need is to look at the guidelines for developing interface standards using the human centered design process described in the ISO9241-210 standard. The Standard provides requirements and recommendations for human-centered design principles and activities of computer-based interactive systems. “It is intended to be used by managing design processes, and is concerned with ways in which both hardware and software components of interactive systems can enhance human–system interaction” [7].

The European Commission has also set principles on human-machine interfaces for in-vehicle information and communication systems. It summarizes essential safety aspects to be considered in human-machine interfaces in such a way that the user is compatible with the driving task, how to present information so as not to impair the driver's visual allocation to the road scene and how to design system interaction so that the driver maintains safe control of the vehicle. The statement underlines the importance and safety implications of HMI design. It could therefore be of particular use to manufacturers who may be unaware of these issues. In order not to create unnecessary obstacles or constraints to the innovative development of products, the statement of principles is expressed mainly in terms of the goals to be reached by the HMI [8].

The general benefit of an interface that is easy to learn and operate assures minimum effort in high risk situations. User errors are less likely to happen with an easier, more user centered interface. A standardized interface decreases the need for vendor specific training. It also shortens the learning curve and possibly provides cost savings as well: all information that is needed is quickly accessible and clearly presented. With a clear, user centered standardized interface most vendors can use it to develop new devices that are compatible with the existing interface.

OneBox [9] is a guideline and a specification for a HMI apparatus. The OneBox concept is formally named as One Box Single Vehicle Architecture (OBSVA). The guideline of the OBSVA is to be used as the basis for emergency service equipment control and data management. The vision is that original equipment manufacturer (OEM) hardware components such as switchgear and screens already in the vehicle are reused rather than additional technology being needed to manage emergency service equipment without compromising safety or functionality [9].

The OBSVA concept compromises a core architecture, consisting of an in-vehicle local area network (LAN) for data transfer, the processing hardware and software to support this and the applications that will run on it. The OBSVA concept includes elements such as power management, wired LAN, control systems and a HMI. Industry standard connectors, outputs and operating systems are defined, but test requirements must be met in order to be compliant with the criteria outlined in the concept. The scope of the core architecture does not include components that may be attached to it, such as cameras or lights. It is currently restricted to the provisioning of cabling and control systems, together with physical interfaces, connectors, operating systems for the control systems and HMI for the hardware [9].

The design process and the actual design of an interface get a clear framework by utilizing standards and guidelines. The ISO standards and the EU principles give an upper level guideline for the design, where the OneBox guideline is already more detailed concept for designing an HMI for an emergency service vehicle.

B. *Existing Products*

Products with consolidated user interfaces are available, and already used by some police departments in the United States. Detailed information about three selected products is studied below.

1) *Rockwell Collins iForce*

The iForce made by Rockwell Collins is an integrated public safety vehicle solution. iForce is a Linux based high availability computer that allows users to control all vehicle electronics such as lights, sirens, radios, radars and video cameras through a single integrated system [10]. The HMI includes three ways to control all electronic devices in the vehicle: a touch screen, configurable hand control device and voice control [9]. These options consolidate the first responder's work environment into a single HMI. Rockwell Collins also manufactures products for military use. Modular Open Systems Architecture from their military systems portfolio implements the integration for vehicle electronics such as lights, sirens and radios to the iForce. It has a push-to-talk (PTT) voice activation with a single button to enable voice control [9].

Integrated devices are located in the trunk of the vehicle with a Linux-based computer [11]. This gives more room to the dashboard but takes up the storage space in the trunk. There is also a Windows based system for non-critical functions.

Devices are designed especially to be mounted to specific car models that are used by police in the United States. California Highway Patrol and the Royal Canadian Mounted Police have acquired the system to be used in some of their police vehicles [13].

2) 54Ward COREcontrol

Project54 is a project that began in 1999 at University of New Hampshire. Project has been implemented in co-operation with the university and the New Hampshire Department of Safety. The aim was to design a system interface that would improve the ability of police to collect and interpret data and to provide a way to integrate the controls of all of the equipment within a police vehicle [14]. Project results have been used in the development of a product called 54Ward COREcontrol made by 54ward Integrated Solutions. 54Ward COREcontrol integrates different police vehicle electronics under one HMI. The HMI can be used from touch screen and by voice control. Voice control is activated by button that can be mounted on the steering wheel [15], [16]. Section *2.C.1* provides more information about applying SUI in Project54.

3) Feniex Olympus

Feniex Olympus is a software product that can be installed on any operating system. It consists of the software, touch screen and a switch plate to be installed inside the vehicle [17]. There is no voice activation. The mechanical switches serve as a backup option to continue the use of the interface in case the software crashes. Three functions can be programmed to the switch plate [17].

4) Comparison of features

Table I presents the summary of the main features of the evaluated products. The features compared are: graphical user interface (GUI) applied via touch screen, SUI, system recovery options and devices that can be integrated to the system.

Table I. Product feature comparison

	GUI	*SUI*	*System recovery*	*Integrated systems*
COREcontrol	X	X		Warning lights, sirens, radios, radar, etc.
Project54	X	X		Radar, radio, lights, siren, video, etc.
Feniex	X	-	Medical switches	Radar, siren, horn, etc.
iForce	X	X	Linux based high availability computer	Lights, siren, radio, etc.

OneBox guideline has a voice activation specification, but it is not a primary HMI. Voice activation as well as text-to-speech functionalities are specified as additional functionality [9].

C. *Speech User Interface (SUI)*

Two out of three above-mentioned products applies SUI integration with the radar, sirens and lights. The main advantages of using a SUI system are that it does not require the user to remove his/her hands from the steering wheel, or to look away from the road while driving. This improves safety when operating a device. It provides a quick response in simple tasks and the user can issue desired commands in one word or a sentence instead of having to navigate through multiple interfaces to reach the target.

The main disadvantage is that the SUI does not always recognize the issued voice command, or still worse, misrecognize it. The surrounding noises can also affect the performance of the SUI. A dialogue between the system and an user has to be managed very strictly to prevent misrecognitions [18]. There are implementations where the SUI repeats the given command after the user. Voice responses from the SUI slow down the interaction with the SUI compared to using a GUI and may require more patience from the user. The more complicated the task, the more concentration is required from the user to operate the SUI. On the other hand, feedback from the SUI may not be required at all in some circumstances such as operating the sirens for example.

1) SUI Research

Hampshire University's Project54 is a system that integrates multiple devices under one user interface and also utilizes a SUI. This system has been tested in the field in authentic environment and situations.

The SUI of Project54 applies commercial speech recognition and text-to-speech engines [19]. The SUI gets speech input from a microphone. Microphone placement on the visor reduces the background noise. SUI is used pressing the push-to-talk (PTT) button. The PTT button helps the SUI to recognize commands. Because of the operating conditions in the vehicle, the location of the microphone that picks up the commands should be planned and executed carefully. Recognition starts when the PTT button is pressed and stops when the button is released. The SUI does not initiate interaction. The officer utters a phrase and the SUI reacts to this. The SUI may execute a command, fill in a data field or initiate data retrieval [19].

The voice command can be recognized, not recognized at all or misrecognized. A misrecognized command leads to wrong execution. SUI can respond by repeating the command that allows the officer to verify whether the recognition was correct. This is a useful feature, correctness of the recognition is verified, but in the other hand it slows down the interaction. Officers have the option to cut off any SUI utterance. Cutting of the SUI response can be risky in some operations. For example, if the officer is spelling a name or a plate number and cutting off the SUI response, the officer cannot be sure if the command was recognized correctly. Command verification requires the officer to listen the command that is repeated by the SUI or checking it from the GUI. [19]

The SUI recognition rate in Project54 was studied; over

49,000 samples of speech commands, along with the corresponding SUI responses were collected and analyzed [20]. Samples were collected from 27 officers during their everyday work. Based on the study results the average recognition rate was 85.34% [20]. About two thirds of the recognition errors were due to user errors and one third was due to speech recognizer errors. A common user error was the improper use off the PTT button [21]. Button was either pressed after officer started to talk or released while still speaking. To reduce these errors one possible suggested solution is to implement a circular buffer for recording utterances and send the starting input a little before the PTT is pressed [21]. To get increase in the recognition rate, one suggested solution to reduce speech recognition errors is to eliminate interference from police radio by ignoring any utterances while police radio is active [21].

2) Safety and Usability

Applying of a SUI makes driving safer because it allows the officer to keep his/her eyes on the road and both hands on the wheel while driving. Driving performance is generally better - there are fewer lane departures and vehicle speed is more stable [22]. SUI allows officer to concentrate on driving especially in stressful circumstances [23].

Which is better, SUI or GUI, depends on how the interface is implemented for a particular task. Based on a Project54 study the SUI is not the most useful interface in all operations. According to Kun's *et al.* [19] the officers select the appropriate HMI (GUI, SUI or original devices' interface) based on the circumstances. According their study, SUI was used to control radio, lights and siren. SUI was not used to control the radar because the delay to capture the speed of vehicle of interest was significant. The SUI was used to access the databases; mostly queries from vehicle record database and driver records database were performed. Based on the study results, the GUI is most useful when large amount of data is to be presented to the officer. The officers found the SUI most useful while driving. In other circumstances they favored the GUI. The officers were satisfied with the speech recognition, although there were recognition errors [19].

D. *RFID Technology*

Radio frequency identification (RFID) is a general term that is used to describe a system that transmits the identity (in the form of a unique serial number) of an object wirelessly, using radio waves. This is sometimes referred to as contact-less technology and a typical RFID system is made up of three components: tags, readers and the host computer system.

1) Tags

An RFID tag is a tiny radio device that is also referred to as a transponder, smart tag, smart label or radio barcode. The tag comprises of a simple silicon microchip (typically less than half a millimeter in size) attached to a small flat aerial and mounted on a substrate. The whole device can then be encapsulated in different materials (such as plastic) dependent upon its intended usage. The finished tag can be attached to an object, typically an item, box or pallet and read remotely to ascertain its identity, position or state [24]. Fig.2 shows examples of RFID tags.

Fig. 1 Different RFID tags

2) Reader

The reader, sometimes called an interrogator or scanner, sends and receives RF data to and from the tag via antennas. A reader may have multiple antennas that are responsible for sending and receiving radio waves [24]. Fig. 3 shows Merlin UHF RFID Cross Dipoli handheld reader that has been applied within the field tests of this case study analysis.

Fig. 3 Merlin UHF RFID Cross Dipoli handheld reader

3) Host Computer

The data acquired by the readers is then passed to the host computer, which may run a special RFID software or middleware to filter the data and route it to the correct application, to be processed into useful information.

4) Automatic Identification

RFID technologies are grouped under the more generic Automatic Identification (Auto-ID) technologies. Examples of other Auto-ID technologies include Smartcards and Barcodes. RFID is often positioned as next generation barcoding because of its obvious advantages over barcodes. However, in many environments it is likely to co-exist with the barcode for a long time.

III. Research Method and Process

This study was conducted as a case study research analysis. This research method was chosen as a case study aims to collect a comprehensive data set of source material and to further describe the subject matter in depth. Yin [25] defines a case study as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident. Yin's case study framework [25] shown in Fig. 4, is useful in situations where the applied understanding of how or why something is practical. The study attempts to proceed in accordance with Yin's iterative phasing according to the scientific precision met at a sufficient level. One of the most important issues in order to obtain the scientific accuracy of the case study is the use of multi-source evidences.

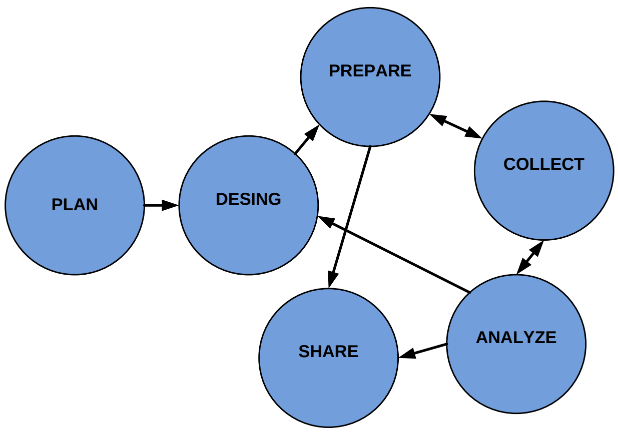

Fig. 4 Yin's case study framework

This case study has been deliberately designed to be part of the MOBI research project. The original research question was: How to improve the safety and usability of future police vehicles? The sub-question was: How RFID technology can be utilized in law enforcement operations? The unit of analysis of the case study is the concept how to improve the maintenance of emergency service vehicles so that they could be ready to service on 24/7 basis. The data collection was done via six different sources: 1) interviews; 2) documents produced during the MOBI project; 3) archives; 4) free observation; 5) participatory observation during the field tests and 6) artifacts. The original test results are available via the Internet [26].

A. *Field tests*

During the field tests, applicability of the RFID technology in the emergency service vehicles was verified. Field testing was carried out in the MOBI demo vehicle, shown in Fig. 5, which is a real police car with extra features. The identification was tested only via the handheld reader shown in Fig. 3. So, the situation was the closest possible to the deployment phase.

Fig. 5 The MOBI demo vehicle

Table II lists the selected models of RFID tags. Fig. 6 shows where the tags were placed during field testing. The tags were placed in seven different storage areas: 1) under front bench, 2) fire extinguisher, 3) inside the upper metal bin 1, 4) inside the upper metal bin 2, 5) inside the upper metal bin 3, 6) inside the lower metal bin 1, and 7) inside the lower metal bin 2. The RFID tags were read from a distance of about 20 cm.

Table II. Selected tag models

Manufacturer	*Model*	*Size (mm)*	*Frequency (MHz)*
Conidex	Conidex Halo	60*12*14	865-869
Conidex	Ironside	51*47.5*10	860-960
Conidex	Ironside Micro	27*27*5.5	865-869
Conidex	Ironside Slim	84*21*10	860-960
Conidex	Steelwave Micro	38*13*3	865-928
Conidex	SteelWing	76.2*18*21	865-928
Conidex	Survivor	224*24*2	865-869

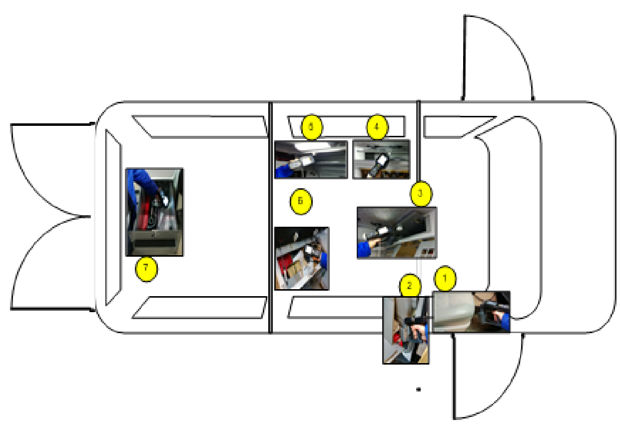

Fig. 6 Field test environment

IV. Results

Fig. 7 shows the applied identification process. The turnaround time for each test was about 3 minutes. Table III shows results of the analysis of observations of how well the RFID tags were able to read a police car's different storage areas. The measurement results (two rounds) were comparable with each other.

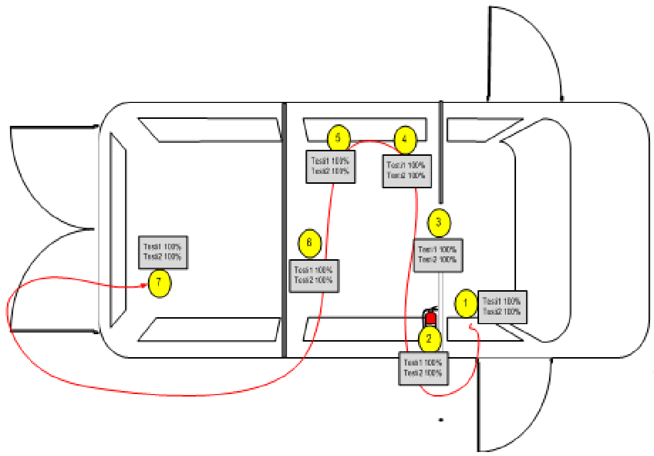

Fig. 7 Identification process

Table III. Measurement results

Police car	Tags		Test results (identifying)	
Storage areas	Manufacture	Model	1	2
1, 2, 3, 4, 5, 6, 7	Confidex	Confide100 Halo	100 %	100 %
1, 2, 3, 4, 5, 6, 7	Confidex	Ironside	100 %	100 %
1, 2, 3, 4, 5, 6, 7	Confidex	Ironside Micro	100 %	100 %
1, 2, 3, 4, 5, 6, 7	Confidex	Ironside Slim	100 %	100 %
1, 2, 3, 4, 5, 6, 7	Confidex	Steelwave Micro	100 %	100 %
1, 2, 3, 4, 5, 6, 7	Confidex	SteelWing	100 %	100 %
1, 2, 3, 4, 5, 6, 7	Confidex	Survivor	100 %	100 %

RDID technology allows checking the locating of equipment even inside metal bins. Also, identification of equipment is easier. Within our field tests, the emergency service vehicle equipment inventory process time was improved from 30 minutes to less than 10 minutes. The conducted field tests resulted in a positive outcome and the benefits of RFID technology in this application are indisputable.

The most significant benefits of RFID technology are improved work quality and time saving. The results show that the remote identification, enable the police to make a car equipped with an inventory of up to three times faster than by hand. The utilization of RFID technology in emergency service vehicles will improve the police work reliability and the work can be made safer, more efficient and economical way. More efficient equipment inventory allows the police to spend more time on patrol and at the same time assisted with a better safety of citizens.

The current trend is that emergency service vehicles will more and more be used as a mobile office [27]. This means that also the number of carried tools increases day by day which further means longer inventory times, if the process is unassisted.

V. Discussion and Conclusion

The amount of technology and other equipment in emergency service vehicles has increased dramatically throughout the years, creating challenges in usability of the systems and safety of the vehicle operators. Law enforcement officials need to operate multiple human-machine interfaces in difficult circumstances, while operating the vehicle at the same time. The need for better HMIs in emergency vehicles has been recognized all over the world. Due to the economic situation, law enforcement authorities' main need is to maintain their core services with significantly reduced budgets. This means that they will apply more ICT and digital services, also in the field. The outgrowth of this progress without good integration of systems will be even more different HMIs the officials should master.

Police cars are equipped with an average of about 100 different types of equipment. Police cars, inventory means a weekly basis the number of hours used in the examination of goods, all of which are out of from normal work. The study concludes that RFID technology is a completely viable option in law enforcement operations. The conducted field tests resulted in a positive outcome and the benefits of RFID technology in this application are indisputable. The study revealed that the subject organizations need to provide employees with a faster way to complete an inventory of emergency service vehicle equipment, by utilizing RFID technology tools and applications. The next step will be a larger scale pilot project. Its duration, scope and objectives must be defined in conjunction with the police. The pilot is good to implement in the right operating environment within a real police car. Police cars' equipment must be accurately determined in co-operation with the police and after that selected a right type of RFID-tag and RFID-reader.

Most new products for integrating first responders' HMIs are marketed and used mainly in the United States. It seems that the United States is currently the main driver of emergency service vehicle HMI design and development in the world, as there were only a few products found outside the United States. This might be because of independency between federal, state and county police, and a bigger market for system manufacturers. The possibility to integrate solutions on a smaller scale makes it easier and faster to test and implement new solutions that improve the efficiency and safety of officers working in the field. In the future the Finnish police and other authorities share the same field command system, so the implementation of the system will take more time, planning, money and bureaucracy.

Finnish police officers normally work in pairs, as in the United States officers usually work alone. In Finland, the vehicle operator does not have to use the field command system while driving, with the exception of motorcycle and snowmobile units. Safety is improved, since the vehicle operator can focus only on operating the vehicle, not using the field command system.

Reviewed solutions were commercial products, apart from Project54 and OneBox. Documents and material related to these products were mainly marketing material and user guides. GUI usability studies in emergency vehicles were not available, and no universal standards for user interfaces in emergency vehicles were found or used. Need for a global standard remains. Current standards for HMI are a good starting point for the development of a new standard.

SUI interfaces have evolved a lot during the past few years, and no doubt a lot of development will occur in the future as well. Many studies [19] – [23] suggest that technology has developed and errors have diminished. The main advantage of SUI is safety; the vehicle operator can operate the field command system by voice, keeping both hands available for other tasks. In some cases this can also speed up the use of the system, as the desired command can be issued in one command instead of having to navigate through various sub-menus to reach the target.

The development of commercial speech user interfaces like Apple's Siri, Samsung's Smart Interaction television, Microsoft's Kinect etc. has introduced a new way of controlling devices, and the future brings technologies that can take usability even further. Clothes can have integrated devices, a windscreen in a car can utilize a head-up display presenting information of the cars' systems and even eyewear like the Google Glass can display information and react to voice controls.

As technology evolves and becomes more mature, solutions like head-up displays on windscreens, helmet viziers and even normal glasses combined with voice controls can bring usability in emergency situations to a whole new level. This makes it possible for officials to focus on the job at hand instead of the field command system, keeping both their hands available at the same time by utilizing a speech user interface.

Future challenges for SUI include localization. As all of the reviewed products and specifications use English as the primary language, the localization needs have not been though about. One problem is that the Finnish language might not be available for out-of-box software. Also as Finland is a bilingual country, there is a need to operate all of the interfaces in Finnish and Swedish. The development and localization of bilingual interfaces may take a lot of time and planning.

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