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# Erklärung zur Verfassung der Arbeit

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„Hiermit erkläre ich, dass ich diese Arbeit selbständig verfasst habe, dass ich die verwendeten Quellen und Hilfsmittel vollständig angegeben habe und dass ich die Stellen der Arbeit, – einschließlich Tabellen, Karten und Abbildungen –, die anderen Werken oder dem Internet im Wortlaut oder dem Sinn nach entnommen sind, auf jeden Fall unter Angabe der Quelle als Entlehnung kenntlich gemacht habe.“

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# Kurzfassung

Obwohl heutzutage bereits viele verschiedene Kommunikationstechnologien verwendet werden, ist es nur möglich die Notrufzentrale über das Festnetz oder das mobile Netzwerk zu erreichen. Dies kann, zum Beispiel, bei Geiselnahmen zu Problemen führen, da es nicht möglich oder zu gefährlich ist zu sprechen. Jedoch ist es auch bei der Verwendung von Voice over IP unmöglich Notrufe abzusetzen.

Neben den Problemen alltäglicher Notfallsituationen, ist es auch notwendig die Koordination in Krisen zu verbessern. Dort sollte, unter anderem, der Umgang mit spontanen, nicht vorher angemeldeten, Freiwilligen verbessert werden. Nachdem nach einer Krise viele Freiwillige erscheinen, müssen diese richtig koordiniert werden. Falls dies nicht geschieht oder die Freiwilligen nicht einmal zum Einsatz kommen, kann es passieren, dass diese Menschen nicht nochmals helfen wollen und die Organisation einen schlechten Ruf bekommt.

Aufgrund der beschriebenen Probleme soll herausgefunden werden welche Kommunikationstechnologien für Notrufe geeignet sind, wie die Koordination in Krisen verbessert werden kann und wie Freiwillige in Katastrophen Kosten reduzieren können. Schlussendlich soll analysiert werden wie ein Unterstützungssystem für Einsatzkräfte aufgebaut sein sollte.

Um diese Probleme zu lösen wurden die folgenden Methoden eingesetzt. Die passenden Notruftechnologien und Verbesserungsmöglichkeiten für Katastrophen-koordination wurden mittels Literaturrecherche herausgefunden. Für die Erstellung des Prototypen wurden als Erstes Experteninterviews durchgeführt. Die Ergebnisse der Interviews wurden für die Erstellung der Mock-ups verwendet. Für deren Evaluierung kam ein Eye-Tracking Gerät zum Einsatz. Mit den erzielten Resultaten wurde ein Prototyp implementiert.

Die Analyse zeigte, dass Kontextinformationen helfen können die Arbeit von Einsatzkräften zu verbessern und zu beschleunigen. Diese Informationen müssen besonders aufbereitet werden, damit sie tatsächlich die Entscheidungsfindung beschleunigen können. Diese kann noch weiter verbessert werden indem Videos und Bilder vom Einsatzort im Vorhinein analysiert werden und die Einsatzkräfte externe Unterstützung bekommen. Für ein Unterstützungssystem für Einsatzkräfte ist es besonders wichtig, dass dieses nicht zu viele Funktionalitäten besitzt. Dies kann zu Überforderung der User führen. Daher müssen die Features sinnvoll gewählt werden, da das System sonst kontraproduktiv wird.

# Abstract

Although all kinds of communication technologies are in use today, the only way to contact an emergency centre is via the wired or the mobile telephone network. This can be problematic in cases of hostage situations where it is not possible to talk but also if the caller uses Voice over IP.

Besides the problems in standard emergency situations it is also important to improve the coordination in crisis situations. There among other things, dealing with spontaneous, not preregistered, volunteers needs to be improved. The large volume of volunteers after a disaster needs to be managed well, otherwise willing people won't try to help a second time and the coordinating organization may get a bad reputation.

Due to the described problems it shall be found out which communication technologies are qualified for the use for emergency calls, how coordination in crisis situation can be improved, and how volunteers can reduce costs in disasters. Finally it shall be analyzed how a support system for task forces needs to be designed.

To solve these problems the following methodologies were used. To find out the adequate emergency communication technologies and to find improvement opportunities for crisis coordination literature research was utilized. For the creation of the prototype at first expert interviews were conducted. The results of these interviews were used to design mock-ups. For the evaluation an eye-tracking device was applied. With the output the prototype was implemented.

The analysis showed that context information can help to improve and accelerate the work of the task forces. The information needs to be prepared appropriately to enhance the decision making process. This can be improved even more by analyzing videos and pictures of the operation ground beforehand or by getting external help in situations expert knowledge is necessary. It is important that systems for task forces do not have too many features as this can be overstraining. The functionalities need to be chosen wisely else the system is contra productive.

# Table of Content

# List of Figures

# List of Tables

# 1 Introduction

Today new communication technologies are getting increasingly more important in our everyday life. Nowadays people not only use telephone calls to get in contact with others, also technologies like SMS, Email or VoIP are popular. Nevertheless it is still only possible to send an emergency call from the wired and the mobile network. Recent events have shown the importance of supporting several different communication technologies for emergency calls. The terror attacks in Norway in 2011 depicted that it can be important to reach out for help quietly. During the shooting on the island Utøya teenagers contacted their relatives via SMS to call for help because it was not possible to send a message to the task forces. Something similar happened during the shooting at Virginia Tech and the Columbine High School massacre.

Besides the issues of standard emergency situations, during crisis situations additional problems occur. The coordination in disasters is very important but also very difficult. It gets even more complicated if many volunteers appear and the coordinators are not prepared appropriately. This could lead to a decrease of the amount of volunteers in the next disaster. However, volunteers are an important and huge resource of manpower and skills.

To identify those problems this work analyses which other communication technologies are qualified for emergency calls and how information, additionally received through these technologies, could help the task forces. Moreover the coordination in crisis situation is observed and improvement opportunities are analyzed. It is examined how volunteers can be used more efficiently and how they can reduce the costs during the emergency as well as for cleanup.

These problems have been analyzed using literature research.

Additionally to the already described part a prototype for supporting task forces was developed. The mobile board computer enables the task forces to get additional context information, like the wind direction or the location of surveillance cameras. It should accelerate response time and improve the work of task forces by tele-translation and tele-analysis of ECG data. Additionally the system should help to enhance the coordination among task forces. Moreover the prototype includes the functionality to receive data of emergency calls from new communication technologies, like videos or pictures of the operation site. The system should help the task force to take fast and accurate decisions.

The design of the prototype was heavily influenced by expert interviews. These expert interviews were executed with a police man, a paramedic and a firefighter to get insight into all areas of application. The results were used to create a preliminary design in the form of mock-ups. These were tested using an eye-tracking device, to find out if the arrangement of the interface is appropriate and easy to understand. The findings helped implementing a prototype.

This work is structured as follows. At first the current state-of-the-art in the field of communication technologies for emergency calls and the coordination of volunteers in crisis situations is discussed. Section 3 deals with the applied methodologies. In Section 4.1 the guideline for the expert interviews and the interview results are presented. The design of the mock-ups and its evaluation are described in Section 4.2. In the next subsection the prototype and the evaluation results are depicted. Subsequently the evaluation results are analyzed and presented in Section 5. Finally, in Section 6 the results of this work are summarized and possible future work is depicted.

# 2 Theory and Technology

The following chapter deals with the definition of emergency and emergency management. Afterwards the aspects of coordination in crisis situation are described. The chapter is concluded with an analysis of the adequacy of different communication technologies for the use as emergency call technologies.

## 2.1 Definitions

The Oxford Dictionary describes an emergency as *"a serious, unexpected, and often dangerous situation requiring immediate action"* [1]. This work uses this term for standard situations in which task forces are called. These are cases were medical attention is needed, people are in need due to the environment or due to other persons.  However, this also includes crisis situations like natural disasters or terror attacks.

According to the International Association of Emergency Managers *"emergency management is the managerial function charged with creating the framework within which communities reduce vulnerability to hazards and cope with disasters"* [2]. This means that emergency management tries to prevent, mitigate, prepare, respond and recover from crises by integrating and coordinating the necessary tasks. This should help the affected areas to be less vulnerable and better prepared.

In this work the term emergency management is seen in a broader way. Additionally to the already mentioned definition the author also includes the coordination and management of standard emergency situations. In these situations different aspects become more important: The main concern is a well-developed access to emergency call centers as well as fast response times. In contrast to that the major priority in disasters is to maintain an overview over the situation and to coordinate all involved parties and resources.

## 2.2 Coordination in Crisis Situation

Preparation for emergency cases is very important. For example the improvement of the hurricane protection infrastructure in New Orleans would have cost $5 billion. This would have saved $200 billion in Hurricane Katrina in 2005 beside the loss of lives [3].

According to Lorenzi et al. the major problems for the government in crisis situations is the communication with the citizens and the efficient distribution of the work need to be done in disaster areas [4]. A key component for the coordination in crisis situations is a good vertical coordination, among intergovernmental organizations, and horizontal coordination, among interstate organizations [3]. The problem is that many different organizations have to work together in a disaster situation. These organizations have different terminologies and organization structures [5]. Therefore it is already difficult for them to work together in normal situations but in crisis situations it is even harder [6]. To efficiently coordinate the work in disasters, an overall management system is needed [7], with defined agency roles [8], adequate task management and division of labor [9].

Information and communication technologies are very important in disaster prediction. Moreover they enable the public to communicate quickly after the disaster and exchange information about the crisis [10].

Marsden et al. created a communication system for disaster situations, called Intelligent Deployable Augmented Wireless Gateway or shortly iDAWG [11]. The system creates a communication network between various people in a crisis area, like coordinators, local response teams and volunteers. Therefore diverse wireless transmission media like police, fire, EMS, municipal, private, cellular and CB bands are connected. The system acts as a signal repeater. The problem today is that these communication devices are not compatible. But to effectively coordinate the resources, a consistent communication technology is necessary. The system enables the user to share information in real time.

The emergency response has two tiers which work in parallel [11]. The first tier consists of emergency responders and the law enforcement. The second one are non-governmental organizations and victims or bystanders and volunteers. The first tier is formally organized and regulated. The latter is very flexible and nearly has no rules. Between these two tiers exist only few communication channels. They act autonomously but in case of a disaster they have to exchange information. For example, if the first tier has resources, or is responsible for them, which are needed by the second tier.

After a disaster, generally speaking, many spontaneous volunteers come to help in crisis situations. Spontaneous volunteers are not specifically recruited volunteers, which do not have a role in advance [12]. They are people who help without any payment and are not associated to an organization [5][13]. Heroic acts of volunteers occurred after the tsunami in Indonesia, Hurricane Katrina in the US and the earthquake in Pakistan and so on [5]. For example in 1985 after the earthquake in Mexico City around two million people volunteered, which are around 10% of the city's population. At the earthquake of Loma Prieta in 1989 60% of the population of San Francisco and 70% of Santa Cruz helped after the disaster. Also after the terror attacks of 9/11 immediately 15,000 people offered their help to assist on Ground Zero [5]. This shows the importance of volunteer coordination in case of a crisis.

On local level, collaboration between volunteers and officials always has been important because they rely on each other. Therefore the community is more involved in official tasks [14]. According to Farazmand et al. people of the disaster area are an important partner in crises [3]. They know the area, culture and speak the language. Moreover volunteers are a connection to the resources of communities and are a great ad-hoc capacity of manpower for the help in crisis situations [14]. Also Fernandez et al. stated that volunteers provide important resources like manpower and skills [12]. Moreover they have an important insight into the community and they can quickly respond because they live in the surrounding area. Fernandez et al. mentioned that *"significant source of timely manpower, and their actions can save lives"* [5, p.4].

Besides these positive aspects of volunteers there are also several challenges that can occur. Volunteers are often applied inefficiently or can even hinder emergency responders. Moreover they can create additional health or security problems [5]. In a disaster area it is more dangerous for volunteers, because they have less training and are equipped worse than emergency responders [12]. Additionally they need food and shelter as well as equipment. Therefore they create even more logistical effort. Moreover it can be complicated to deploy volunteers, if you are not aware of their skills, physical abilities and similar attributes. So you have to examine them first [5]. Furthermore volunteers can also cause traffic jams and hinder the task forces to arrive at the scene [12].

Another problem arises if the emergency personnel are not prepared for the volunteers [12]. As they arrive personnel have to be assigned to coordinate them. But probably these personnel are needed for other tasks. Moreover it can be very difficult to match the volunteers to the needs. Additionally it is problematic if there are no available tasks for the volunteers [5].

For instance after the storm sandy in 2012 many people wanted to help cleaning up in the area. But there was no organization which could assign tasks to the volunteers efficiently [4].

Volunteers can do simple tasks so that the trained personnel can concentrate on more specialized work [5]. They can for example provide food for the emergency responders. Volunteers can also support the task forces if they have specific skills that are needed in a disaster situation.

The coordination of spontaneous volunteers is often delegated to organizations, like non-governmental organization, for example in Florida, California and Ohio [5]. However, existing volunteer management plans have often the problem that they only assign volunteers to tasks of one organization or only plan the coordination of pre-registered volunteers [12]. Moreover the communication between organizations is not good enough. If a volunteer with specific skills want to contribute his or her help, he or she needs to search through all organizations to find one which needs this specific skill [12].

Pre-registration can help to store volunteers with their relevant skills, but it cannot stop here. It must be planned how the volunteers are considered in the incident management system, which tasks are available or need to be done and that the health and safety of the volunteers is assured. Moreover it is very important not to forget to plan the appearance of spontaneous volunteers [12].

Fernandez et al. describe three different volunteer management strategies [12]: In the first strategy the citizens build there “own" volunteer network. This network is able to react in case of a crisis. The people receive training and get access to equipment, which can be necessary in case of a crisis situation. The problem of this strategy is that many people are only motivated to help after a crisis already occurred. The second strategy informs the public or organizations via the media what is needed after a disaster occurred, like material and manpower. This strategy is used in the most disasters and its problems are already described previously. In the third strategy a special amount of pre-trained volunteers and official responders are available. These people can work with the spontaneous volunteers and know where and how to use them.

A crisis management system needs to assign not only individual volunteers to task but also groups of volunteers or a whole organization [5]. This helps to stop duplication of work and fostering of coordination. It is necessary that organizations are aware of the other organizations, else coordination cannot work. An emergency manager needs a system that helps to coordinate the available volunteer resources and guarantee their safety. Moreover such a system needs to support the emergency responders to effectively perform their tasks. Volunteers need a system where they can contribute their skills and resources.

According to Cheung et al. the best way is to have a centralized command center on the ground, to effectively coordinate complex situations like a disaster [15]. Such a centralized command center helps to communicate between organizations and to coordinate the tasks between the organizations.

Lorenzi et al. introduce an emergency response system called Public Engagement for Emergency Response System, or briefly PEERS [4]. It consists of a volunteer database and an incident reporting system. The people can register with contact information, location and their skills and tools which can be helpful in a crisis situation. This information is stored in the volunteer database. In the incident reporting system the people can report incidents or problems to the government. These problems can be solved by the volunteers and the citizens do not have to wait for government workers. Moreover it is a sort of communication tool between citizens and the government. An incident report consists of a picture of the problem, GPS coordinates if available or else the nearest crossroads, a description of the problem, the user who reported the problem and a timestamp. A web portal depicts a real time map with the reported incidents, how many people reported it and who is responding to it. The system should decrease the time until a problem is solved. Moreover the system includes rewards for people who get active in reporting and volunteering. An example for rewards can be tax relief. As soon as there is a crisis the government can query the volunteer database to find adequate people to help. This helps to use the available resources more efficiently. The volunteers are allocated, by an assessor of the government, to the incidents in the reporting system. After the work is finished it is verified by an official, if it is done correctly. For automated assignment of workers to problems semantic ontologies can be used. It decides whether a volunteer or government worker solves the problem to be most efficient. Moreover it can be useful to provide the gathered information to private supply companies, like AT&T, power and gas utilities. This can help to solve problems faster and to have more transparency where their service is unavailable.

In [6] a decentralized approach for disaster coordination is described. The Synchronized Disaster Response System creates and maintains shared awareness. It depicts resources and the logistic situation in disaster areas, in a way that there are no security risks or competitive advantage for someone. Each existing resource has a location and the following parameters: resource type, palletized, number, weight each, unit of measure, quantity each, and quantity total. It is possible to search for the resources and to filter for location and specific resource. Moreover it can be posted if critical resources are transported to a different location. The system can be used without top-down coordination. Nevertheless the organizations can work on the same overall goal but still act independent [6].

Also in nonprofit organizations social media technologies get more important. These technologies are mainly used for fundraising [16] [17] and to promote the doings of the organization and the causes for these doings [18]. Facebook is mainly used to publish events and to recruit new volunteers [16]. The use of twitter is not widely spread among nonprofit organizations. The one using this social media apply it similar to Facebook. Moreover these technologies are mainly used for one-way communication [18][19][17]. They are not used for interactive dialogs, for which these social technologies are made for. Although it is very important to stay in contact with the volunteers and have community among them, today mainly mass-emails are used [16]. Social media would be adequate for communication and community building. But it needs to be designed especially for such a purpose.

There are some challenges in the use of social technologies in nonprofit organizations. At first the texts written in social media are influenced by the role the writer has in the organization [16]. Moreover new systems are mainly created for volunteer recruiting. But an analysis showed that this is not important to volunteer coordinators. They get enough volunteers via other channels. The problem with social media is that the coordinators do not know the persons and if he or she really wants to volunteer. They need a system which helps to support the community among volunteers and to recruit volunteers of targeted demographics. Another challenge is mass calls of volunteers. They can have negative consequences if there is not enough work for the high amount of volunteers. It is better to have too little volunteers as to have too many but not enough work. Volunteers who are not used in an emergency will not come again, moreover the organization gets a bad reputation. Additionally the organizations are afraid to lose control over the recruiting and scheduling process. The volunteer coordinators need volunteers that really want to participate and want to invest time. They do not look for any volunteers.

The system VolunteerMatch lists volunteer opportunities at different organizations. The user can search for volunteer opportunities filtered by geographic area or interests. Other similar websites are Serve.gov, HandsOnNetwork.org or Mentoring.org [16].

Another idea compared to classical volunteering is micro-volunteering, where tasks are crowdsourced [20]. Therefore the assignments are divided into small tasks, so called micro tasks. These tasks can be finished very fast, even on a mobile phone while waiting for the bus. Such a task can be a simple data entry, image tagging or categorizing of information. These online volunteer tasks are often information processing tasks [21]. Emergency responders have only limited resources to analyze the data in the web [22].

Examples for virtual volunteer organizations are Crisis Commons, CrisisMapper, the Standby Task Force and Humanity Road [22]. They use tools to analyze twitter traffic like TweetDeck or TweetGrid and also tools especially designed for emergency situations, like TweetTracker and Crisis Tracker. In such organizations the work is divided by assigning volunteers to search terms for the twitter analysis or allocate specific geographic areas to them. Experienced volunteers decide which search terms shall be used or which area shall be observed.

In the following paragraph the economic effect of volunteers will be described. To the author's knowledge there are only very few studies done so far to measure the economic impact of volunteers. Nevertheless it is interesting to take a look at existing numerical values.

According to a report of the Red Cross the initial investment which is necessary for volunteer management efforts are worth it [23]. The Danish Red Cross participated in a study, which discovered that one dollar, which is spent into their volunteers, results in eight dollars saved through community activity and assistance.

After the tornado in Osceola Country the costs for cleanup were estimated at $8 million [13]. The actual costs were only $1.4 million, due to the enormous help of volunteers. Moreover the time for cleanup was shortened from estimated 90 days to only 55 days. Another example is from Seminole county where the cleanup was estimated with $1,525,000, due to volunteers the cost could be reduced to $660,000.

These examples show that volunteers have the potential to save money of the authorities and to be an economic benefit. To get a better understanding of the economic influence of volunteers in crisis situations more studies need to be conducted.

## 2.3 Communication technologies

In this section various communication technologies, their advantages and disadvantages as an alternative or extension of the current emergency call system will be described. In the current emergency call system only the wired and the mobile telephone network can be used to do an emergency call.

Recent events showed how important it can be to support several different communication technologies. At the Columbine High School massacre in 1999 and the shooting at Virginia Tech in 2007 [24] students tried to text to "911" but could not reach it [25]. Also the attack on the island Utoya in Norway in 2011 showed that the victims used new communication technologies, SMS, to reach out for help because they were afraid of talking [26].

People expect to send emergency calls or messages via the same technologies they use in their daily lives [27]. Moreover it can be important to use additional communication technologies like sending a text message. That can be useful in the following cases [24]:

- If it is dangerous to talk, for example in case of a hostage.
- For deaf and hard of hearing people.
- In disasters where the voice network can be overloaded due to the vast numbers of voice calls. In such cases messages may still reach their destination.

Finally young people use text messages more often than voice calls [24].

In the following subsections different communication technologies are analyzed for their adequacy as technology for emergency calls. Different implementation possibilities and advantages and disadvantages of the various technologies are described.

### 2.3.1 Voice over IP

Today approximately 67% of the population in Europe uses the Internet regularly, which means at least once a week [28]. Furthermore the software Skype is getting more and more popular and had more that 50 million concurrent users worldwide on 21 January 2013 [29]. Due to the fact that Voice over IP (VoIP) is getting more popular it is advisable to implement an emergency call service which supports this technology. Moreover the use of VoIP allows, according to Mintz-Habib et al., *"higher resilience, faster call setup, better information presentation, multimedia support, and lower costs"* [30, p.1]. The United States and the European Union already started a project for a next generation (NG) emergency call service, called NG911 and NG112. These projects try to improve and expand the existing emergency call services and both have defined standards for the new service. These standards are described in [31] and [32]. In the US it is already obligatory for VoIP providers, which are connected to the public switched telephone network (PSTN) to offer a service enabling emergency calls. However, this service is often associated with costs for the caller and therefore is not mandatory for them [33]. So far it is not compulsory for VoIP providers in the European Union to enable emergency calls but there are ongoing discussions.

Although there are a lot of reasons to use VoIP for emergency calls it is necessary to consider several issues so that these calls can be transmitted to the PSAP (Public Safety Answering Point) [30]. One essential aspect is to find out the location information of the caller. This can be more difficult when using VoIP compared to PSTN

(Public Switched Telephone Network). For example a caller can be located in New York but *"communicates through a SIP proxy in Hong Kong over a VPN tunnel"* [30, p.1]. To deal with these aspects, Mintz-Habib et al. divided the emergency call handling into four steps: First, it is identified whether it is an emergency call or not. Afterwards the location of the caller is found out and is included into the INVITE message of the Session Initiation Protocol (SIP). In step three the appropriate PSAP depending on the callers' location is assigned. Finally, the call is directed to a call taker at the proper PSAP. In order to execute these steps the SIP of the VoIP Network is used. The SIP is an *"application layer signaling protocol for initiating sessions between hosts to exchange media" content"* [30, p.1]. The protocol is not responsible for the transportation of the media content itself, but is used for agreeing on how to exchange media content.

As a first step emergency calls are identified depending on their destination URIs and the caller's location. Subsequently the location of the caller needs to be determined. The steps executed by the proposed prototype of Mintz-Habib et al. are shown in Figure 1 [30]. One possibility to determine the location is to manually enter it. The user can, for example, figure out its position using GPS or a location service that calculates the location of the user, using three wireless access points (1a). This can either be done before starting the emergency call or already in advance, e.g., when installing the VoIP application. The disadvantage of manually entered location data is that it depends on the reliability of the user. If there is no manually entered location the outbound SIP proxy automatically looks up the caller's location. Therefore it sends a DHCPINFORM query with the MAC address, which was received out of the packages of the caller. The system administrator of the caller's network has stored the location of the PCs of its network. So the civic address of the caller can be delivered when query for the MAC address (3a). Moreover the location can be received via the MapInfo's Envinsa service if the call is from a PSTN-to-VoIP gateway. The service can find the address associated to a specific telephone number (3b). In both cases the determined location is returned to the Outbound SIP Proxy (4a, 4b). After the identification of the caller's location the appropriate PSAP has to be found, described in detail in the next section.

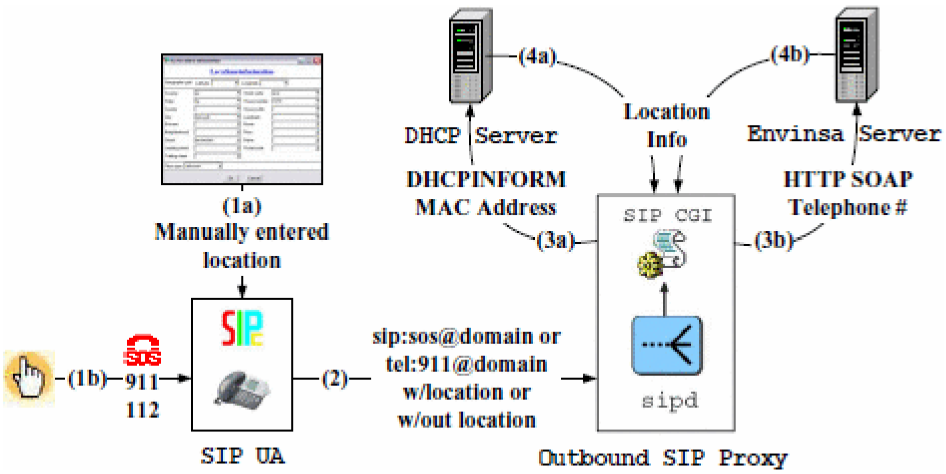


Figure 1: Identifying emergency calls and determining location [30]

Kim et al. describe another possibility to determine the location of an emergency caller [34]. Beside the use of DHCP, GPS and manual entry they propose the use of the Cisco Discovery Protocol (CDP). CDP is a protocol which helps to find a device in a network. Therefore a message is sent to a multicast address every minute. It includes the name of the switch and the ID of the port where the message is coming from. According to Kim et al. the granularity of switches and ports is sufficient for the determination of the location. Normally a switch covers a floor or a half floor and the port is assigned to a specific room. But to get the final location a database is necessary where the name of the switch and the ID of the port are mapped to a specific civic address. This database has to exist in every administrative domain. The location lookup starts with the listing on the network for switch and port information. As soon as this information is collected it is sent to the SIP User Agent where a query is sent to the database to get the civic location of the caller. A disadvantage of this method is that a network administrator is necessary to administer the mapping between the switch/port information and the real address. As the name of the protocol already implies, it is Cisco-specific. It has to be noted that there are several other Ethernet switches which provide a similar protocol.

In the following table advantages, disadvantages and the resultant useful situation for the different location determination methods are described [34].

| | CDP | DHCP | GPS | Manual Entry |
|---|---|---|---|---|
| Merits | • Cisco devices7 are ubiquitous<br>• Less burden for Administrators than DHCP | • DHCP is ubiquitous<br>• Applicable to both SIP UA and SIP proxy | • Delivers precise location<br>• No work for administrators | • Is always a backup method |
| Drawbacks | • Only works with Cisco switches and access points<br>• Administrators have to enter switch–location mapping | • Not good for wireless connections<br>• Administrators have to enter machine – location mapping for each machine | • GPS does not work indoors or when a significant portion of the sky is blocked from view. | • No guarantee of timely update<br>• Prone to human error |
| Useful Situation | In organizations that use Cisco devices | In organizations where computers are fixed in one place | Outdoors | When all else fails |

Table 1: Comparison of location determination methods according to Kim et al. [34]

Beside these technologies it is also possible to get the location information via a location service of the Internet telephony service provider (ITSP) [30]. The ITSP gets the IP address of the caller and can use it to get his or her physical address. If the IP address is a fixed address, e.g., of a company, only a simple mapping between the IP address and the physical location of its origin has to be done. In case of a dynamic IP address, like in a normal household, the ITSP has to look up which customer was dedicated to the specific IP address at this time. The information about the customer's location and its name was recorded by the ITSP as the customer registered his or her Internet access. So every IP address can be mapped to a specific physical location. Nevertheless this method has some significant disadvantages. One drawback arises when the call is directed through VPN. When using VPN not the IP address of the caller is transmitted but the one of the network the caller is directed to. Thereby it is not possible for the ITSP to figure out the correct location information of the caller. To solve this problem there are already ongoing discussions that all end devices (devices used by the caller) need to transmit their IP address when using VPN. Moreover the use of mobile devices is problematic because the ITSP cannot save a specific physical location to mobile user. However, it would be possible to solve this problem by committing the ITSP to determine which IP address is used by which mobile phone number. Afterwards the phone number can be used to locate the caller like it is already done today for normal emergency calls from a mobile device. Here the location is calculated by using the location of the used base station and the field intensity of the call.

Another similar approach is proposed by Lee et al. [35]. They use the Internet phone number of the user to get his or her district code. This mapping is done by the telecom company which must have a database including the customer information. The customer needs to provide his or her district code and residential address when subscribing. The residential address is needed if the district code query does not deliver a result. In this case the address is used to find the proper district code. Afterwards the detected district code is used to figure out the appropriate PSAP.

The following paragraphs describe different possibilities to route an emergency call to the proper PSAP. In general there are two different approaches to route the call. The first approach uses the PSTN to transmit the VoIP emergency call. The second possibility intents to send all emergency calls, of PSTN and VoIP, via the Internet to an Internet based PSAP.

Mintz-Habib et al. describe two different approaches to find the appropriate PSAP [30]: either through DNS lookups or by using the MapInfo Envinsa Location Platform. If the Outbound SIP proxy receives the location information as geographic coordinates it can use DNS lookups as well as the MapInfo Envinsa Location Platform to find the correct PSAP. This decision depends on the configuration of the Outbound SIP Proxy. If a civic location is returned to the proxy it has to use DNS lookup to get the appropriate PSAP. The DNS lookup works as follows: When having the civic location the location elements need to be separated from the most granular to the least granular. Afterwards a DNS query is started with the most granular location element, if no result is delivered the second most granular element is used and so on, until a match is found. If a match is found a NAPTR record is returned which includes the emergency URI to the proper PSAP. An example for a returned NAPTR record of the location "Houston, TX" would be:

```
houston.tx.us.sos-arpa.net IN NAPTR 50 50 "u" "SOS+ECC"
"/.*/sip:houston_tx@emergency.info/i"
```

DNS can also be used to get the right PSAP using geographic coordinates. The result of this query is a pointer to a XML document which describes a specific geographic area like a state, district or PSAP coverage area. The query process works as follows: A proxy server searches through the records of geographic areas from the least granular to the most granular. Thereby it checks if the record includes the geographic coordinates of the caller. This is done until the most granular matching record is found. This record is used for a DNS query as described in the previous paragraph to get the appropriate emergency URI. If no location was found in the previous step the emergency call is routed to a default PSAP.

Kim et al. see a problem using DNS queries [34]. Thereby it is necessary to provide the resource records for the location determination in a hierarchical structure, although geographic coordinates do not have any hierarchy. Therefore the Location-to-URL Mapping Protocol (LUMP) is used because it does not need resource records in a hierarchical structure. Nevertheless the resolvers are structured in a tree. The root LUMP node is a nation-wide resolver, the child nodes are state-wide resolvers and so on. Every LUMP node has a dedicated LUMP URL, for example "lump://leonia.nj.us". The query works as follows: The location of the caller is sent by the SIP proxy to the root resolver. There the LUMP query starts with working through the tree until it reaches a leaf node which can resolve the request. Afterwards the query is stopped and the URL of the PSAP, which is saved in this leaf node, is returned.

Also Park et al. propose to introduce an Internet based PSAP [36]. They use the REGISTER message of SIP to find the proper PSAP. The user sends its contact address to the Registrar and there the mapping is done. The PSAP information is stored in a database and is sent back to the caller. Afterwards the caller can contact the PSAP directly or a proxy can be used to do the routing process. This solution transmits the location information via a XCAP (XML Configuration Access Protocol) Server (see Figure 2). The caller publishes his or her location information to a Presence Agent (PA), a XCAP Client. The PA stores this information and passes it on the PSAP as soon as it sends a request. If the caller updates his or her presence information the PA immediately notifies the PSAP. Publishing and notification is done via HTTP methods PUT and GET because XCAP resources are HTTP resources as well.

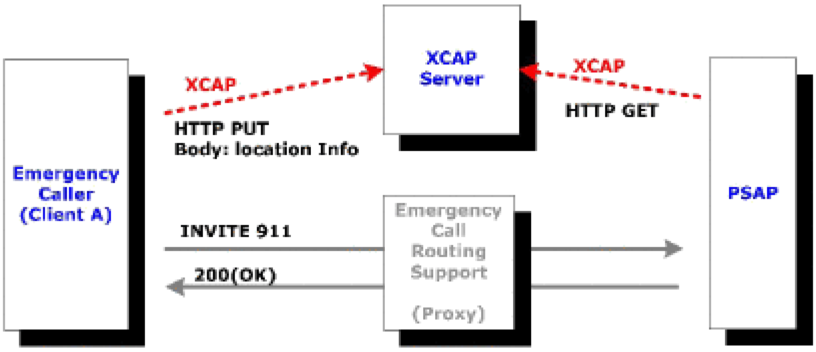


Figure 2: Location Information Supporting Mechanism using XCAP [6]

In [35] the district code of the caller is used to create a routing number to the correct PSAP. The district code is retrieved from a database of the telecom company as already described previously. To get the routing code a database provided by the Internet provider can be queried using the district code. The result is a specific code that is used to construct the routing number to the PSAP. The call is transmitted via the public switched telephone network [35]. Also in [37] the PSTN is used to transfer the voice of the emergency call. But they also describe a possibility to additionally use the IP Network to transmit images and video data [37].

Despite the use of VoIP it still would be possible to utilize the current procedure to find the appropriate PSAP. Today it is done by an algorithm which finds the proper PSAP depending on location information, telephone number and other parameters.

To assure that emergency calls are transmitted securely to the PSAP some security issues should be implemented. Mintz-Habib et al. advise to use secure DNS to prevent manipulating of DNS entries and as a consequence sending an emergency call to a faked PSAP [30]. Moreover Mintz-Habib et al. proposed to assure the signaling and media integrity and confidentially by using TLS (SSL) and SRTP. For secure call routing TLS is used and for media routing SRTP, an encoded protocol for real-time transmission. Another problem that arises when using VoIP for emergency calls is denial of service (DoS) attacks. According to Fuchs et al. it is not possible to use preventive measures, like authentication, to protect the PSAP [38]. Such measures could easily restrict the accessibility of the PSAP for example when a caller is in shock and cannot pass an authentication test. For this reason reactive measures need to be used which can only start as soon as an attack is already detected. In IP networks Intrusion Detection (ID) is often used to prevent a DoS attack. Therefore the network traffic is analyzed and a DoS attack can be discovered via anomaly detection or misuse detection. The anomaly detection has a previously learned normal behavior which is compared to the current traffic. If the deviation between the normal behavior and the current traffic exceeds a specific threshold a DoS attack is detected. The misuse detection uses a database with known attack patterns and compares these patterns with the current traffic. False positive alarms mainly occur when using anomaly detection because irregularities occur in the normal traffic as well as in disaster situations. In comparison to false negative classifications, which appear more often in misuse detection. If the attacker uses a new pattern this method cannot detect it. In disaster situations it is extremely important not to classify these calls wrong. One idea is to compare the number of calls from PSTN and from VoIP [39]. In case of an attack only the number of calls from VoIP will rise. As a consequence PSTN and the mobile network could be prioritized. Such a method can only be used in case of an attack, else the VoIP callers are disadvantaged. Therefore it is very important to detect an DoS attack early. Fuchs et al.'s prototype monitors the emergency calls in an ID module which expands the Private Branch Exchange (PBX) [38]. PBX is for example responsible to distribute the incoming calls. The first step is to determine the origin of the emergency call, either PSTN, mobile network or VoIP. Calls originated from PSTN or the mobile network can be distinguished by the phone number. This is not possible for the differentiation between PSTN and VoIP because they use the same structure for the phone number. There are two possibilities proposed to solve this issue: The information of the origin can be integrated into the transmission protocol at the VoIP gateway or different routing numbers depending on the origin can be established. The next step is to divide the calls into the three domains (PSTN, mobile network and VoIP) and assign a specific capacity to every area. In every domain a checkpoint is established which measures the interarrival times and the number of rejections. Moreover a checkpoint is needed in the agent (call taker) area. There the metrics occupancy and residence time are measured. If a DoS attack occurs the arrival rate increases and if the PSAP is on the limit of its resources the rejection rate rises as well. The residence time in the three domains reflect how long a caller needs to wait to be serviced. In the agent area it represents the call duration. This can be an indicator for an attack because faked calls are hung up immediately and thereby decrease the mean call duration. The prototype consists of an ID module in every domain which reports to a meta ID component if a metric exceeds a defined threshold. The results are used to set one of the following alarm levels for every domain:

- *"Alarm level 0: interarrival alarm of domain is not set*
- *Alarm level 1: interarrival alarm of domain is set*
- *Alarm level 2: interarrival alarm and occupancy alarm of domain are set*
- *Alarm level3: interarrival, occupancy and rejection alarms of domain are set"* [38, p.6]

After setting these levels in every domain the results are combined to find out whether an alarm needs to be triggered or not. In the following table the alarm criteria are depicted [38].

| VoIP | PSTN | Mobile | Attack Alarm |
|---|---|---|---|
| 0 | * | * | No |
| 1 | * | * | No |
| 2 | 0 | 0 | Yes |
| 2 | 0 | 1 | Yes |
| 2 | 1 | 0 | Yes |
| 2 | 1 | 1 | No |
| 3 | 0 | 0 | Yes |
| 3 | 0 | 1 | Yes |
| 3 | 1 | 0 | Yes |
| 3 | 1 | 1 | Yes |

Table 2: Alarm criterion based on the domain alarm levels [38]

*: alarm level 0, 1, 2 or 3

In case of a DoS attack the alarm level of the VoIP domain needs to be at least 1 (interarrival alarm set) because the goal of a DoS attack is to paralyze the PSAP [38]. Nevertheless an alarm cannot be triggered until level 2 is reached. Alarm level 1 only shows a short increased call rate which can be normal. An attack alarm is released if one or both of the other domains (PSTN, Mobile) are in level 0. No alarm is triggered if both other domains are in level 1 because this is an indication for a disaster situation. If the VoIP domain is in level 3 an alarm is also initiated if the PSTN and mobile domain are in level 1 because the capacity of the queue is already exhausted. All other states which are not depicted in Table 2 do not trigger an attack alarm.

### 2.3.2 Video stream

An important feature of VoIP is that it can send audio, video data and pictures. If the PSAP would be able to additionally receive to the audio data video material it could help to rescue someone in need [40]. Moreover Krishnamoorthy et al. stated that video data can give more detailed information about the situation and the operation site [41].

Jeong et al. suggest sending audio data via the PSTN and using the IP network for the transfer of multimedia files [37]. This approach was already described shortly in Chapter 2.3.1. As depicted in Figure 3 the ITSP (Internet Telephony Service Provider) gets an emergency call from a SIP client. Thereupon it sends an SIP INVITE message to the gateway of the PSTN network. The PSAP proxy server, which is connected to the PSTN and the IP network, receives the SIP INVITE. Then it checks if the message is from a VoIP number. If yes, the PSAP proxy server sends an SIP INVITE to the ITSP proxy server to exchange multimedia data. As soon as the ITSP proxy server accepts the INVITE a SIP session is established between the two proxy servers. The INVITE message is only accepted if there already is an established audio connection. The PSAP proxy server forwards the incoming video data to the call taker.

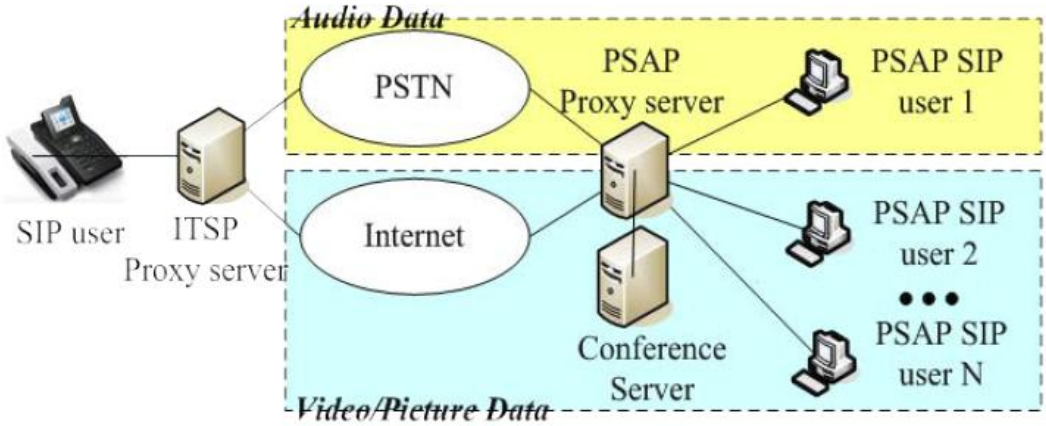


Figure 3: Method to support multimedia data [37]

The system M-Urgency proposed by Krishnamoorthy et al. [41] enables to establish a video stream to the PSAP. The application runs on smart phones, tablets, laptops, PDAs and the like. The user can click a button to make an emergency call. That triggers the sending of an audio/video stream and the location information of the caller to the PSAP. The PSAP receives the call and the system enables the call taker to see the real-time position of the caller on a map, the audio/video stream and a list of available emergency responders [41].

### 2.3.3 Instant Messaging

In 2007 there were 71 million instant messaging (IM) users in the US [42]. Two years later there have been 1 billion IM users worldwide [43]. A prediction of the year 2011 says that in 2016 there are going to be 1.3 billion mobile IM users [44]. These numbers show how widespread instant messages are today. Therefore it is important to enable emergency messages for this technology.

Most Instant Messaging protocols are proprietary and therefore cannot be used for emergency messages. To integrate Instant Messaging into the NG911 system the service providers should use SIP MESSAGE requests [42]. According to Barnes et al. many protocols of instant messengers can be translated to SIP via a gateway [45]. Nevertheless there are also many providers which use protocols that are completely different to SIP. It will not be possible to translate these protocols. The functionality of SIP requests is already described in Chapter 2.3.1. Shortly summarized it works as follows: The location of the caller is received from the LoST server. A SIP INVITE with the location information is sent to the ESPR (Emergency Service Routing Proxy). The ESPR asks the LoST server to find the appropriate PSAP according to the location data of the caller. Then the SIP INVITE is forwarded to the PSAP. The problem when using this approach is that every SIP MESSAGE stands alone and requests new routing. Therefore a solution has to be found to send multiple messages to the same call taker. Song et al. proposed to open a chat window on the client side which sends all messages to the same ESInet (Emergency Services IP Network) also if the location of the "caller" changes [42]. In the ESPR a timer is started or reset as soon as a SIP MESSAGE of an emergency caller arrives. As long as the timer is running the messages are routed to the same PSAP and same call taker. Besides this mechanism the call taker in the PSAP has the possibility to manually stop a session.

### 2.3.4 E-Mails

Seth et al. developed an approach to send emergency e-mails via Wi-Fi hotspots without authentication [46]. In 2011 there have been more than 750,000 wireless hotspots worldwide and more than 700 million people used Wi-Fi. Moreover in 2009 more than 800 million Wi-Fi capable devices have been sold. It is getting more and more difficult to send data via Wi-Fi without authentication because the number of secured hotspots increases.

The prototype does not need to authenticate by the hotspot [46]. It can use every access point in the surrounding independent if it is secured or not. The association and authentication phase is skipped. However, the established connection can only be used to send an emergency message to the appropriate PSAP. To select the best and most reliable hotspot the prototype analyses the signal strength and the current connections and transmission failure rate of previous emergency messages. The location of the user is identified with the so called Skyhook’s Wi-Fi positioning system at the access point. Therefore the mobile device sends information about all visible access points to the Skyhook location database. There the location of the user is calculated using the information of the access points and their signal strength. The resulting location data can be combined with other existing location data like from a GSM station or GPS.

The communication between the mobile device and the access point is executed with the management frames of the 802.11 protocol [46]. The management frames are used for the connection to the wireless network and to move the association if the access point changes. For sending information via the management frames no authentication is needed. The emergency message is transmitted via the probe request and probe response management frames.

Advantages of this prototype are that one can send an emergency call even if there is no telephone signal [46]. Moreover it can be used by people who cannot hear or are hard of hearing. Additionally the internet is one of the fastest ways to transmit an emergency message. The analysis showed that it takes 1.8 to 2.4 seconds to send a message to the PSAP using this prototype.

The disadvantage of this approach is that the user's device needs a wireless card which supports packet injection [46]. So far no such chipset is available for smart phones. Another drawback is that you cannot find out if the PSAP received the message or not.

Like for every emergency service there are also possible points of attacks for this approach [46]. There can be fake access points, which for example do not forward the emergency message. A possible solution would be to allow the sender to send the message to all available hotspots. Not all of them will be fake access points. Another problem can be denial-of-service attacks. An attacker can send continuously false messages to an access point and thereby paralyze it. To avoid that the MAC address can be tracked and multiple senders can be blocked. This approach is not applicable if the attacker changes its MAC address. Finally fake calls can be problematic but they are an issue for every technology.

### 2.3.5 Social Media

The research showed that most papers in this scope deal with the analysis of traffic in social networks. The analysis shall depict if a crisis or other event is going on [47][48]. Moreover there is some research about the use of social media as communication tool of the authorities to the public. To the author's knowledge there is no research about using social networks as medium to send an emergency call or message to the PSAP.

### 2.3.6 Short Message Service

At first it has to be mentioned that in some European countries it is already possible to send emergency SMS, for example in Finland or Sweden [49].

The advantage of using SMS in emergency situations is that it is widely spread and cheep [50]. Moreover the Short Message Service may still work when the signal is weak or the network is too busy to handle calls [51]. For example during Hurricane Katrina in 2005 people used SMS to stay in contact because voice calls were not possible [52]. But there are also several problems regarding the use of SMS for emergency calls: At first "112" (or "911") SMS are not defined as emergency communication in the network, therefore they cannot be prioritized [51]. Another issue is that messages can get lost or arrive delayed. It is possible to get a delivery confirmation but the sender cannot get the information if the SMS was read or not. Moreover the localization of the SMS sender is not contained in the standards for SMS. Finally it is a challenge to route multiple messages of the one session to the same call taker [42]. Problems for the call taker may be that it is harder to value the condition of the person in need, due to missing information about voice and breathing [51]. The use of SMS can have even an economic problem. The call taker needs 7-8 minutes more, compared to a normal emergency call. Therefore more resources are required to keep the current service level.

Due to the fact that the location information is extremely important in emergency calls, different solutions have been developed to enable localization [51]. In the UK it is possible to do a location request by the Mobile Network Operator (MNO) with similar protocols which are used for voice calls. In some countries (like parts of Spain) you first have to make a call to "112" to be routed to the appropriate PSAP. Afterwards the SMS communication can be started. However, in most countries where SMS emergency calls are possible preregistration is necessary. In most cases this infrastructure is maintained for people with disabilities, like deaf, dumb or hard of hearing people. During the registration process it is required to enter personal information and possible residences, like home, school or work address. The users are informed about possible limitations and are provided with a how-to manual. Moreover a draft message with important information in case of an emergency should be saved on the cell phone. These preparations can also be beneficial because they speed up the communication with the call taker. Moreover a compulsory registration decreases the risk of malicious messages. The disadvantage is that only the registered numbers can send a "112" SMS. This can be problematic if the need arises unexpected, as in a hostage situation. Another issue can be that visitors from foreign countries cannot register to the local emergency SMS service. The registration SMS will always be sent to their home country [50].

Song et al. propose a new solution to get the location information and resolve the problem of multiple messages belonging to one session [42]. Therefore they attach the location, retrieved by the user's cell phone, to the SMS message. This approach needs an application that recognizes an emergency message but it uses the already existing infrastructure.

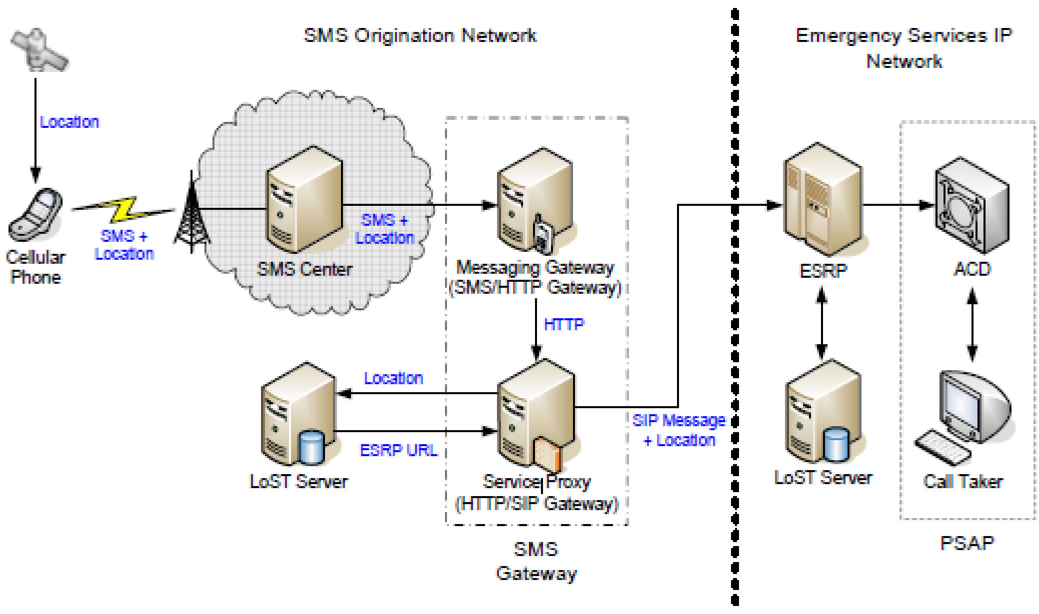


Figure 4: The SMS prototype system [42]

As depicted in Figure 4 the message is forwarded to the SMS Gateway after sending [42]. There the location of the SMS is extracted and sent to the LoST server (Location-to-Service Translation). The LoST server uses the location information to find the appropriate PSAP. Then a SIP message is formed with the information that it is an emergency message, the routing address discovered by the LoST server and the original message. The ESRP (Emergency Service Routing Proxy) notices an incoming SIP message and starts a timer. All messages of the same user are transmitted to one call taker as long as the timer is not over. The start and ending of a session can also be handled manually by the call taker.

As already mentioned SMS can get lost or arrive delayed. Meng et al. analyzed the reliability of SMS by testing a cellular network with 20 million subscribers [53]. For the analysis 59 million messages were collected in a period of three weeks. It turned out that both, message delivery fail ratio and latency, are not better or even worse compared to e-mail, VoIP and telephony. The measured delivery fail ratio was 5.1%. E-mails only have 1.57% end-to-end message loss [54]. This can be explained by the fact that there are more often network resource shortages and intermittent connectivity, compared to the wired internet [53]. The fail ratio is even less for telephony with only 0.01% [55]. The latency is the time measured between the arrival of the SMS in the SMS centre, which stores all SMS messages, and the delivery to the receiver [53]. The analysis showed that 91% of the messages were delayed for less than five minutes. According to Moors et al. 92% of all email messages are delayed for less than 3 seconds [54].

The applicability of SMS for an emergency call can be affected by the fact that the short message service is not secured in the public mobile network [56]. Security aspects like authentication of the sender, integrity of the message and non-repudiation (sender cannot deny that he sent the message), can become important for emergency messages. Saxena et al. proposed to cipher SMS messages with AES and sign them with a digital signature [56]. For the first prototype they used DSA (Digital Signature Algorithm) for digital signature. Additionally they stated that for future work a better algorithm is needed given that DSA is not unbreakable.

Shirali-Shahreza introduces in his paper a prototype which sends information about the patient/user and his or her location to numbers defined in advance [57]. Therefore the user previously specifies the residence address, personal information and his or her medical history. Moreover they have to declare several phone numbers which receive the SMS in case of an emergency. These numbers can be of the family doctor, relatives, friends or the emergency phone number. This information is saved in a text file on the mobile phone. As soon as the program is activated, for example by pressing a special key for several seconds, the GPS coordinates are retrieved or if not successful the network base system is used to get the approximate location data. Subsequent a SMS with the predefined data and the received location information is sent to the defined numbers. It is an easy to learn approach because the user interface is already common and also many elderly people know how to use it. Moreover this procedure enables first responders to be better prepared, given that the medical history is already known in advance.

Paredes et al. have a different approach by using an iconographic touch interface to get information about the current emergency [58]. Therefore the user has to select icons depending on the emergency (like accident, or a stroke). The icon selection follows the request protocol of PSAPs. Moreover simple questions have to be answered. The result is a SMS which is sent to the emergency center including the user data, location coordinates and the emergency occurrence code. After sending the SMS a communication channel between the user and the PSAP is established. The communication channel is a live chat, like instant messaging, but via the short message service. For their system registration is necessary.

# 3 Methodology

This chapter describes the methodologies which were used in the empirical part of this master thesis.

## 3.1 Expert interviews

An expert is someone who has specific expert knowledge, which is relevant for one's research. Many different kind of people can become an expert. It can be a scientist but also a car mechanic, if an expert for cars is required [59].

An expert interview is a specific form of a semi-structured interview. In semi-structured interviews every topic is started with an open question and specified with a confrontational question [60]. In an expert interview one is interested in a specific function or activity of the expert. More specifically the activity in which the person has expert knowledge. Compared to biographical interviews the interviewer is not interested in the person as a whole.

Expert interviews can be used for either getting to know a new field or to receive additional context information. Moreover it can be conducted to create a new theory [60].

During the interview a guideline can help not to get lost and talk about the relevant topics [60]. Moreover the guideline should not consist of multiple choice questions. Open questions enable to get additional information which has not been considered during the creation of the guideline [59].

One major problem of expert interviews is to find the right experts, it can be difficult to identify them. Additionally it can be hard to convince experts to an interview, because they only have limited time resources. Moreover confidentiality can get problematic. For that reason some experts may do not want to answer to specific questions [60].

## 3.2 Prototype Testing

During this thesis two prototype tests were contacted. One mock-up test with an eye-tracking device and a test of the final prototype. The following aspects needed to be considered in both test phases.

It always has to be considered that prototypes and mockups are only a representation of the real product. But they can be used to have an early representation of the final product to get feedback concerning the design and performance [61].

A prototype is a tangible artifact which represents an interactive system [62]. It is not only a description of the product. The advantages of prototypes are that they help to create ideas and simplify their evaluation. Moreover they improve the communication among different stakeholders and enable an early evaluation.

A mock-up looks like the final product but does not have its functionalities, it is the *"embodiment of form"* [61, p.4]. The mock-up helps to identify design's problems in an early development phase. At this point of time there is not too much work invested in development. Mock-ups can be a starting point to get ideas and inspiration [61].

In contrast a prototype has the functionalities of the final product, it is the *"knowledge of function"* [61, p. 4]. However, it does not look completely like the final product. For example it can be larger or heavier than the final product or has not the same performance time. Moreover it is possible that only parts of the functionalities are implemented [61].

It can be distinguished between online or software and offline or paper prototypes [62]. The software prototypes run on a computer and consist of computer animations, interactive video presentations, little programs and applications. An offline prototype is less complex and less expensive. It enables the developers to test different design ideas. Moreover the early use of online prototypes may limit the creativity, because the use of software produces constraints. Another advantage of offline prototypes is that they can be developed by many different people, also by someone without programming knowledge. Offline prototypes can be problematic if the design cannot be represented offline, for example if it includes many visualizations.

During the test session it is important to have a task list [63]. The listed assignments will be performed during the test and represent the functionalities of the product. Every task should consist of a realistic scenario. That helps the user to perform the task as he or she would use the product in reality. Moreover no extra explanation from the moderator is necessary.

In a prototype test it can help to use the Think-Aloud-Practice. It is an approach which instructs the interviewee to think out loud his thoughts while testing the product [63]. Thereby the researcher gets information where and why a problem exists and how the user tries to solve it. Moreover it helps to find out how the user thinks about the system and if it works and is used as intended. Additionally the test users can describe ideas for improvement. The problem of this technique is that it slows down the execution of a task. Moreover some test users see the practice as unnatural. And lastly it can simply be exhausting to say out loud all thoughts. This approach should not be used for short tests because the tester needs time to get used to it. In shorter tests there is not enough time to do that. The test user should be assisted by showing him or her how the method works by doing it yourself. This also helps that he or she is more confident. Moreover it needs to be considered that if the participant really does not want to apply this method you cannot push him or her. For analysis it is important to pay attention where the user stops talking. This is an indicator that he or she has to solve a problem. This needs to be examined closer afterwards.

During the test it is crucial not to help the users to early [63]. A hindrance shows that there is a problem which should be considered more in detail. If the moderator helps too early and moves on too fast he or she may miss an opportunity to get good feedback about the system. It is important to animate the tester. Nevertheless it is also important that the user does not get frustrated. Therefore a compromise needs to be found during the test session.

The results of a user test can be measured qualitatively as well as quantitatively [63]. The qualitative analysis is done with the think-aloud protocol. Results can for example be how the product matched the expectation or how easy the use of the product was. Quantitative measurements are for example how many incorrect menu choices occurred, how many incorrect icons have been chosen or the time to complete each task.

## 3.3 Eye-Tracking

Eye-tracking helps to find out where users look at a specific time, how long they look at it and what the path of their glances is. So eye-tracking gives information about the location, duration and movement of a gaze [64]. The main goal of eye-tracking is to find the current visual attention of the user [65]. This can assist to understand the user's experience [64].

Eye-tracking can help to improve the design of a system or more specifically the placement of screen elements. It reveals where the tester really looks at. So the researcher does not have to rely on the testers statements where they look at [64]. According to Schall users are *"terrible at self-reporting where they looked"* [64, p.20]. Also Schiessl et al. stated that self-reports are biased or could even be false [65]. Another problem which occurs, if it is only possible to talk about the design, is the following: As soon as the researcher asks the tester about a specific element his or her attention is drawn to it and the tester is affected. Another advantage of eye-tracking is that it is noninvasive and therefore the tester can still concentrate on the tasks of the test [64].

Nevertheless there are also several problems which arise when using an eye-tracking device. At first the calibration of the eye-tracking device can sometimes be difficult [64]. This can lead data loss if the calibration did not work correctly. Moreover the interaction between the test user and the interviewer can be influenced. Asking questions or give the test user material can have influence on the results of the eye-tracking. Therefore these actions should be minimized while doing an eye-tracking analysis. Additionally eye-tracking needs additional time, for preparing and conducting the test and to analyze the results [64][65]. Furthermore equipment and analysis software is needed which is a big investment. Moreover so far it is not researched if the think-aloud technique influences the eye-tracking results [64].

Eye-tracking can be used in all stages of a development process, in low-, middle- and high-fidelity prototypes. The data which was collected with the eye-tracker is not significant, it needs to be connected with the verbal information gathered during the test session [64].

For the analysis of the eye-tracking data the following metrics are used: fixation, gaze duration, area of interest and scan path [65].

A fixation can be interpreted differently. If a long fixation time occurs, for example on a web site, it could imply that the user has difficulties to find the target object [64]. Moreover it can be that the user finds the area he or she is looking at to be confusing. But a fixation can also say that the user is interested in the target. Rapid eye movement between the fixations can indicate that the user is confused.

A heat map which depicts the gaze duration shows where the users look or do not look at [64]. This map is important when trying to find out which areas got realized by the users or may distract the user from its task. A heat map can help to analyze if the information depicted on a website is presented in a good way or not.

An area of interest specifies an area that is of interest for the researchers [64]. In a research it can be important to know how long the user looks at a specific area or where the user looks first. Eye-tracking can help to find out whether the user does not see, e.g., a link or he or she sees it and just not uses it. This can help the researcher to draw a conclusion, for example that the labeling is confusing and not the placement of a specific button.

A scan path or a gaze plot gives information in which order the user sees the content. It shows the path of the views of the user [64]. The fixations are depicted with a dot.

Concluding it has to be mentioned again that the data of an eye-tracking analysis needs to be combined with the verbal comments and the behavior of the test users to be significant [64].

# 4 Empirical Study / Prototype

In this chapter the execution of the empirical study and the results are presented. At first the interviews with a police officer, an ambulance man and a firefighter are described. Subsequently the mock-ups and the corresponding test results are depicted. Concluding the developed prototype is introduced and the outcome of the final tests is presented.

## 4.1 Interview

Due to the differences in the various task forces the aim was to interview someone from every group, namely a police officer, an ambulance man and a firefighter, to get an overview about their requirements. The first attempt was to find the interview partners within the personal environment of the author. Thereby an email contact to a policeman could be made where the topic and reasons for the interview was explained (see Appendix B: E-Mail). The contacting was successful and the interview was conducted in a café. The interviewed ambulance man is a personal contact of the author and therefore no closer explanation of the work and its necessity was required in advance. The interview took place at the author's home. Finding a firefighter was more complicated because the search within the personal surrounding was unsuccessful. Therefore the next attempt was to convince someone unknown from the Viennese professional fire brigade, by sending an email to a contact address of the fire brigade found on the homepage of the city of Vienna [66]. Unfortunately it turned out that these efforts were unsuccessful as well, due to limited resources for interviews in the fire departments. Afterwards the author tried to contact a commandant of a fire department directly but did not receive an answer. After this failed as well, the priority to find a professional firefighter had to be changed and therefore the next attempt was to find a volunteer firefighter. An interview partner was found within the personal surrounding of the author. A short introduction about the topic of the master thesis was conducted before starting the interview. The interview took place in the interviewee's home.

The interview partner stayed the same throughout the whole development phase.

### 4.1.1 Interview Guideline

In order to get comparable results an interview guideline was developed. Furthermore it should help to create a good flow in the interview and to decrease the possibility of omitting a question. Compared to other interview methods (like single or multiple choice questions) a guideline has the advantage of being more open. Therefore it has the opportunity to retrieve additional information of the interviewee, which was not directly asked for. This already became noticeable during the first interview, by getting further information.

Before creating the questions of the guideline it was necessary to analyze what information had to be acquired through the interviews [67]. As basis therefore the research question "Which characteristics are necessary for an interface supporting task forces on the ground?" was consulted. Considerations determined to the following information aims:

- General improvements. Which aspects of their work can be improved?
- What does the actual system on the ground look like?
- Do they need a better system for coordinating volunteers?
- Can new communication technologies help improving emergency calls and the work on the ground?
- Do they need a better system for their work on the ground?
- How would an optimal solution look like?
- Which requirements are needed for a system for task forces? Does it need speech control or translation possibilities?
- Which information needs to be displayed on a system for task forces?

Afterwards the final question for the interviews could be formulated. In the following paragraphs the question of the interview guideline are described. The questions in the guideline are ordered in a way that similar topics are one after another. The first question is a simple one to create a good atmosphere between the interviewer and the author [67]. This is important for the development of the remaining interview. The following four questions are formulated generally and open. This helps getting additional information which was not considered during the development of the guideline. Afterwards concrete questions about possible requirements are asked for.

*1. "What are your tasks at the police/EMS/fire brigade?"*

This information can help to better understand and analyze the answers by knowing the background of the interviewee. Furthermore as already mentioned this question is used to create a comfortable atmosphere.

*2. "Which problems do you see during your work?"*

This question tries to receive information about problems that hinder a smooth working flow. The received data should help to analyze which situations need to be improved and subsequent how it can be implemented within this master thesis. The abstract formulation of the question allows a wide range of possible problem descriptions.

*3. "What do you see as interference during your work?"*

It should improve the information about technical devices and work flows, which can hinder someone at work. This data is also needed for the analysis of possible improvements for the work of task forces.

*4. "How do you think these problems and interferences can be improved?"*

The question connects the two previous ones. It tries to give the interviewee the opportunity to rethink the mentioned problems and trying to find a possible solution.

The output can have very rich information content due to years of job experience of the interviewees. This can of course include data which is only known within these organizations. The question shall help to get starting points for possible advancements.

*5. "Which additional information is needed to enhance the work on the ground?"*

The result of this question shall be integrated into the decisions which information needs to be provided in a software system for task forces on the ground.

*6. "How do you want to get additional information?"*

This question seeks to find out which tool (mobile device, embedded computer, touch device, radio) is most accepted within task forces. This analysis will be included into the design process of the system that will be implemented.

*7. "How would the work of the police/EMS/fire brigade be improved if a software system can enhance the coordination of volunteers?"*

This question deals with the use of a software solution that shall improve the coordination of volunteers. The aim of it is to find out if task forces see a necessity for advancement in volunteer coordination and how it would look like.

*8. "Imagine it would be possible to send videos of an accident etc. attached to the emergency call. How helpful would such a video be during an operation?"*

This question tries to figure out if task forces see an application for videos of an emergency. Furthermore their expertise knowledge shall help to estimate how a video needs to be prepared to be useful.

*9. "How useful would the possibility of requesting dangerous good indicators via a software system be?"*

The question is included in the guideline to find out how important databases in an onboard system would be and which ones would be useful.

*10. "Would your work be improved if you can be connected to a translator via a video chat?"*

Thereby it shall be analyzed if such a featured would be demanded and subsequent if it is relevant for the solution which will be implemented in the course of this thesis.

*11. "How helpful would speech control for a system which provides task forces with additional information be?"*

It aims to concretize the features which need to be included in a tool for task forces.

*12. "How would your work be improved if reports could be created in a software system?"*

Through question twelve it shall be found out if task forces have an application spectrum for a software reporting system. Moreover it intends to get information if such functionality can save time and improve their workflow.

*13. "Does a software system already exist? If yes, which functionalities does it have?"*

The last questions tries to find out which software systems already exist within the emergency car.

All questions described previously are formulated in a way that it is not possible to answer neither with yes nor with no [67]. So they are not written dichotomous. Compared to other conversations an interviewee takes questions literally and using questions which can be answered with yes or no can hinder the progress of the interview. Furthermore the guideline tries to be as neutral as possible to avoid the suggestion of an answer. Moreover the author made sure that only simple and not multiple questions are used. This is important to avoid overstraining and unsettling the interviewee and to keep control of the interview. As mentioned previously it is also important to sort the questions by topic to enable a natural way of conversation.

Due to the fact that all interview partners speak German as their native language the guideline was formulated in German and can be found in Chapter A.1 Initial Guideline.

### 4.1.2 Adaption of the guideline

The previously described interview guideline had been adapted after the first two interviews to further increase the quality of the outcome.

During the first interview, with the police officer, it turned out that the second question was too superficial to be understood correctly. Since the question was positioned at the beginning the interviewee did not understand what problems he shall describe. The reason for this could be that at this point of time the theme was not completely clear to the interviewee. Therefore this question was extended by adding to think about all kind of problems, about situations which annoyed them and about potential room for improvement. The second interview showed that this question is still tough. Nevertheless it was necessary to keep it this way to get further information which is not biased due to concrete question.

The third question was adapted after the first interview so that the term interference became more comprehensible. The new phrasing concentrated on issues that can lead to interference and says: Are there any equipments, systems, processes or coordination drawbacks which lead to interferences? This change had a positive effect on the following interview where it was understood immediately and provided important information.

The first interview showed that question four was not specific enough to get a concrete answer. The interviewee provided irrelevant information and several times expressed his concerns about financial issues. On these grounds it was important to lead the interviewee to a more utopian thinking. Therefore the adapted question says: What needs to be introduced, bought or invented to create a perfect working situation? The second interview showed that the rephrasing opened the mind of the candidate.

The next question, discussing possible needed additional information, encountered difficulties during the first interview. The interviewee did not understand what sort of information is meant here and was always concerned about the technical realization. I suppose the question was too target-oriented for the author's goals and was therefore too abstract in the interview. For improvement it was adjusted by asking: "Which information are you missing during operations?" and "Which information would be needed to work perfectly, think utopian?". This adaption helped to animate imaginative thinking.

Already during the first interview it was obvious that question six is not positioned right because it does not fit into the flow. The reason for this order was that the answer to question six shall not be affected by the following questions. Nevertheless it turned out that it is useless to ask it at this point of time because the interviewee does not know the specific purpose of the interview yet. This could lead to confusion and have a negative effect on the interview. Therefore the question was positioned at the end and a possible affection had to be accepted. Instead the last question about existing software systems was inserted in this position. During the first interview it turned out that this information is already essential before asking the detailed questions.

Question seven was a little bit rephrased after the first interview. The part "due to an appropriate software system" was omitted because it is not relevant and can only lead to confusion. The second interview showed that the question can be misunderstood by supposing that the mentioned volunteers are the volunteers within the organization. Therefore the question was adapted to clarify that the volunteers are out of the general public and are only used in crisis situation. The adjusted question is: "How can the work of the task forces be improved due to better coordination of volunteers out of the general public in crisis situations?".

The analysis of the first interview resulted into an additional sub question to question eight. The interviewee was talking about the time aspect which may make videos of the emergency irrelevant. Due to this information the sub question: "How much time is left in the emergency car to take a look at videos of the emergency?" was added.

The first interview showed that there are far more relevant databases than the one mentioned in question nine. He talked about the database of tracing cars which would be useful to have on a board computer. Therefore the question was expended by asking which other queries could be useful during an operation.

Question twelve was adapted because the first interviewee was talking about time savings and about the distraction of one's attention when using electronic form on the ground. Therefore two additional sub questions were included: "Would it be timesaving?" and "Could it draw off the attention of the current events?". These inclusions helped to get important information in the following interview and helped to understand differences in the requirements of the various task forces.

The adapted interview guideline in German can be found in Chapter A.2 Adapted Guideline.

### 4.1.3 Interview results with a police officer

In the following paragraphs the results of the interview with a police officer are presented.

According to Mr. W. the police do not need to coordinate volunteers more efficiently in crisis situations, because firefighters are better trained in this field.

The interviewee stated that a video of the incident could be very useful because usually the police just have to believe the witnesses. When having a video proof it sometimes would extremely simplify their work. Moreover Mr. W. explained that the police often try to use local video recordings of shops and the like to get more information of the incidents.

According to the interviewee it would be very useful to have a possibility to query license numbers, persons, and so on, on a board computer. Nowadays these data has to be retrieved via radio which is, compared to a software solution, more time-consuming. Furthermore he stated that it can be useful to receive information of dangerous good indicators via a board computer. However, Mr. W. also said that this concerns the traffic department of the police more.

The possibility to consult a translator via video chat would decrease waiting times and improve the communication compared to the use of language tables. According to Mr. W. in many situations a translator is required. Today they need to be requested, which always takes a lot of time. A video chat would definitely improve and accelerate their work. Mr. W. stated that using a tele-translator can help to get important information faster, but he believes that such a measure would only rarely be life saving.

Furthermore the interviewee said that he does not see the need for speech control of a board software system. Justified with the statement that there are usually two police officers in a vehicle.

Mr. W. was very skeptical about writing the whole report of the operation using a board computer. According to the interviewee the time used to write these records is missing while patrolling. Mr. W. stated that when writing the report during patrol the police officers cannot concentrate on the on goings around them. This maybe could degrade the work of the police. Today only basic data is recorded on the ground. The remaining work is done in the police station. Thereby no time is lost for patrolling. A suggested idea about using voice recorders with automatic transliteration was declined due to fears that it may not work properly. Also an idea about using simple voice recorders was rejected because he feared that mistakes could be made during the transliterate process. He specifically mentioned names being spelled wrong.

The interviewee believes that the best way to provide task forces with additional information would be a board computer. The advantage having a mobile device is that you can take it out of the car and on the ground. The resulting drawback is that it thereby can break more easily. Referring to Mr. W. the best solution would be a mobile computer for every officer.

### 4.1.4 Interview results with an ambulance man

In the following paragraphs the results of the interview with an ambulance man are presented.

When asking about interferences during his work the interviewee gave important input. He mentioned the annoying paperwork and that he would appreciate a sort of board computer. It should provide data about the patient, found out during the emergency call (namely: evaluation, address, patient information, consciousness, and so on) and enable to write the report of the operation electronically. According to Mr. U. such a procedure would not save time during the operation but the subsequent work, like the depositing of the paperwork and the accounting, can be improved. Today the transport and the operation protocol are filled in manually. Afterwards they need to be deposited in folders and for the accounting the information has to be entered into a computer system. The interviewee supposes that this workflow would be enhanced with the digitalization of the data input.

Furthermore the interviewee stated that a board computer with the necessary information could advance the workflow very much. The data can be synchronized with the emergency call centre all the time. Additionally it would not be necessary to stamp the transport protocol in the hospital anymore because the whole information could be provided in an online system. Moreover the status of the operation - for instance "arriving at destination", "arriving at hospital", ... can be sent automatically, compared to today where it has to be sent via radio. Another improvement could be a tele-analysis of the ECG through a doctor. This would avoid unnecessary requests of an emergency doctor. According to the Mr. U. this is already practiced in Germany.

Moreover the interview said that a board computer could help to depict how exactly the questions in the emergency call at the PSAP have been answered. This could help to evaluate the situation because today the amount of information is limited. The ideal would be to get the medical history of the patient because this is very important for a correct and fast anamnesis and an early evaluation of the situation. Furthermore it is often hard to get all medical information and diagnostic findings of the patient. The best case-scenario would be if information of the medical history would be provided out of ELGA ("ELektronische GesundheitsAkte" - electronic health file). However, Mr. U. has concerns about data privacy.

According to the interviewee a better coordination of volunteers is irrelevant for the emergency medical service because only qualified persons can help patients in the ambulance car. Furthermore he is convinced that it is also senseless in crises.

Regarding attached videos to an emergency call Mr. U. supposes that they can help the scheduler (Disponent) to analyze the situation and to send the appropriate rescue vehicles. The videos can be used after the call to adapt the needed task forces. But the interviewee does not see an application area for these videos in the ambulance vehicle. It is not necessary due to the fact that most injuries are not visible in such a video and that the situation can be assessed on the ground within seconds anyway.

According to Mr. U. it is better to use the time getting to the emergency location with reading data of the patient. This is more useful because it takes much more time to get the required information from the patient.

The integration of a database of dangerous good indicators into a board computer would be very useful referred to the interviewee. The database could help the paramedics to behave correctly. For example if the dangerous good can be transported via air they should not wait for the other task forces (firefighters) downwind.

During the interview it turned out that a translator connected via video chat could have the potential to improve the anamnesis enormously. According to the interviewee the anamnesis is their most important instrument, it is responsible for around 70% of diagnoses. Therefore it is very important to understand the patients and that is why a translation can be so relevant. Moreover a translator can help to reduce the dispatch of emergency doctors. They are also needed in the case that the paramedics cannot make a diagnosis due to language barriers.

Furthermore the interviewee said that speech control would only irritate the patients. They maybe would be afraid to be recorded which could decrease their communicability. It would only enable the driver to use the computer as well but that is not necessary because the driver never works alone.

Mr. U. stated that they do not have a board computer so far. He supposes that a mobile board computer would be the best hardware solution because the paramedics are always sitting a bit different and have to sit next to the patient. A keyboard would increase typing but complicates the contact to the patient.

### 4.1.5 Interview results with a firefighter

In the following paragraphs the results of the interview with a firefighter are presented.

According to the interviewee Mr. R. the biggest problem during a fire fighting operation are coordination issues during big operations. He mentioned that the clarification and communication between commandants or the officer-in-charge is problematic. The officer-in-charge decides where, what is needed, for example where to place the turntable ladder strategically, and communicates the tasks to the commandants. In a big operation the officer(s)-in-charge works in a control room on the ground which is located in one of the vehicles. He or she is connected with the commandants via radio to get feedback and be informed about the status quo. The commandants are responsible to assign the tasks which are allotted to their groups. Often these tasks are not executed correctly due to misunderstandings and because the commandant do not ask the officer-in-charge, if he or she understood the instructions correctly. These problems mainly arise during big operations. Such events occur quite rarely, therefore the fire departments are not used to do such cooperation. There is another issue that appears in big operations: Mr. R. mentioned that there is quite often the problem that the officers-in-charge do not inform themselves for example about the underground water pipe system. In an operation it is often essential to know details about the connection of the hydrants to know how many and which hydrants can be used to have enough volume of water. Therefore analogous prints of hydrant plans exist in the cars and also a digital version is available in the department.

Additionally the firefighter stated that currently it is necessary to note on a paper as soon as a troop goes into a building to know when they need to come back and who is inside. He stated that a software support can be beneficial.

The interviewee told about interferences by old machines, which do not work properly or do not start during an operation. But he also mentioned that these problems only happen very rare and therefore he does not see a necessity to improve the subsequent process. Nevertheless he wanted to discuss it, because sometimes it can be a problem and already happened to him. Moreover Mr. R. mentioned an operation where they used a fixed induction line of a small river to douse a fire. The problem was that they did not consider that it had not been used for a long time, so it was chocked and was unusable.

Aside of the already mentioned improvements the interviewee stated that the use of a tablet would enhance their work. Some fire departments already have tablets, where it is possible to sketch the location of every vehicle and to write a status report. Mr. R. meant that it is not necessary to have a tablet in every car but at least one for every operation.

The interviewee mentioned that the wind direction is a very important factor by every fire. Depending on it the cars and the respiration equipment filling station, where empty compressed air cylinder are refilled with ambient air, are positioned. On enquiry Mr. R. confirmed that information about upcoming changes in the wind direction would be helpful. They have to react to the changed situation and have to e.g. relocate all cars. Moreover according to the interviewee it would be very useful if callers could be located via GPS. In many cases they do not know exactly where they are and the localization via the mobile network is not accurate enough. The interviewee liked the idea to send the GPS position of the caller and his or her viewing direction. This information could be used to find the approximate position of e.g. a forest fire and possible access roads. However, Mr. R. was skeptical how such a system could be implemented.

In general Mr. R. does not see the necessity to integrate the organization and coordination of volunteers in crisis situations into the duties of firefighters. According to him the work of "Team Österreich" is very good and he does not see a reason to change the way how it is organized. Moreover the interviewee mentioned that the activities for the volunteers will not change if the fire department would take over the organization. In crisis situations volunteers are needed to make relative simple work, without the necessity of specific knowledge, like filling sandbags. Furthermore Mr. R. is convinced that it is contra productive to obligate the volunteers to bring specific materials like shovels. He believes that such a measure would alienate volunteers and that it is better to bring the materials voluntary. Moreover the interviewee mentioned that not every volunteer need materials, like shovels. There are also a lot of volunteers needed to organize the food for the working forces.

According to the interviewee videos of the site can be very helpful to get a picture of the situation. Thereby it can be found out where the dangers are, where the vehicles can be parked and if for example an overhead contact line is nearby and need to be turned off. The videos can improve and accelerate an operation, if for example a specific organization like ÖBB (Österreichische Bundesbahnen – Austrian Federal Railways) need to be alerted in advance. The video can help the firefighters to start their work as soon as they arrive on the ground because they are already able to arrange the turn off of the power to the overhead contact line. Mr. R. stated that it is crucial to see the surrounding area on the video to get an impression of the situation. For that reason it is more important to make the emergency call first and afterwards make a video with the instructions of the emergency call centre. Moreover he said that there is enough time to watch such a video when getting to the site. Normally they need five to ten minutes to get to the site from the fire station.

Currently the fire department, where Mr. R. is working, uses folders and the radio to get information about dangerous goods. The interviewee supposes that a software can help to get the information faster, compared to retrieval in a folder. Moreover it can be useful because it provides more information than communicated via radio e.g. how the substance reacts. Else such details need to be asked via radio which can be time-consuming. Mr. R. mentioned that the ideal case would be a database where to query for the license number and get the load details of the truck. This would be extremely helpful in situations where e.g. the dangerous good indicator is missing. But this approach is not realistic as no such database exists and to create one is very complicated considering the amount of countries involved.

According to the interviewee a tele-translator is not necessary for firefighters since it is not in their scope to get information about involved people. Furthermore the possibility that a truck has neither a dangerous good indicator nor loading papers with information about it and the driver speaks absolutely no English or German is just too little to justify such a system.

Moreover the interviewee stated that also speech control is unnecessary because the fire truck is always manned by more than one person.

The view of the interviewee is that it is not required to start writing the report of the operation while driving home because they normally only need five to ten minutes to get back to the fire station. Furthermore they need additional information like the attendances and who was assigned to which task. Moreover the interviewee noticed that it is impractical to write a report on a tablet in the car. An idea of Mr. R. to improve the process is to electronically tick your attendance in an operation either on the way back or on a PC at the fire station.

A supportive software device for firefighters should be realized as a touch-device with a pen to be usable with gloves as well. There should be a base station in the car where it can be mounted while driving and can be charged.

## 4.2 Mock-ups

Out of the previously described expert interviews the following functionalities and mock-up designs were developed.

All probands stated that the system shall be developed for a mobile board computer (see Chapters 4.1.3, 4.1.4 and 4.1.5). According to the police officer this has the advantage that the task force can use it outside the vehicle. Moreover the ambulance man explained that they have to move inside the vehicle all the time. Therefore the mockups were designed for a ten inch touch-screen tablet. The firefighter Mr. R. stated that it can be helpful to use the device with a pen, because they often have to wear gloves during an operation.

The prototype consists of three parts, one for every task force (police, EMS and firefighters). Each task force has different functionalities which are described in the following chapters. First the functionalities that are similar in all three parts are depicted.

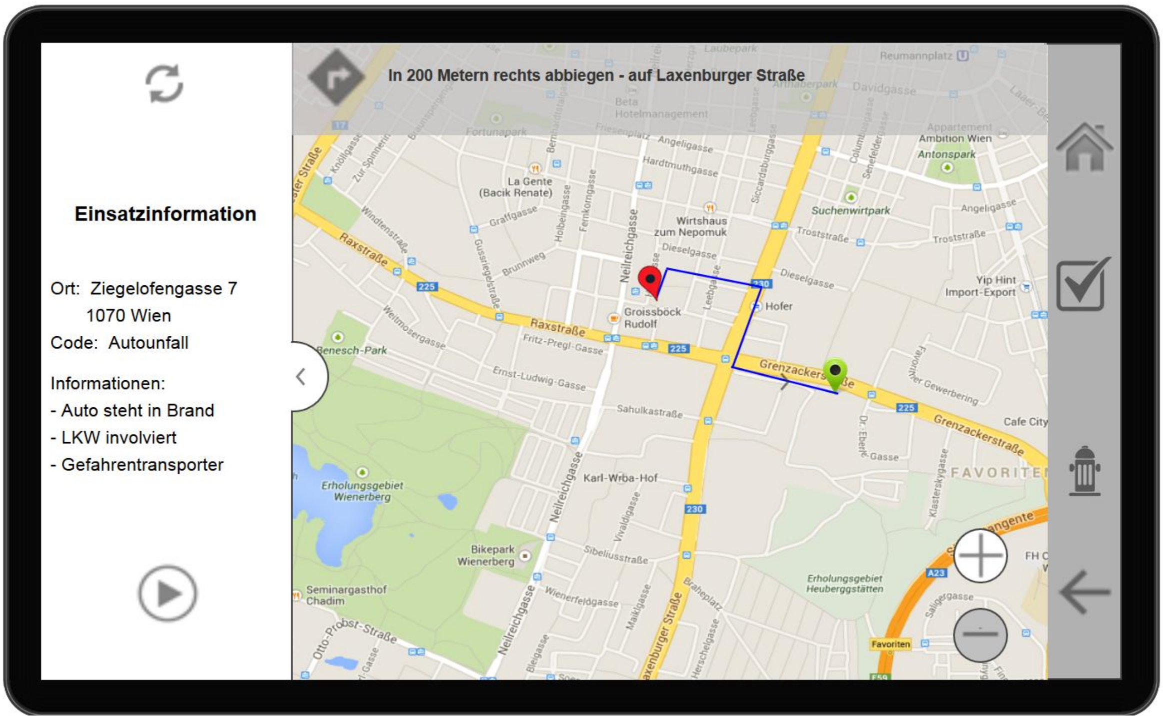


Figure 5: Mock-up

The structure of the interface is always the same. The left column is reserved for operation information, the middle part contains the content of the current activity and on the right side the navigation bar is positioned. The left column can be closed to have more space for the current content.

To refresh the operation information, depicted in the left column, the button in the upper left corner can be used.

On the starting screen of all task forces a map is located on which the current location of the user is marked. Additionally it should possible to show the route to the current operation site. The route planner is located at the head of the map view. To zoom into the map the fingers shall be used. In the mock-ups this functionality is not available, because the software used to design the mock does not enable it. In addition it is possible to use plus and minus buttons to resize the map.

In the navigation bar on the right side two buttons are constant for all task forces, the menu button (depicted with a house) and the back arrow. With the menu button the user can open the main menu, a more detailed description can be found in the following chapters. The back arrow allows the user to get one step back.

### 4.2.1 Police

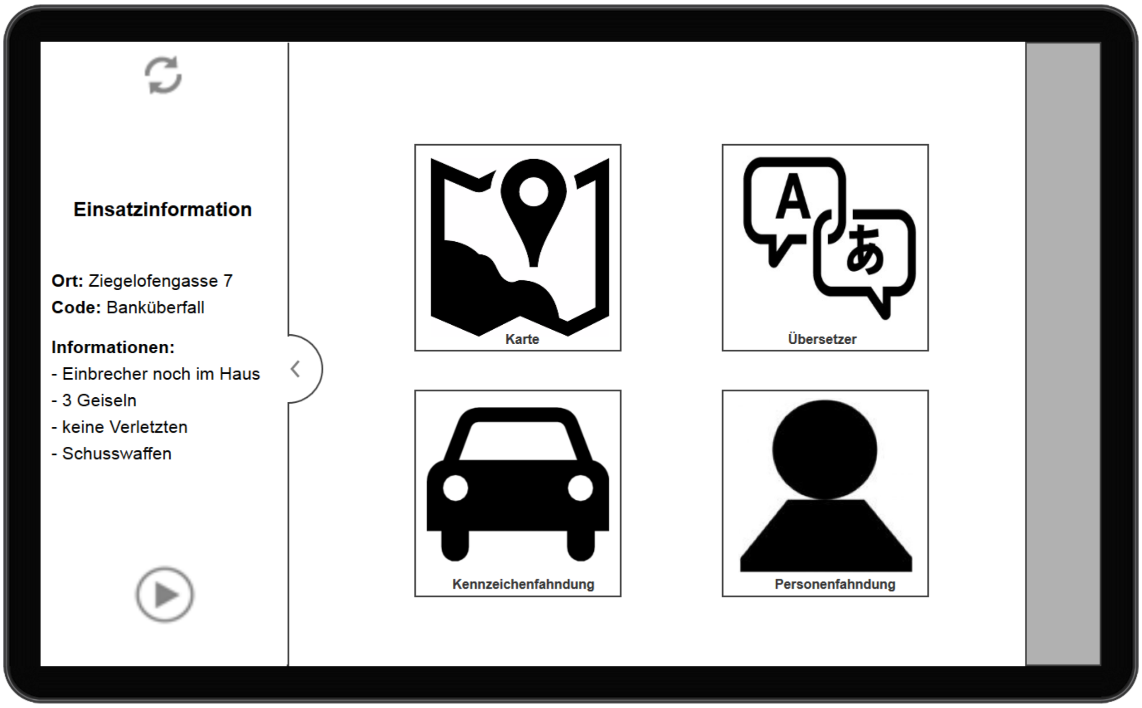


Figure 6: Mock-up Police

The menu selection "Karte" ("map") opens the screen with the navigation map, already described in Chapter 4.2.

The second element of the menu ("Übersetzer") enables the user to contact a translator. This can be used if the officer has problems to communicate with a suspect, person in need and the like. The language to be translated can be selected either by choosing one language of the short list or by selecting "weitere" ("more") and pick one in the dropdown list. The short list depicts the languages which are used most frequently. After choosing a language a video call view opens in the middle column of the prototype.

The button "Personenfahndung" ("wanted persons") opens an input dialog to get more information about persons registered in the police records. Similar to that the search for "Kennzeichenfahndung" ("license numbers") gives information about queried license numbers, like owner and registration date.

On the left bottom corner in the operation information bar the video play button is located. By clicking the user sees a video of the operation site taken by passersby or participants. In the new emergency call system (NG911) it shall be possible to send multimedia material to the PSAP [68]. Selected videos can be streamed by the task force using this functionality.

In the map view it is possible to depict surrounding surveillance cameras by clicking the camera button (see Figure 7). After pushing the button the location of the cameras are displayed with blue push pins.

Figure 7: Camera button

### 4.2.2 EMS

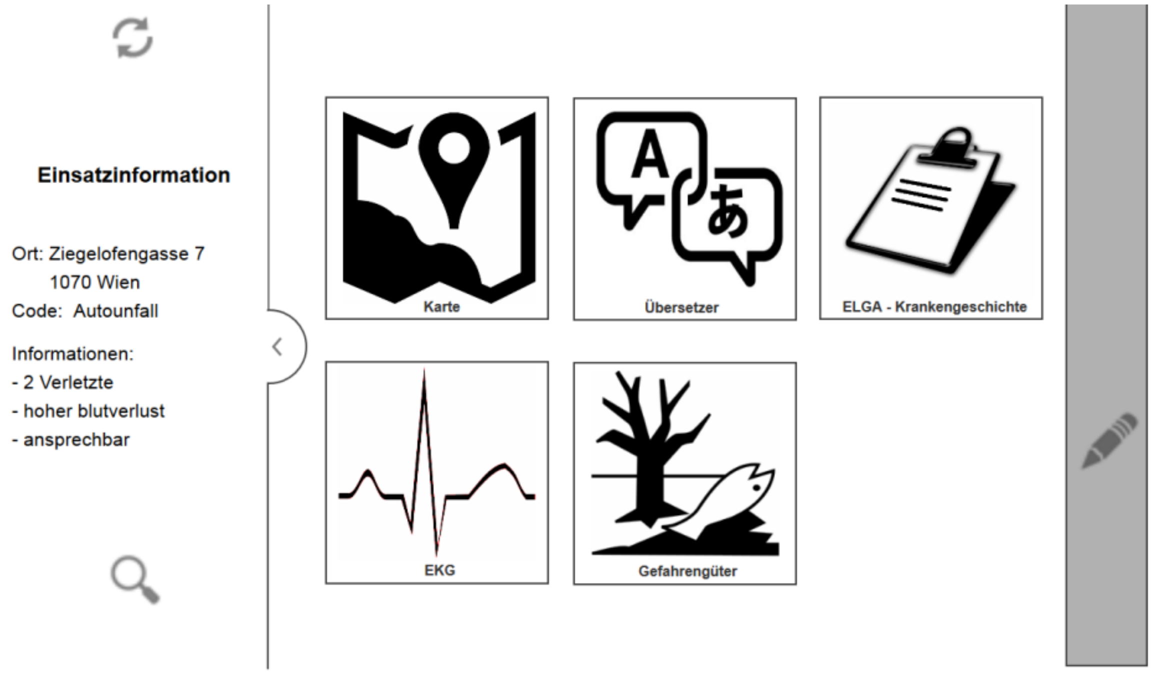


Figure 8: Mock-up EMS

The menu item "Karte" ("map") and "Übersetzer" ("translator") are already described in chapter 4.2.1 and have the same functionalities.

The functionality "ELGA" shall provide the EMS with information about the medical history of their patients. Therefore a card reader is needed to retrieve the data. Access authorization to the data is received via the e-card because no medical data is saved on it.

The "EKG" ("ECG") feature sends the ECG measured by the defibrillator to a doctor for analysis. As soon as the doctor has analyzed the ECG the results are depicted in the prototype.

The menu item "Gefahrgüter" ("dangerous goods") enables the user to request detailed information about a dangerous good, by entering the UN number. After sending the request the specifications of the dangerous good are displayed.

Clicking the report button, located in the right navigation bar (the pen), opens a selection list of reports which are currently used in hardcopy form. In the prototype these reports can be filled in electronically.

Detailed operation information can be opened by clicking the magnifier icon in the left column. This view shows how exactly the questions of the emergency call have been answered. According to the interviewee this can help to analyze the occurrences.

### 4.2.3 Firefighters

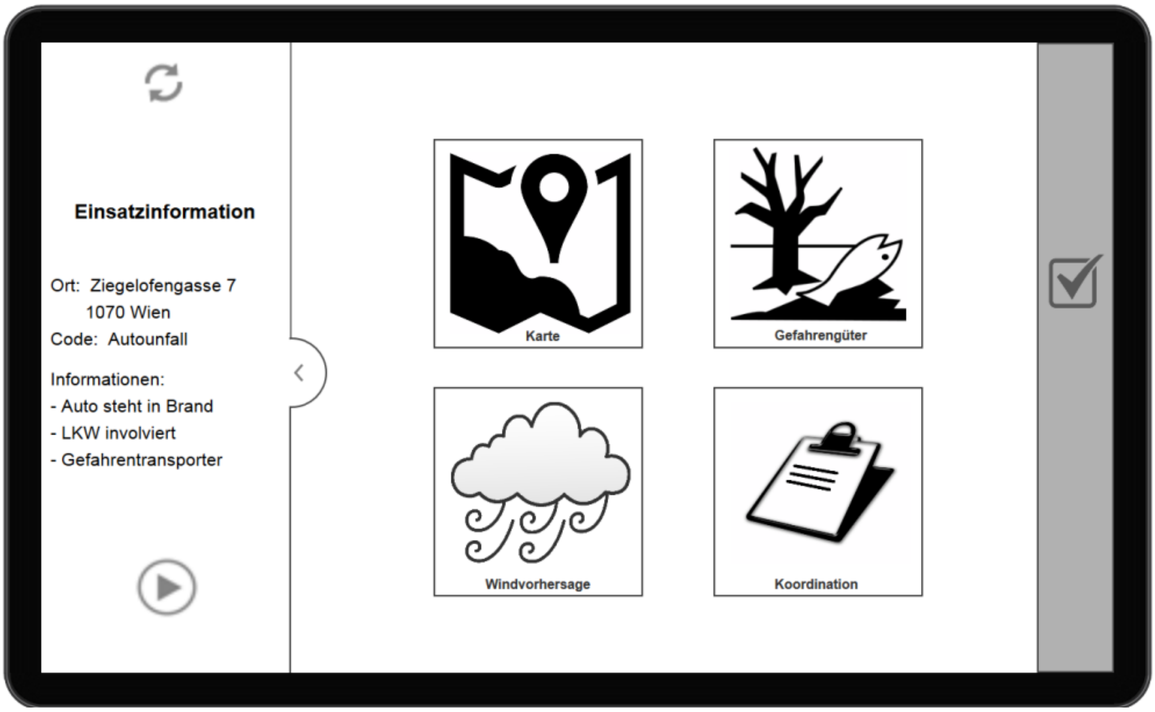


Figure 9: Mock-up Firefighters

The menu items "Karte" ("map") and "Gefahrgüter" ("dangerous goods") are already described in Chapter 4.2.1 and 4.2.2 and have the same functionalities.

The "Windvorhersage" ("wind prediction") feature gives information about the current wind direction and a prediction for the next hours.

The last item in the main menu "Koordination" ("coordiantion") enables to coordinate firefighters in groups. Therefore firefighters can be added to groups. When a firefighter starts working the user has to press the button "jetzt" ("now"). Then the time interval, which represent the time the firefighter is allowed to stay inside the building, is shown. If the predefined time expires the user is informed and the display of the time interval turns red.

The functionalities of the video play button are already described in Chapter 4.2.1.

The button in the right navigation bar opens a list of to-dos or tasks for commandants. The commandants can check off tasks as soon as they are completed and have an overview of the work. An example for a task can be the securing of the first floor.

The right navigation bar has an additional button in the map view, displayed with the icon depicted in Figure 10. This button can be used to show the position of hydrants on the map. Hydrants are depicted as red circles with the diameter of the supply line.

Figure 10: Hydrant icon

In all views the user is informed, if the wind direction changes. The user is notified with a red information button in the left bottom corner, see Figure 11. Clicking on the icon opens the wind prediction view.

Figure 11: Notification icon

### 4.2.4 Evaluation Mock-ups

For the evaluation clickable mock-ups are tested by the probands on a Samsung Galaxy Tab 10. To find out which icons or labels are not intuitive enough and which spots are most frequently looked at an eye-tracker was used.

In the following paragraphs the results of the mock-up tests and the analysis of the eye-tracking are described. For the test previously specified tasks have been used.

The analysis of the first task, to zoom into the map, showed that the ambulance man and the firefighter looked into the area of the +/- buttons after a time interval of only 500 ms. The police officer needed a bit more time, around 1.5 seconds. He first made sure that there is no button on the other side of the map. But after a look on the other end of the map he instantly looked back to the bottom right corner, where the +/- buttons are positioned. As a conclusion it can be supposed that they immediately knew where to click. All of them had no problem to carry out this task. Just the police officer wanted to make sure that his first suggestion was correct and that there is no alternative. This can also be explained by the characteristics of this proband. The police officer was in all tests more cautious and is less computer affine than the other two test users. Moreover the tests showed that the users try to zoom in using two fingers. The firefighter and the ambulance man stated that the familiar finger gestures, for example as in Google maps, should be supported. According to them such a behavior is expected when using a tablet with a touch screen.

The second task, to zoom out the map, was immediately solved by all users. The ambulance man and the firefighter even looked at the button the second I said the keyword "map". It can be assumed that they already expected this task. It can be concluded that this exercise was influenced by the previous question. Therefore it can be supposed that this functionality is easy to learn.

The next task, executed by the firefighter and the police officer, was to watch the video of the operation site. The firefighter already looked in the area around the play button before the question was asked. But after the keyword "video" his glance got closer to the button. He provided the feedback that he first expected the button to be a functionality to read out loud the operation information. Additionally he stated that it is clear after the first usage. Moreover he said that the used icon is the adequate icon for a play button. Also the police officer had problems to find the correct button. He needed around 54 seconds to find it, in advance he tried several other buttons. He first looked to the button which depicts the surveillance cameras. He identified it as a camera, as he stated while testing it. Afterwards he tried to find the video functionality in the main menu. Because he was not successful there, his glance wandered to the operation information column. In the feedback he reported that he interpreted the play icon as "further" button, which provides you with more information about the operation. It can be concluded that both interpreted the video button wrongly in the beginning. Afterwards they stated that it is the adequate icon because the same icon is used in other software applications. Both said that after they have used it once it became totally clear. The additional problem for the police officer was the confusion between the surveillance cameras and the video of the operation. These functionalities are a bit similar because both are connected to cameras. Therefore it is supposable that the surveillance camera icon can easily be interpreted wrongly when using the system for the first time.

Instead of the previously described task the ambulance man had to open the detailed information of the operation. He immediately looked to the right button, but then he started to look around the whole screen. The presumption is that he controlled that there is no other suitable button. So he made himself certain that his first intuition is right. After a view over the screen he focused again on the right button and clicked it. Moreover he already correctly identified the functionality of this button at the beginning of the test. This can be another indicator for the assumption that he just wanted to assure his first guess.

The following two tasks for the ambulance man and the police officer dealt with the functionality to contact a translator. First they had to contact a Croatian translator. Both looked several seconds (6 and 10 seconds) on the screen to find the appropriate button. They looked for a button which immediately opens the translator. After they detected that there is no such functionality both of them understood that they have to find a menu with more features. Then they opened the main menu. There both of them took around 10 seconds to fix on the translator button. First they took a detailed look on the available menu items. It can be assumed that they wanted to get to know the functionalities of the menu. The language selection in the translator view was clear to the ambulance man. He only took 200 ms until he looked at the correct language button. But then he further tested the system and tried the "further languages" button. The police officer needed more time. He had problems to read the text because he was not using his glasses due to the eye tracker. But the eye tracking evaluation showed that he knew what he needed to read. The police officer stated that the system is easy to use because it is always the same principle. If the functionality is not in the navigation bar, the user needs to get back to the menu and there are all the different features. According to the police officer it is clear that it took a bit more time to find this feature because it was located in a new menu. Therefore you first have to find the menu button and then get used to the new view.

Next the connection to the translator needed to be terminated. Already at the beginning of the question the ambulance man moved his glance to the bottom right corner. After 500 ms he directly looked at the button. The user had no uncertainties. It can be presumed that he already supposed that he had to terminate the call. Therefore he already looked in that corner. The police officer needed much more time, nearly four seconds. He changed his view several times between the left and right side of the screen. After four seconds he glanced in the area of the terminate button. If one considers the spoken word of the test user, it results that he wanted to use the back arrow in the right navigation bar. After an explanation that the terminate call feature has its own button he looked at it. The police officer stated that his problem was that he could not read the label of the button. He tried to work with the navigation he already knew. This shows that he is already used to the structure and navigation in the system.

Instead of these two tasks the firefighter worked with the hydrants on the map. The user first had the problem to get back to the map view. It took him nearly 10 seconds to focus on the menu button. First he tried to use the enlarge button because, as he stated, he thought he could close the video view with this button. After he noticed that it has another functionality he looked to the menu button. In the menu the firefighter first glanced to the map button, after 400 ms. But afterwards he read all other menu items. In the map he needed 700ms to look at the hydrant button, his glance went directly to the right button. It can be presumed that he knew the button already from the beginning. His only problem was to get back to the map. In the feedback the firefighter stated that additional information about the water supply would be interesting. This information can help to decide which hydrant to use.

Next the firefighter had the task to stop showing the positions of the hydrants. It took him only 200 ms and he immediately knew where to look at. The conclusion is that he understood what to do and it was clear to him that he had to press the hydrant button again.

The sixth task (8th for the firefighter) was to open the menu. The police officer and the firefighter did not look on the menu button anymore, but directly clicked on it. The ambulance man needed 1.5 seconds because in the meantime he asked which menu was meant. It can be concluded that all of them knew what to do. The ambulance man just wanted to make sure he should open the main menu.

The next task (9th for the firefighter) was to expand the menu. The police officer only needed 600 ms to look at the right button. He already looked at the button in advance therefore he already knew it. It took the ambulance man around three seconds to find the button. He looked all over the screen and searched for a button in the right navigation bar. After he did not find it there he looked back to the left side. Moreover he stated that so far this functionality would not be necessary. Also the firefighter needed a while to find the button, around seven seconds. He looked all over the screen and focused on every button. Already at the beginning he shortly glanced at the correct button but then he was probably not sure enough to use it. Therefore he looked at the rest but found nothing else adequate. According to the firefighter such a feature is not important. The tablet is big enough to depict all the information. Moreover the operation information is the most important part and therefore should not fade out. It can be concluded that this feature is not necessary and therefore it is not implemented in the prototype.

Another task that all test users needed to complete is to refresh the operation information. The police officer and the ambulance man needed less than two seconds to find the correct button. The ambulance man said he already noticed the button earlier. According to the police officer the used symbol is clear because it is also used in other systems. The firefighter needed much longer, around 20 seconds. He misunderstood the question and first wanted to update the coordination view. After recognizing this mistake he immediately clicked at the correct button. He stated that he thought that the mentioned operation information has something to do with the menu item "coordination". This uncertainty occurred because the feature "coordination" was not explained or tested so far. According to the police officer a refresh button is important to be always up to date. Moreover he questioned how else he should know that the information is at the newest stand. In comparison the firefighter and the ambulance man thought that this feature is unnecessary because it should be updated automatically. Additionally the firefighter stated that a feedback about the last refresh or if there is currently no internet connection would be relevant.

Next the evaluation of the task to read the information about a dangerous good is described. The firefighter immediately looked at the right navigation bar. There he looked up and down and then focused on main menu. The presumption is that he saw that there is no dangerous good button and therefore he used the menu. To focus on the menu button he needed 800 ms. As soon as the menu opened he directly clicked at the dangerous good button. He only needed 100 ms to look at the button. It can be supposed that he already knew the structure of the menu from beforehand. At the final page he directly focused on the input box. The reason for this can be that this view is very simple and there is only one possibility to enter a number. The ambulance man needed three seconds to glance on the main menu button. He waited until the question was finished and meanwhile looked somewhere else on the screen. As soon as the question was finished he focused and clicked at the correct button. Like the firefighter he immediately pushed the dangerous good button. The same assumption can be made, that he already knew the system. To the final page the ambulance man stated that he expected that he can start the search for a dangerous good using the enter button on the keyboard. According to him no additional search button on the screen is necessary. It can be concluded that the users already understand the structure of the system good. If the functionality cannot be found in the right navigation bar they have to use the main menu. According to the short time the users needed to find the appropriate menu item, the menu is easy to learn and use.

In the following paragraph the task to connect to a translator of a language which is not available in the short list is described. The ambulance man needed four seconds until he focused on the menu button. This can be explained by the fact that the keyword "translator" was at the beginning of the question. But he did not start to execute the task until the question was finished. In the main menu he looked at the translator item after 600 ms. It can be supposed that he found the button so fast because he already knew it. The ambulance man needed 1.5 seconds to look at the "further languages" button. He needed much more time here because he read all existing languages in the short list. In the view of further languages he immediately looked at the selection menu. The police officer needed 1.5 seconds to open the menu. He also waited until the question was finished. In the menu he directly clicked on the translator button. Again it can be supposed that he already knew the structure of the menu. In the next view his glance immediately moved down to the end of the screen. Therefore it can be presumed that he already knew where the button is located. He remembered it from the previous test, where he should connect to a Croatian translator. At the final page he had the problem that the font of the selection menu was too little. He could not read "Please select" in the dropdown list and the arrow aside was also too small. Therefore he thought in the first moment that he has to enter the desired language. After clicking in the field he understood what to do. It can be concluded that the execution of this task was easy for both of them. But the font which was too small complicated the execution of the task for the policeman.

#### 4.2.4.1 Tasks of the Police Officer

The following two paragraphs describe the handling of the police officer with the surveillance cameras on the map. The test started in the menu view. He looked at the tablet after the question was finished. After 700 ms the police officer first glanced at the map button. But then he looked around the screen. The presumption is that he searched for a direct button to see the surveillance cameras. After around four seconds he focuses again on the map button and pressed it. In the map view he first look 1.5 second on the operation information. Then he looked back to the right navigation bar and directly pressed the correct button. It can be suggested that he first searched for the feature in operation information because he remembered that the video was there. Or he was looking if information about the positions of the cameras can be found there. It can be concluded that he understood the icon and also now knew the difference between the video functionality and the depiction of surveillance cameras.

The task to stop showing the cameras was executed immediately. The police officer did not hesitate to click the right button. It can be deduced that he understood that the same button needs to be pressed to stop showing the cameras.

Another task the police officer had to carry out was to search for a license number. He immediately knew that he had to press the menu button which only took him 100 ms. In the menu his glance went directly, in 200 ms, to the right menu item. Again it can be presumed that he already knew the structure of the menu good. In the license number view he directly looked at the input field and asked what he has to enter.

The final task for the police officer was to get information about a wanted person. He nearly needed three seconds until he first looked at the menu button. The reason therefore is that he first terminated the video call with a translator. The view of the translator was still open from the previous task. After he terminated the call the policeman immediately glanced at the menu button. In the menu he needed 700 ms until he looked on the "wanted persons" item. In the final view he exactly knew what to do. It can be supposed that the final view is that easy to understand because it only consists of one input field.

#### 4.2.4.2 Tasks of the Ambulance Man

Another task for the ambulance man was to open the medical history (ELGA) of a patient. Currently the menu view is opened. He only needed 500 ms till he first glanced at the right menu item. The evaluation showed that he immediately looked in the direction of the button. It can be presumed that the ambulance man already identified all menu items in advance. This assumption can be confirmed by the fact that as he first opens the menu he observed it in detail for around nine seconds.

In the following paragraph the evaluation of the task to send an ECG to a doctor is described. The question for the task was long and the keyword "ECG" was at the beginning of the question. Therefore the ambulance man needed around 9 seconds until he focused on the menu button. He already shortly glanced at it after 200 ms. Then he waited until the question was finished to focus on the menu button. In the menu he needed 400 ms to look at the right item. He directly moved his glance to the ECG button. In the final view the ambulance man needed 500ms to look at the button "load and send ECG". It can be concluded that the menu is already well known and that the ECG view is easy to understand due to the little time needed to work with it correctly. The ambulance man stated that he expected a notification if the results of the

ECG analysis are available. He approved the proposal to use a pop-up window for such a notification.

Furthermore the ambulance man had to write the protocol of the operation. He needed twelve seconds until he looked at the protocols button in the right navigation bar. The reason for this was that he first tried to find the feature in the main menu. After he noticed that there is no such functionality he looked on the pen in the navigation bar. In the selection view of the different protocols the ambulance man focused on the "operation protocol" button after three seconds. He needed this time because it was a new view and he first had to look on all buttons. It can be concluded that the pen icon was not the obvious choice as icon for protocols. The interviewee stated that a form as icon would be more intuitive. Moreover he said that this function should also be provided in the main menu. Additionally the ambulance man mentioned that after filling out a protocol a feedback shall be depicted that the protocol had been stored. Furthermore he mentioned that it would be nice to display the stored protocol again after clicking the save button. This helps to show the user what was stored and to establish trust to the system.

#### 4.2.4.3 Tasks of the Firefighter

The firefighter had to open the to-do list and check off one task. At the beginning of the question he wanted to open the menu. But as the question was finished with "in the to-do list" he immediately looked to the right button. He needed two seconds to focus on the right button. In the to-do list he knew what to do and directly checked off the desired task. The firefighter mentioned that a pop-up which says "stored" shall be included to get a feedback that the check off was registered. Moreover he proposed to include a list of standard to-dos. This shall simplify the input of tasks. Furthermore it should not be possible to uncheck already checked off tasks. Overall he immediately understood what he had to do.

Another task the firefighter had to execute was to read the wind prediction. The user was currently in the menu and even before the keyword he looked to the right menu item. He glanced at the item after he heard the words "big fire", it is possible that these words sufficed as keywords. Again this test showed that the menu is simple to understand because the user did not hesitate. The firefighter proposed to insert an arrow in the map which depicts the current wind direction.

Next the red information button occurred which shall inform the firefighter about a change in the wind direction. The firefighter looked at the button within 100 ms. Then his glance wandered around the screen for three seconds. It can be supposed that he made sure that he found the right button to get information about a change in the wind direction. He said that it is easy to understand and that it can also be used for other important information. The firefighter proposed to show additionally to the red information button a pop-up window with the relevant information.

A further task for the firefighter was to coordinate a troop which starts to work now. He immediately pressed the menu and needed only 300ms to look at the right item there. It can be presumed that he knew the menu already well because the test case was executed at the end. It took him only one second to understand what to do in the coordination view. The firefighter briefly read the information but then focused on the start troop (now) button. The conclusion is that it is easy to understand how to start the work of a troop.

Another task was to open the to-do list again. The firefighter only needed 100 ms to look at the right button. It can be concluded that he remembered this feature from beforehand and therefore it is an adequate icon which can be remembered easily.

Finally the task to add a man to a troop shall be evaluated. Again he immediately clicked on the menu button. There his glance went to the right button before the view loaded completely. This shows that he already knew the structure. In the coordination view he needed one second to focus on the plus button.

In the following paragraphs additional features which would be important according to the interviewees are described.

The operation information should be enhanced with information about other already alerted task forces. According to the ambulance man this is relevant because they need to know which task forces are needed to be requested as soon as they arrive at the operation site. The police officer stated that it saves time and avoids unnecessary requests.

Another idea of the firefighter was to have a functionality which reads out load the operation information.

The firefighter and the police officer stated that it would be interesting to have the possibility to write back to or chat with the PSAP. This would be for example relevant if the operation information was not correct.

Moreover the font size needs to be adapted because the police officer had problems to read all information without his glasses. The system should also be usable for older people or if the tablet is fixed somewhere in the vehicle.

According to the police officer it is very important to get a detailed description of a suspect in the operation information. This helps to immediately look for the suspect at the crime scene.

For the fire department the following features would be relevant.

The firefighter stated it would be important to position the vehicles of an operation in the map view. According to him this would facilitate coordination, especially in big operations where several departments work together. Moreover it can also be relevant to know where all cars are parked if the wind direction changes.

Another idea of the firefighter was to include a functionality which shows ongoing information of the operation, like "person located". It should be implemented as a sort of live ticker with the creation time and next to that the information.

Moreover the firefighter required a telephone book with important emergency numbers, like the one of the ÖBB.

Finally the already existing coordination functionality should also produce a pop-up window if the time of a troop ran out. The firefighter said that this is even more important than a pop-up about a change of the wind direction. In the troop coordination the life of people is affected directly.

## 4.3 Prototype

The prototype is developed for android devices. This decision was taken because to use such a system on the ground a robust hardware is required [69][70] and embedded system are often implemented using Linux. To be comparable to existing software, android was chosen as development platform due to the fact that it is running on a Linux kernel.

In the following paragraphs new functionalities and changes compared to the previously described mock-ups are illustrated.

The software starts with a login in screen, which opens the four different views, one for each of the following: police, EMS, commandants and officers-in-charge.

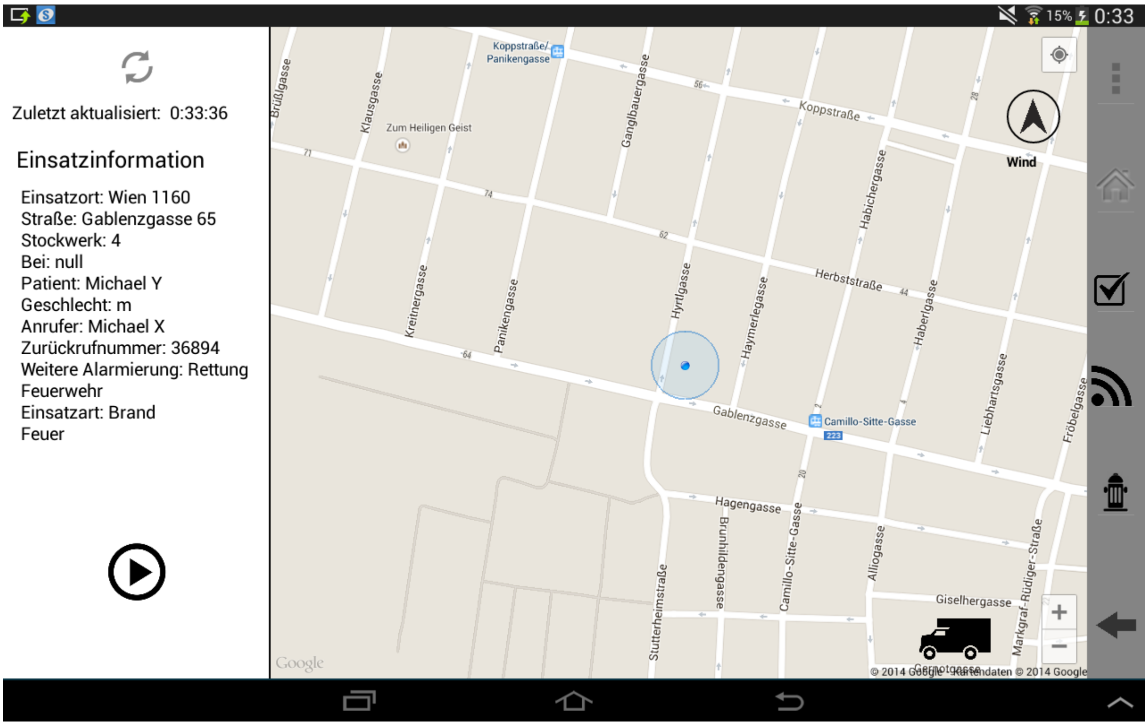


Figure 12: Starting screen after logging (in this case of the firefighters)

As already described in Chapter 4.2, the left column includes information about the current operation, which is provided by the emergency call centre. The following data fields are depicted:

- city
- postal code
- address
- floor
- location is near to
- name of the patient
- age of the patient
- sex of the patient
- name of the caller
- number of the caller
- further alerted task forces
- type of operation
- date
- other information

Every minute the system automatically refreshes the operation information. Moreover it is possible to manually update the information by clicking the refresh button. This button is illustrated with the icon depicted in Figure 13 and is positioned in the upper left corner (Figure 12). Beneath the refresh button the time of the last actualization is displayed ("Zuletzt aktualisiert: ..").

Figure 13: Refresh button

So far it is not possible to show the route to the current operation site on the map. This feature is not implemented because this is standard feature and does not need a prove of concept. To embed the navigation the Google Direction API can be used [71]. It is necessary to send a request with the start and target location to the API. The results are received in JSON format. The gained information can be used to depict the route on the map.

The navigation bar on the right side has changed, compared to the design of the mock-ups. Now three buttons are constant for all task forces. The already described menu button and the back arrow were extended by the dropdown menu, see Figure 14. The dropdown menu includes the options "logout" and "close operation". The second function reports to the operation database that the user (emergency vehicle) is ready for the next operation. So the dispatcher knows that they are available and can assign the emergency unit to their next task. Additionally it needs to be mentioned that the back arrow has the same functionality as the back button of the android system. The reason for the existence of this button is, that if using a special hardware and operating system the android navigation would not exist.

Figure 14: Dropdown menu

In the following three chapters the changes of the specialized functionalities of the different task forces are described.

### 4.3.1 Features Police

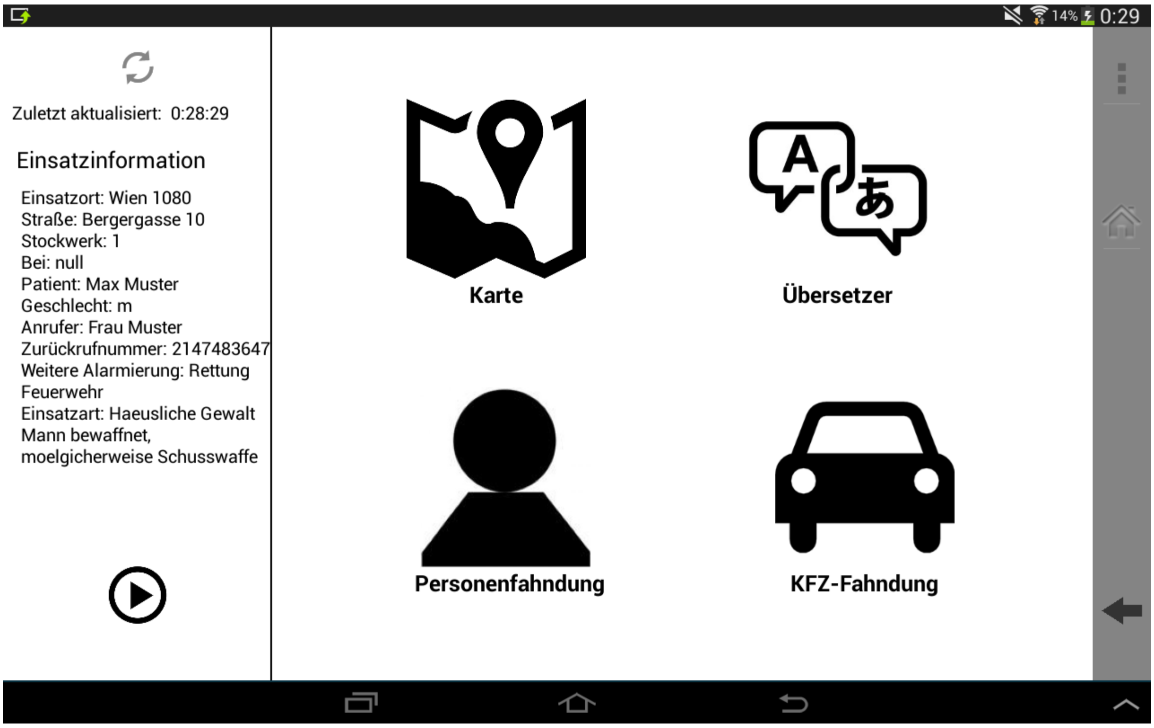


Figure 15: Main Menu of the Police

The translator functionality has changed as follows: Compared to the mock-ups no video chat view is included into the prototype directly. Instead the software opens the Skype App and this application is used to establish the connection. The contact address of the translators is stored in a database with the information about the spoken languages and if they are available at the moment. If no adequate translator is available the user gets informed.

The "Personenfahndung" ("search for wanted persons"), described in Chapter 4.2, queries a database which simulates the Schengen Information System (SIS). The following data is stored in this database:

- first and last name; middle initial
- date of birth
- sex

- nationality
- possible aliases
- flashy attributes
- whether the person was armed and/or violent
- reason for the report
- action to be taken if person encountered [72].

The changes compared to the mock-ups are that it is possible to query for incomplete names and that after clicking enter a list of results is depicted. Choosing a desired result opens the detailed information of this entry.

Similar to "person tracing" the functionality "license number tracing" is structured. First the user has to enter (parts of) the license number and then receives a list of results. Out of the list the user can choose which entry shall be depicted with more details. The prototype again uses a simulation of the police license number database with the following records:

- license number
- owner
- registration date
- location of registration

These database fields needed to be estimated because to the author's knowledge no information about that is published. Moreover it was not possible to get information of the police due to confidentiality issues.

In Chapter 4.2 the feature to play videos of the operation ground is already described. Therefore the PSAP has to choose helpful film material. After picking, the system stores the memory location of the selected videos to the proper record in the operation database. Then the task forces can stream the assigned videos.

As already described it is possible to depict surrounding surveillance cameras in the map view. The locations of the cameras are displayed with red markers. To get the address of a camera position the user needs to click on the desired marker. The location information is provided from the database of open street map and is retrieved via the Overpass API (more details 4.3.4).

### 4.3.2 Features EMS

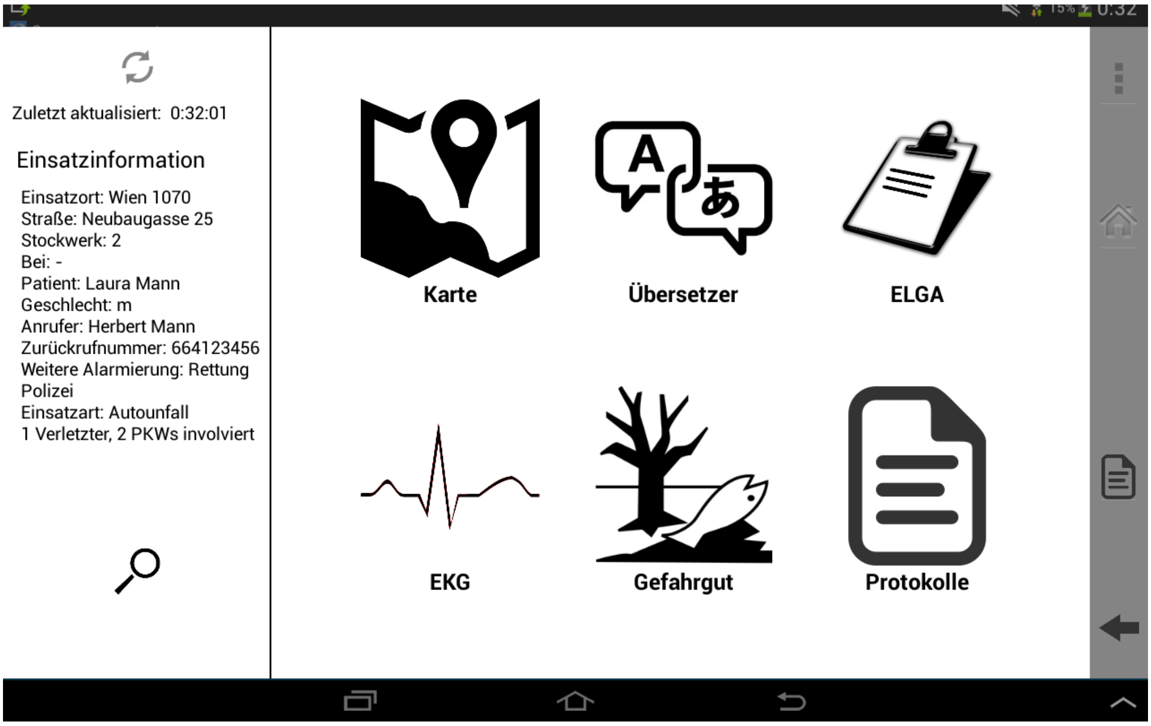


Figure 16: Main Menu of EMS

The ELGA functionality enables the paramedics to look at the medical history of the patient. Therefore the use of an e-card reader is simulated via a button. After successful access the user is provided with a selection menu of the different data types:

- discharge summary
- labor-analyzed findings
- eMedication

After the user chooses one of these selections the existing medical records are depicted in an overview. To get a detailed view of one record the user has to select it.

This functionality is structured using the existing implementation guide of ELGA [73].

The goal of the "EKG" ("ECG") feature is to send the ECG measured by the defibrillator to a doctor for analysis. So far this functionality is not included in the prototype because the defibrillators used in Austria do not have the functionality to download the raw data [74]. This can be explained by the fact that these defibrillators have their own service to send the ECG data to hospitals/doctors for analysis [75]. Therefore it is only possible to download and send the data with a certain software for PCs [74]. To implement the service in the prototype it is necessary to get the recorded ECG waves in formats like JPEG and PNG. Such an image can then be transmitted to a doctor for analysis.

The menu item "Gefahrgut" ("dangerous good ") enables the user to query dangerous goods similar to the feature designed in the mock-ups. After sending the request, the

UN-number, all results are depicted beneath the input box. Clicking on a result opens detailed information about the chosen good. The database includes the following data:

- UN number
- name
- class
- category
- tunnelcode
- attributes
- dangers
- personal protection
- general measures
- measures by release of the substance
- measures by fire
- first aid
- preventive measures for rescue operations involving dangerous goods
- preventive measures after the operation, depositing of protective clothing
- preventive measures after the operation, cleaning of the equipment

So far the database is filled with sample data of some dangerous goods. The goal is to complete the database or use a commercial API.

Clicking the button "Protokolle" ("reports") opens a selection list of reports which are currently used in hardcopy form. In the prototype these reports can be filled in electronically. The data is stored in a database and is connected to the current operation.

### 4.3.3 Features Firefighters

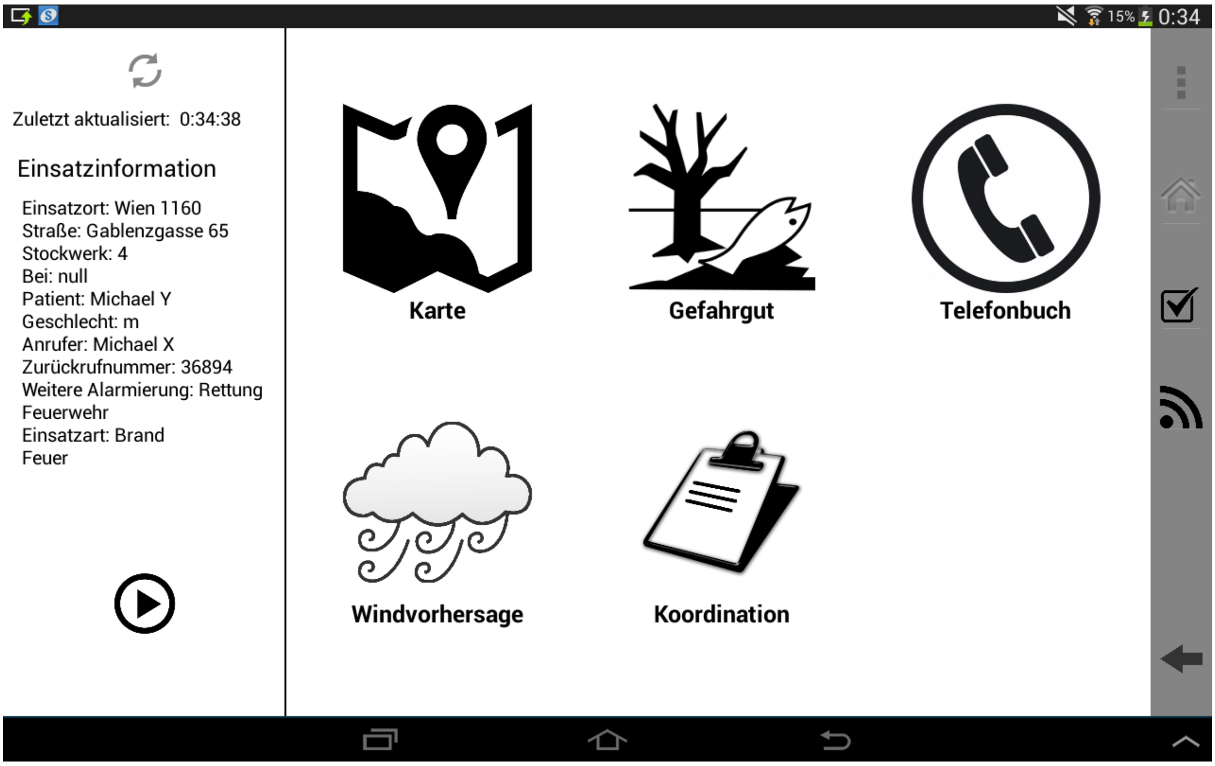


Figure 17: Main Menu of the Firefighter

The button "Gefahrgut" ("dangerous good") is similar to the one described in the previous chapter. The input box is designed identically but the information depicted subsequent is adapted for the special needs of firefighters. It includes the information which currently exists as handbook [76]. The following data is depicted:

- UN number
- name
- firefighting
- leak
- first aid
- fire or explosion
- health
- arriving, blockade, protection, warning
- protection measures

Clicking on the "Telefonbuch" ("phone book ") icon opens a list of important telephone numbers, like the number of the railway.

The already described functionality to request the wind direction is retrieved from OpenWeatherMap using their API [77], a detailed description can be found in Chapter 4.3.4.

The feature "Koordination" ("coordination") in the main menu enables to coordinate firefighters in groups. Therefore firefighters can be arranged in groups and it is determined how long they can stay, e.g., inside the building. When the group starts working the user has to press the button "losschicken" ("launch"). The commandant has to notify the system as a firefighter is back. If the predefined time expires the prototype user is informed, if not all firefighters are back. The notification is depicted via a pop-up window, which is described more detailed at the end of this chapter.

As already described the commandants can check off tasks, in a list of to-dos. In this software the to-dos are created by the leading commandant. This user group has a submenu in the menu item "Koordination" ("coordination") of the main menu. There the leading commandants can choose between the already described troop coordination and the creation of to-dos. In the creation view the leading commandant has the possibility to create to-dos for the various commandants. All to-dos are stored in a database to be synchronized between the commandants of an operation.

The next button in the right navigation bar opens a "Live-Ticker" of the current operation. The icon depicted in Figure 18 is used for the button. The "Live-Ticker" gives all users the opportunity to publish to their colleges what they are working on, which task has been finished and so on. Moreover the user can see a list of all feeds with the timestamp of their creation, to get an overview of what is going on.

Figure 18: Live-ticker button

In the map view the current wind direction is depicted with an arrow, using this icon depicted in Figure 19. The data is requested from the same source used for the wind prediction, described previously.

Figure 19: Wind direction

Moreover it is possible to show the position of hydrants in the map view. Hydrants are depicted as red markers, clicking on one opens a box with the hydrant address. The location data is retrieved from open street map via the Overpass API (detailed description in 4.3.4).

The user has the possibility to position vehicles on the map. The icon is located in the right bottom corner of the map and is depicted in Figure 20. Pressing the button inserts a vehicle marker in the middle of the screen. A short click on the marker rotates the vehicle by 90 degree and shows a box with the commandant who created this marker. A long click enables to move the marker on the map. The vehicle marker is located where the user drops it. All vehicles from all users of the current operation are depicted. The markers are stored in a database including the positioning coordinates, the rotation, the name of the commandant who created it and a connection to the appropriate operation.

Figure 20: Button to position vehicles

In all views the user is informed via a pop-up window, if the wind direction changes or the time of a troop expires. The window is located at the left bottom corner and consists of a message and an "OK" and a "Cancel" button. Pushing "OK" opens the wind prediction or the coordination view depending on the current message. The "Cancel" ("X") button closes the pop-up window.

### 4.3.4 Technical Setup

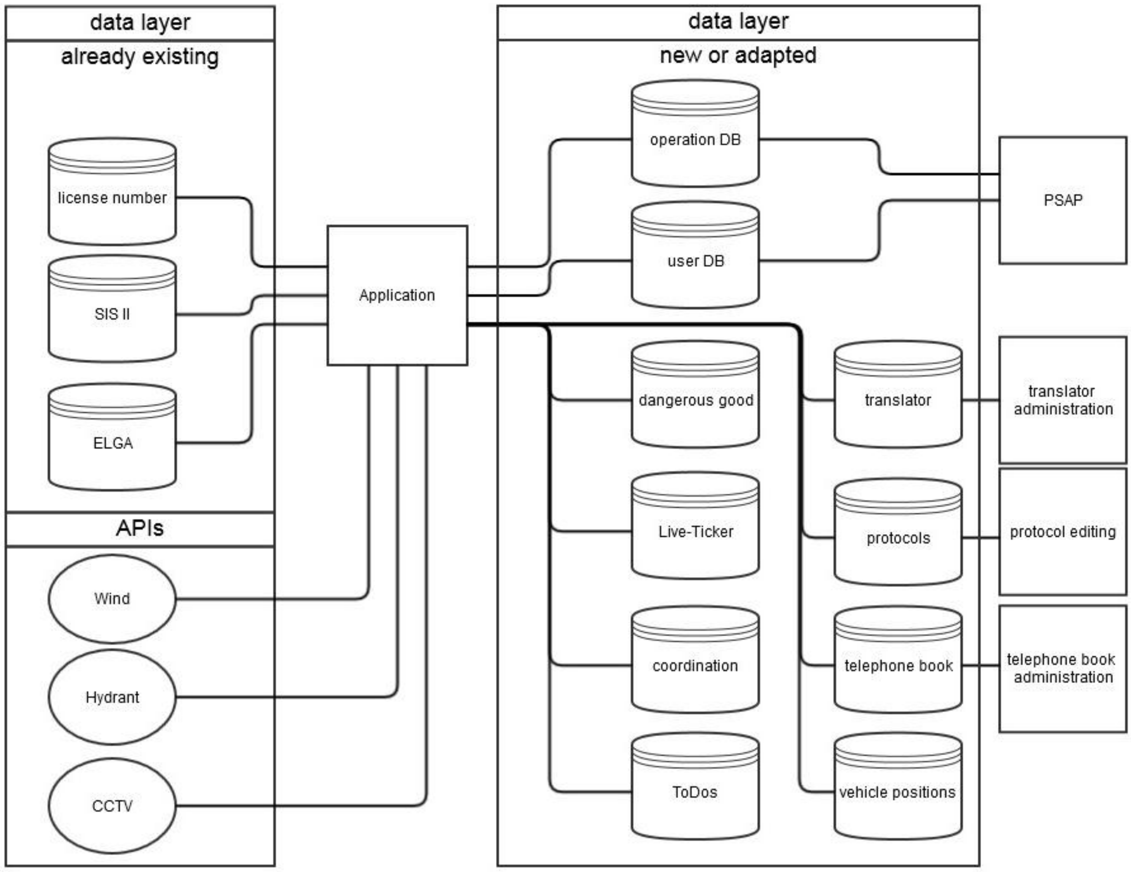


Figure 21: Software architecture

The application is connected to several databases and APIs. The databases can be divided into already existing and new or adapted databases. The already existing databases have been simulated. Due to the sensitive content it is not possible to get a connection to these databases.

It was not possible to get detailed information about the structure of the existing license number database due to confidentiality issues. Moreover a research in the web resulted in no exact list of data fields. Therefore the data fields needed to be estimated via some information from the police officer and important data which is provided (e.g., in the license).

The database for wanted persons simulates the SIS database. The abbreviation stands for "Schengen Information System" and is an information system for the European security authorities [72]. The stored data sets are described in Chapter 4.3.1.

The ELGA database was build up according to the technical documentation of the ELGA GmbH. The documentation gives information how the medical documents need to be structured and which information is included [73]. The designed database includes all of these relevant data fields. However ELGA does not have a central data storage. The documents are still stored in the various health care facilities. The improvement is that the documents are stored as standardized XML files. ELGA provides the functionality to access these documents [78]. The database of this prototype is used for reasons of simplicity. This simplification has no consequence on the data because the same data sets are depicted.

In the following all new or adapted databases are described.

The user database administrates the usernames and passwords. Additionally it stores the information whether the user is available or currently working on an operation. This information is used by the dispatcher to correctly assign the task forces.

In the operation database the data of an operation is stored. This database is filled in by the employees in the PSAP while executing an emergency call. The database simulates the storage of the already existing input mask. In addition the database includes the information about the storage location of the video of the operation site.

Additionally to the already existing data fields in the operation database detailed information about how the emergency call questions have been answered shall be stored. To enable such functionality the input mask in the PSAP has to be adapted. The emergency call schema needs to be depicted and next to every question an input box shall be displayed. These boxes will be used to enter the answers of the caller. The database consists of data fields which match the standard emergency call questions. The entries in the fields are answers the emergency caller gives to the employee in the PSAP.

The translator database stores the Skype address of the translator, the language to be translated and whether the translator is engaged or not.

Protocols are stored in a database with all relevant data fields which are also used in the hardcopy forms. In addition the operation ID is stored.

The coordination database stores the members of a troop. A data set has the following fields:

- name of the member
- assigned troop
- launching time
- end of the timer (time the member needs to be back)
- boolean if member is back or not
- time the member got back
- operation ID

The telephone book is stored in a database with the telephone numbers and the name. The data is associated to a user.

The database for the Live-Ticker stores the text of the feed, the time it was created and the ID of the operation where it belongs to.

The to-dos are stored with the following data fields: the to-do text, the corresponding commandant, whether it is checked off or on and the corresponding operation.

Another supporting database stores the positioning of emergency vehicles on the map. The stored values are: positioning coordinates, the rotation and the name of the vehicle.

The database of dangerous goods for the EMS is filled with some sample data. To get a complete data set the raw data (CSV-files) can be bought for example from the German "Bundesanstalt für Materialforschung und -prüfung" [79].

The used sample data of the database for firefighters is from a handbook about dangerous goods published by ecomed Sicherheit [76]. It provides detailed information how firefighters shall handle the various dangerous goods in different situations. The publisher offers a web portal but unfortunately no API is available to query the data. Moreover no other API provider could be found. Therefore it would be necessary, for further development in the future, to get in contact with the publisher and try to buy the necessary raw data.

All previously described databases are mounted on a server which executes the queries from the application using PHP. The results are returned in JSON Format and are processed by the application.

Besides the already described databases the following three APIs are used.

The current wind direction and the forecasts are received from OpenWeatherMap. The data is obtained in JSON format via their API. An example for a retrieval would be the following: api.openweathermap.org/data/2.5/forecast?lat=35&lon=139 [77].

The location of the hydrants and the surveillance cameras are both received using the Overpass API. This API gives the possibility to query data of Open Street Map and returns the results in XML format [80]. The query to get the hydrants of a section of the map looks as follows:

```
http://overpass-api.de/api/interpreter
<?xml version=\"1.0\" encoding=\"UTF-8\"?>
      <osm-script>"+
            "<query type=\"node\">"+
                  "<has-kv k=\"emergency\" v=\"fire_hydrant\"/>"+
                        "<bbox-query s=\""+latsw+"\" w=\""+lonsw+"\"
                        n=\""+lat+"\" e=\""+lon+"\"/>"+
            "</query>"+
      "<print/></osm-script>
```

The query to get the location data of the surveillance cameras is similar. The only difference can be found in the element <has-kv>. To get information about the surveillance cameras it has to be exchanged with the following:

```
"<has-kv k=\"man_made\" v=\"surveillance\"/>"
```

### 4.3.5 Evaluation of the Prototype

For the evaluation of the final prototype the software was installed on a Samsung Galaxy Tab 10. The implementation was tested by the three probands, who accompanied the whole development phase.

Altogether the prototype was well received and all interviewees noted that it was easy to work with the system. The police officer, Mr. W., even stated that someone who is computer illiterate immediately knows how to interact with this software. Nevertheless some problems or improvement opportunities exposed during the final test phase. The results are described in the following paragraphs.

The dropdown menu, in the upper right corner, created problems for all three test users. They all did not know the icon and did not associate it with a menu button. However, this symbol is the new standard android menu icon. Therefore it is not advisable to change it, because it can be supposed that it will be more familiar in the future. According to one interviewee it can be learned easily. He stated that you just have to use it once and afterwards the functionality of the button is clear. Another test user said that the position of the button is good because it is clearly visible. Additionally the fact that this button was not included in the mock-ups, could be a reason that the icon was not immediately identified correctly.

Another problem could be identified in the presentation of the search results. None of the test users understood that they had to click on one result row to open the detailed information in the dangerous good search, search for wanted persons and so on. It turned out that the reason therefore is an incorrect design. According to the interviewees the results either need to be underlined, so that they can be identified as links, or their background needs to be highlighted, to look like a button. An additional idea of an interviewee was to insert an arrow icon next to the results. This could help to inform the user that there is more information available.

During the tests it turned out that the users have problems to close the video call with a translator. The call is executed with the Skype App and to get back to the prototype the user has to push the hardware back button. The test showed that this process is not intuitive. Therefore it is maybe necessary to find a software that can be embedded into other applications. Nevertheless both interviewees stated that this navigation is clear after an explanation. Moreover the test users noted that the most popular languages should be provided in the short list. The most popular languages are the ones which are requested most frequently. The list with further languages should be sorted alphabetically.

According to all three probands the font size is big enough. Anyhow Mr. U., the ambulance man, stated that it would be useful to provide the functionality to scale the font size by zooming in or out. This can help if the tablet is fixed somewhere in the vehicle. Moreover people have different preferences, thereby they can be easily satisfied.

In the interview with the ambulance man the following suggestions for improvement emerged.

In the view of the "ELGA" data (medical information) the name and date of birth of the patient should be depicted after reading out the data of the e-card. According to the interviewee it happens frequently that patients hand over the wrong e-card. For example if the person keeps the cards for the whole family. Another desired adaption is to show the continuous medication at the beginning of the list, since previous medication is not as important in emergency cases. According to Mr. U. the best way is to depict the results in reverse chronological order. Moreover he stated that a filter for a period of time is not necessary, because old data is irrelevant. A further idea for improvement was to categorize clinical evidences. Therefore symbols should be used which distinguish between internal medicine, surgical medicine and so on. According to the interviewee such a categorization helps to quickly decide what is currently relevant. Moreover Mr. U. suggested to insert information about possible effects of a medicine overdoses to the e-prescriptions.

During the test the interviewee realized that he prefers to fill in the reports, like the transport protocol, in hardcopy form. As stated by Mr. U. it takes more time to enter the data via a display keyboard. Moreover it is easier to make notes on a paper or quickly cross out wrong information. Another issue which needs to be considered when using electronic forms is signatures. For example when a patient is admitted to hospital, a form of the EMS needs to be signed by the hospital. According to Mr. U. such reports could be signed by an online digital signature or NFC can be used to establish a connection between the tablet and a terminal in the hospital. Due to this reasons the interviewee believes that the best solution is to still use paper forms, but to enter the data, directly after an operation, into a computer at the office.

Additionally the interviewee suggested inserting a control mechanism to force the users to log out the system, as soon as they leave the vehicle. Therefore it should only be possible to get the operation data (or write the reports) if the user has logged out. This mechanism should help to improve data security.

The following paragraphs deal with the results of the final test with the firefighter, Mr. R..

The functionality to position vehicles on the map should be extended by a selection menu for vehicle variants. Such variants should be turntable ladder vehicle, bus, fire truck and so on. The icon of these vehicles shall be different. Clicking on a positioned vehicle should depict the name of the vehicle variant (tactic term). The described selection menu should open when clicking on the button in the bottom right corner of the map. Then the user can position the different vehicles via drag and drop. Moreover the interviewee stated that the way how the vehicle can be rotated on the map should be changed. The idea for improvement was to depict arrows around the vehicle when clicking on it. These can be used to rotate the car.

The interviewee did not expect the coordination of troops at the menu item "coordination". But he stated that it is easy to learn. Furthermore the firefighter suggested including a countdown for the remaining time of a troop, instead of the timer which actualizes every minute.

According to Mr. R. the Live-Ticker should be extended by the possibility to include audio records and photos. Like written feeds these media files should also be recorded with date and time. This can help to document witness statement or the like. Moreover it provides the opportunity to include photos of sketches. Sketches can be helpful for the coordination of an operation. Mr. R. suggested translating the audio files to text. This way it is faster for the user to find out which information is recorded in the files. Alternatively it would also be useful if it would be possible to write notes about an audio file and to store them together. Finally the interviewee stated that he expected the button to the Live-Ticker in the main menu and not in the right navigation bar. The Live-Ticker and the To-do-List are not special functionalities and are as important as the coordination or the wind prediction functionality. Therefore both of them should also be presented in the main menu. The buttons in the right navigation bar can still remain there, because both of them are used frequently. Consequently a fast navigation to these features is advisable.

During the interview it turned out that all users have to be able to create new to-dos. For this reason the creation of new to-dos must be included into the to-do list functionality. Moreover the time when the to-do was created and when it was set to done should be depicted. Another idea was to give the users the possibility to insert a list of standard to-dos. This can be done by selecting the type of operation, e.g., fire in a one-family house.

To accelerate the work with the software the interviewee proposes to include a button to the map in the right navigation bar.

The telephone book shall be enhanced by customization. The users should be able to include their own important numbers. The list of numbers should be ordered alphabetically by name. Moreover it should be possible to call the numbers directly via the tablet. Therefore the hardware needs to be equipped with a SIM card.

Finally the results of the prototype test with the police officer Mr. W. are described.

Mr. W. stated that it would be helpful to extend the location information of a surveillance camera. Additionally to the address it should be depicted if the camera is located in a shop, bank or the like. Moreover it would be helpful to know if it is a camera for traffic supervision.

According to the interviewee the search for license numbers and for wanted persons should be adapted. If the search only results in one outcome, it should be depicted immediately. Furthermore the query results of a license number are not complete. Information why this license number is traced, like stolen, and which consequences this implies should be shown.

Additionally to the already described changes the following issues were found out during the interviews.

At first the probands wished to be informed as soon as something changes in the operation information. Therefore a popup window, with the required information, should be used. This notifies the user immediately if something has changed or new information appeared. Moreover during the final test with the police officer, it turned out that important information needs to be highlighted. The discussion showed the best way would be to depict the important information in a popup window. The interviewee explained the importance of such a feature with the following example: If a weapon is involved in an operation, it is extremely important that the task forces know that. But to be sure that a police officer does not read over the information, his attention needs to be drawn to it additionally. This can be achieved by a pop-up window which needs to be confirmed. Such a feature can be important for all task forces, therefore it should be implemented for all of them.

During the interview with the ambulance man an idea to improve the search for dangerous goods developed. He stated that it would be far easier to directly click on the dangerous good number if the number is provided in the operation information. Clicking on the number should open the detailed information of this dangerous good.

Moreover a functionality should be included which enables the task forces to send a message to the command center. According to the ambulance man, Mr. U., this would save time, because you do not need to make a call. In contrast the firefighter, Mr. R., stated that such functionality is not extremely relevant, because it is fast enough to contact them via radio. In the final discussion with the police officer he proposed to insert buttons which send different information to the control unit. Such buttons could be "EMS needed" or "firefighters needed". This would be a fast and easy way to request additional task forces. Moreover a selection menu can be included to send more detailed information like the reason why a firefighter is needed, e.g. for a door opening or a fire. Summarized a selection menu should be included, which enables the task force to request additional help, by choosing some icons. Detailed communication with the command center will still be done via radio.

The interviewees were asked if they would like to have the possibility to listen to the operation information. All of them stated that it would be a nice feature but it is not absolutely essential. Mr. W., the police officer, explained that there are normally two officers in a car. Therefore it is not necessary to read the operation information out loud.

Navigation in the map was addressed by the police officer. According to him it would be practical if the system automatically routes the user to the operation site. The destination data is provided by the PSAP.

Finally the ambulance man stated that an adequate hardware is extremely important. It needs to be robust and compact, else it will be damaged immediately.

# 5 Analysis

This chapter analyses the functionalities of the developed prototype described in the previous chapter. The analysis includes information which was gathered during in the empirical study compared with data out of existing literature.

## 5.1 Mobile Device

The interviews and the literature research showed that the best way to present all of the previously described information and functionalities is by using a mobile touch device. The following paragraphs describe the findings in detail.

The interviews with the three experts showed that all of them prefer a mobile touch device. The reasons therefore are that it can be taken on the ground and also be moved in the emergency vehicle. Mr. U. stated that it is important to stay mobile because paramedics often have to change their position in the vehicle. Moreover the prototype tests showed that the device needs to be robust and compact to be carried easily. As described in [69] the devices for task forces need to be ruggedized. The devices may need to be washed after they have been used, e.g., by an ambulance man who used it with dirty protective gloves [69]. The findings of this work are also supported by Hafner et al. who stated that rugged devices are needed. The hardware requires special coatings and sealants which sustain extreme temperatures, humidity, dust and vibration [70].

Already during the first interview it turned out that a big disadvantage of mobile devices is its keyboard. Typing takes longer than on a hardware keyboard. Nevertheless according to Luyten et al. for their fire brigade system it helped for acceptance that no additional tool, like a pen, was needed to use their device [81]. Also Hafner et al. stated that the use of a touch screen is easier compared to the classical mouse and keyboard because a touch input is direct manipulation [70]. However, the interviewed firefighters mentioned that the possibility to use of a pen would be advantageous because of the gloves. Luyten et al. describe a system which is designed so that it can be used with gloves on, a so called "fat finger" interface [81]. It is recommended to consider such an interface design because task forces often have to wear protection gloves. These may hinder them to interact normally with electronic devices.

Finally it needs to be mentioned that a simple interface design is important [82]. Moreover information overload needs to be avoided [83].

## 5.2 Medical History

Data about the medical history of the patient can help to improve the work of the emergency medical service. This thesis is evaluated in the following paragraphs.

The interviewed ambulance man already stated during the first interview that the medical history is an important factor for a correct and fast anamnesis. The problem behind it is that the patients often do not know the medical data anymore and also cannot find their medical reports because they are confused and in a stressful situation. Such situations take a lot of time because the paramedics either have to search for the reports or question the patient in detail. The interviewee stated that it would be much faster to use a board computer to look the information up. Moreover the medical history can be very useful if the patient is unconscious or similar and cannot communicate that he or she has a specific illness or allergy. This already shows the benefits of being able to query the medical history of a patient. Additionally the ambulance man stated that it also would be useful to read the medical data before arriving at the scene. He said that they would be prepared and moreover there would be time to read the data while driving to the operation site. Also Shirali-Shahreza et al. mentioned that first responders are better prepared if the medical history is already known as they arrive at the scene [57]. However, the system which is currently implemented in Austria, called ELGA ("ELektronische GesundheitsAkte"), does not allow first responders to read the medical history before arriving. The system needs the e-card of the patient as authentication key.

The advantages of ELGA amongst others are that the patient has the possibility to get an overview of his or her own reports and medication history. The information flow between health services is improved [84], therefore the amount of multiple treatments can be reduced [85][84][86]. The eMedication of ELGA helps to reduce pharmacological interactions because doctor can see the prescribed drugs [87]. Moreover the medical data of the patient can be exchanged faster and more in detail [86] [85], which makes the work of the medical personnel more efficient [87]. Additionally it can have an economic benefit [85] because it helps reducing inefficient treatment and thereby saves time and money [88][85][89]. Generally the quality of the medical care and of medical decisions can be improved [86][87][89]. Moreover ELGA can improve the management of patients with, e.g., the electronic referral [87].

Also scientists and doctors can benefit from ELGA. They have the possibility to analyze the anonymized data of ELGA, which can be used for clinical tests and studies [85].

However many doctors are afraid of the "transparent doctor". They fear that their risk of liability increases because all of their steps can be traced [86][90]. The biggest concern about ELGA is data privacy issues [89]. Therefore measures need to be conducted to ensure data privacy, like access rights concept, a protocol of accesses as well as data encryption during transmission and the like [87].

As already stated it is only possible to get access to ELGA with the e-card. The e-card only serves as a key and for the identification of the person, this means that no medical data is stored on it [87][78]. Weichert et al. stated that it would be useful to store emergency data on the e-card, so that this information would be available if the ELGA system is offline [88]. This data could be information on chronic illnesses or the blood group. However, one has to be careful with the storage of discriminating data like an HIV infection.

Although there are some problems which occur though the implementation of ELGA the advantages described above seem to outweigh them. Many of the described benefits can also be noticed in EMS. ELGA provides the paramedics with the medical history of the patient, which is every important as stated by the interviewee. Pfeiffer et al. and Hörbst et al. agree to this statement by their finding that medical decisions can be improved through the use ELGA [87][89]. Also in emergency response, time and money can be saved if inefficient treatment can be reduced through the use of ELGA [87]. Despite the concerns about data privacy it is advisable to provide the emergency responders with the medical history of their patients, due to the vast amount of advantages. Moreover Pfeiffer et al. stated that it is only possible to improve the health care if medical information of the patient is available among all health services.

## 5.3 Tele-Analysis of Medical Data

The health care can be improved and costs can be reduced if the Emergency Medical Service sends ECG data to a doctor for analysis. This statement is analyzed in the following paragraphs.

The interview and testing phase of the empirical study showed that tele-analysis of ECGs can become very important. On the one hand the paramedics are supported as long as no emergency doctor is on the site. On the other hand unnecessary requests can be avoided, which can save money. The interviewed ambulance man stated that he would use tele-analysis in critical and complex situations.

Telemedicine uses audio, video and other telecommunication and electronic information, like sensors, to provide health services or assist medical personnel from the distance [91]. Paramedics neither have the experience nor knowledge about critical situations. However, with the help of tele-emergency doctors they can make better decisions [92]. Tele-emergency doctors support the paramedics on the ground. The doctors can get different data like audio and video data, vital signs and the ECG data to help [93]. Moreover it is getting more and more important to arrive fast at the scene and do a fast diagnosis. Nowadays more than 30% of the emergencies are because of cardiovascular problems where the treatment has to be performed as soon as possible [93]. However, in Germany it is not always possible for emergency doctors to come immediately. There are not enough doctors due to resource shortages. This is particularly a problem in rural areas [93].

The advantage of tele-analysis of medical data is an increase in the quality of service [93]. Moreover the treatment gets more efficient and the response time is faster. This can lead to an economic benefit. Finally especially structurally weaker regions profit from telemedicine.

There are already several telemedicine systems, some of them are described in the following section.

An example of telemedicine is a system for patients with heart problems in Brandenburg [94]. The system enables patients to measure several medical data (ECG, blood pressure etc.) at home and send it to a virtual hospital. There the data is analyzed and if something critical is detected the patient and doctors are informed. This system enables patients to be more mobile because they can get health care outside of the hospital.

The ASTER project aims to improve the care of strokes [95]. In case of a stroke every minute counts and immediate support of experts can be lifesaving. With ASTER paramedics should be supported in complex and time critical decisions. Therefore a so called Stroke Unit should be integrated into an ambulance vehicle as far as possible [96]. The following data are gathered, combined and processed with a decision-support-system: medical data of the patient like oxygen saturation, information of the target hospital like specialization, traffic data and vehicle information. This information can be used to decide about the following steps.

The Weidener Herzinfarkt-Netz is a system which enables emergency responders to send ECG to a hospital [97]. There it is analyzed and an emergency doctor can give instructions to the paramedics on the ground. This improves the prognosis for patients with a myocardial infarct. Moreover rural areas are served better.

TemRas, a similar system, sends ECG data, heart rhythm, blood pressure, pulsoxymetry, data of an electronic stethoscope as well as audio and video data to an emergency doctor in real time [93]. The doctor can decide about measures to be done. The specialty of this system is that the emergency doctor can also be consulted from outside of the ambulance vehicle. The data collected outside of the vehicle is transmitted to the ambulance vehicle where the further transmission takes place. The limited factor for this system and similar ones is bad network connection in some areas. Besides of these functionalities TemRas provides the possibility to register patients for more treatment before they arrive at the hospital.

The prototype described in this work was intended to have the functionality to send ECG data to a doctor who gives written feedback. This feature was not implemented in the final prototype because of the lack of possibility to get raw data of the ECG monitoring devices. The devices used in Austria, like LifePak, have their own infrastructure to send ECG data and other medical information [74]. It is possible to transmit the data recorded with the defibrillator to a computer or via a gateway to the LIFENET-System. The computer needs a specific software to receive and depict the ECG data. LIFENET provides a web based platform for EMS or hospitals [75]. It can be used to transmit medical data of the patient as well as the ECG to the personnel in the hospital. There already preparations can be started before the patient arrives. Thereby a fast transfer and referral to the right department can be guaranteed.

The already existing systems and research projects show that the original idea of this work, to transmit only the ECG data and get written feedback, should be extended. It seems to be important to get more information about the patient like blood pressure, heart rhythm and the general condition. Therefore it is advisable to extend the original idea and include a live video chat with the doctor as well as the transmission of additional medical information.

This analysis showed the usefulness of telemedicine, especially of the tele-analysis of medical data in emergency cases. The interviewed ambulance man stated that it helps to be supported by qualified personnel. Also Pavlopoulos et al. mentioned the importance of tele-analysis to help the medical personnel on the ground to make better decisions [92].

## 5.4 Electronic Reports

Electronic reports can help to save time and helps to exchange data in real time. However, they can also create problems with the input methods which are different to the classical paper forms. A detailed description can be found subsequently.

According to the interviewed ambulance man writing reports electronically can save time afterwards. Today paper forms are filled in during the operation. Afterwards these protocols need to be entered into an electronic system for accounting and depositing. Moreover electronic data can be exchanged with the command center or hospital. However, during the test phase it turned out that the inserting of data on a touch device takes too much time and is too complicated. Therefore the interviewee changed his position during the test and stated that he prefers paper sheets over electronic reports. He said that it is easier to make notes on a paper and faster to change data by crossing out.

The police officer and the firefighter were both from the beginning skeptical about writing electronic reports on a mobile device. The police officer stated that the time which is needed to write the report is missing while patrolling. According to the interviewed firefighter there is only little time to write the report while driving back to the fire department. Moreover he stated that it is impractical to write on a touch device.

As it was stated by the interviewees today still paper sheets are used for reports. Existing literature came to the same result [69][70]. However these paper reports have several problems. One crucial issue is that they can easily get lost, torn or dirty [69]. This is not the case for electronic reports. Moreover it can be difficult to find a report if no database exists where the reports are entered subsequently [98]. Furthermore paper sheets can easily get hard to read if text is crossed out [69]. Additionally there are often inconsistencies in between the data because it is not possible to analyze it on a paper sheet. Finally Chittaro et al. found out that the structure of the paper reports is not useful. It is designed according to the available space on an A4 sheet.

Also Hafner et al. found out that an advantage of electronic reports is that the data can already be transmitted earlier to the medical personnel [70]. Then they can prepare for the arriving emergencies. Moreover an electronic report can help to add additional data to the report [98]. This can be pictures which can be an evidence later, voice records from witnesses, GPS data for the exact location and the like. Such data can help afterwards to reconstruct the scene for a trial or the insurance company. Also Chittaro et al. stated that reports can be improved with additional data, for example the exact results of the ECG monitor [69].

Existing literature tried to evaluate different input possibilities and thereby improve the usability of electronic reports. Chittaro et al. tested handwriting recognition but the results were not satisfactory [69]. Many words were not recognized correctly. Moreover the test users were concerned that the performance even decreases if the vehicle is moving. Recording data with voice recognition has the advantage that the ambulance man has his or her hands free [70]. Nevertheless the interviewed police officer stated that it is problematic because data can be transliterated wrong. Another idea use was to use an electronic pen [69]. The advantage of it is that still paper protocols can be used [70]. There exists a form of the Swedish company Anoto. It has no free text areas because thereby no handwriting recognition is needed [70].

According to Chittaro et al. accurate reporting of patient data can be lifesaving [69]. Therefore it maybe should be considered to enter the reports electronically because it is more reliable. Nevertheless it should not be disregarded that many concerns arose during the test phase of this prototype. Therefore it is advisable to only implement electronic reports with a fast input possibility and a good structured electronic report. Further research needs to be done to find out how reports need to be designed to be filled in quickly by the different task forces.

## 5.5 Tele-Translators

Tele-translators can help the task forces on the ground to improve their quality of work. Moreover thereby the safety of the public can be increased. This thesis is analyzed in detail in the following paragraphs.

During the empirical study of this work it turned out that the police as well as the EMS are interested in such functionality. According to the firefighter Mr. R. translation is not relevant for them because they rarely have to communicate with people of the public while working.

The police officer stated that he would use such a feature immediately because it is complicated to request a translator and it takes time. Additionally he mentioned that a translator is often required during their work. Moreover the interview depicted that a tele-translator could improve the communication and information would be received faster. However, the police officer believes that such a measure would only rarely be lifesaving. According to the ambulance man a tele-translator can be very helpful for the diagnosis. He stated that 70% of the diagnosis is anamnesis where it is important to understand the patient correctly. Also the platform for video translation for health care in Austria stated that a central role for diagnosis is anamnesis [99]. Moreover the interviewee noted that less emergency doctors are needed if the paramedics understand the patients. If a patient cannot be understood he or she needs to be examined by the emergency doctor.

Currently a project is running in Austria which examines the surplus of tele-translators for the safety of patients [100]. Additionally it is analyzed if the project can reduce costs and increase the quality of health care in the long run. For the project the translators are available between 6-22 o'clock. The advantages of the tele-translators are the following: Waiting times could be decreased, because requesting and arrival of the translator is omitted. Costs could be reduced because the amount of wrong treatment could be decreased which occurs due to miscommunication. Additionally the working situation of the personnel should be improved. Today medical personnel are often used for translation but this approach depends on the linguistic background of the personnel therefore on chance [101]. Moreover such a system can be used to support deaf people [102]. There are approximately 10,000 deaf people in Austria but translators are not available immediately. Frequently relatives are used as translators.

This project and examples show which benefits tele-translation can have for the public as well as for the medical personnel. Several aspects which have been mentioned in the described project can also be relevant for task forces on the ground, like decrease of waiting times, wrong treatment and reduction of costs. The findings in the empirical study of this work as well as the comparison with an existing tele-translation project for hospitals are a confirmation of the thesis.

## 5.6 Surveillance Cameras

The empirical study showed that the depiction of the location of existing surveillance cameras can help police officers performing their work.

According to the interviewed police officer the police already look for surveillance cameras in the surrounding after a crime occurred. This process can be improved if they have the possibility to get information of surrounding cameras on an electronic device. The interviewee stated that it would be even more comfortable to have a direct access to the surveillance camera, to watch the recordings directly on the device. This would help to get even faster information of the occurred incidents. Although the police is interested in such a functionality it is not recommended to implement such a cross linking due to data privacy issues. Nevertheless as long as such integration is not possible it is also useful to depict the location of the cameras on the device. Additionally during the prototype testing it turned out that it would be useful to know what sort of camera it is, like traffic supervision, in a bank, in a shop and so on.

In Austria all surveillance cameras need to be registered at the "Österreichische Datenschutzbehörde" [103]. It is possible to search for the existing cameras via their registration number. Information about address, name etc. is stored for every surveillance camera [104]. However, there is no API or possibility to download the raw data. Therefore the prototype designed for this work uses the data available in Open Street Map. To improve transparency the government should provide better access to the location of existing surveillance cameras. A good example is the webpage http://www.data.gv.at/ which provides several transparency data. Several data of the government can be accessed and integrated in external applications [105].

The interview showed that it is useful for police officers to know where the next surveillance cameras are located. However, the provision of data is not yet good enough. Therefore the government has to make efforts to create interface which allows developers to query the data about existing cameras.

## 5.7 Coordination of Firefighters

A very important factor for good work of firefighters is good coordination. Therefore it is important to support firefighters with electronic coordination tools. In the following paragraphs this statement is explained and several functionalities of the developed prototype which are used for coordination are analyzed.

The interviewed firefighter stated that especially during big operations coordination problems occur, because these events only happen rarely. Moreover often misunderstandings happen between commandants which lead to incorrectly executed tasks.

According to Luyten et al. it is important that the commandant, the person who is not involved in exploring or extinguishing the fire, has a good overview over the current situation [81]. In an emergency situation is it important to have many different information and data about the operation site [82]: 1) the dangers of the emergency (type, size, forecast), 2) what is affected, 3) the location of the emergency and information about the surrounding (school, industry, elderly-care houses etc.), 4) who is already working on the site (number of fire trucks, police and medical support). All this data is needed for organization and coordination in operations of the fire brigade. Similar aspects are described by Jiang et al. [83]. Also Luyten et al. stated that it is important to get additional information of the surroundings like the next the hospital as well as information of the crisis situation [81]. Luyten et al. also mention that information about the environment (e.g., the wind direction), the so called contextual data, is important. Today data like floor plans, hydrant location, emergency exits and the like are on paper plans. It is often difficult to access them, because they are saved in thick binders and there is often no time to search for them [83].

This literature overview shows the importance of the functionalities wind prediction and depiction of the location of hydrants of the prototype developed in the course of this work.

According to the interviewed firefighter the wind direction is an important factor in every fire. Depending on the wind the car and the respiration equipment filling station need to be positioned. As soon as the wind changes they have to react. Therefore a prediction of the wind direction can help firefighters especially to improve coordination issues.

Moreover information about hydrants is important. The interviewee stated that commandants often fail to inform themselves about the underground water pipe system in advance. This information is required to know which hydrants to use. In case that several hydrants are connected to the same underground pipe not all of them can be used because of limited water supply. Therefore it is useful to have a system where the location data and the underground water supply of the hydrants are depicted. Luyten et al. describe a system which enables to update the information to hydrants for example if it breaks [81]. This functionality can also be useful for the system of this work. Such information is an additional help for the coordinator because the loss of a hydrant can result in additional coordination measures.

So far no database of the hydrants in Austria exists. The data used for the prototype of this work was received from Open Street Map. It would be ideal if the data of hydrants is provided by the government similar to surveillance camera data as already described previously.

As described by Luyten et al. and Monares et al. information of the surrounding can be important [81][82]. Therefore location data of schools, hospitals, industries etc. should also be integrate into the introduced system. Such information can be helpful for example if you have to evacuate the area. Or if the fire spreads and there could be dangerous material in the surrounding like in a chemical industry.

Besides of the context information the commandant should know the status of all operating firefighters [81]. Moreover Jiang et al. stated that it is extremely important to know who and what equipment is at the operation ground, where they are and if they are safe [83].

Parts of these requirements are covered by the proposed prototype with the functionality to coordinate troops. It should help that no one gets lost and to schedule operations of different troops. This feature was requested by the interviewed firefighter because it would help the commandant during coordination and to keep an overview of the situation.

Jiang et al. describe different paper based coordination tools. For example a form which helps to keep track of the tasks and who is assigned to which tasks. The weakness of paper based coordination tools is that they have to update it manually which is error prone [83]. This problem can be solved with an electronic to-do list as used in the introduced system. There the tasks are documented electronically and in writing. This helps to avoid misunderstandings because the tasks can be read multiple times. Also Jiang et al. found out that electronic command boards can improve the communication of coordination task between the coordinator and the commandants [83].

Monares et al. depict a similar problem which can be improved with the use of electronic to-do lists [82]. They mention that the first firefighters arriving on the scene inform the command center about the situation. The next ones arriving already have more information. However, they still have to contact the commander to ask for tasks as soon as they arrive. The problem behind it is that the commander is always occupied. Therefore many firemen have to improvise and act without sufficient instructions and only limited information. Such a situation can be improved with the use of an electronic to-do list. The commander can quickly assign firefighters to tasks and still have time for further coordination tasks.

Additionally to the already described coordination issues it is also important for firefighters to detect and notify all task forces about hidden hazards like weak floors or oxygen-starved fire etc. [106]. This requirement can be fulfilled with the live-ticker functionality of the introduced prototype. It informs all participants about what is going on. According to the interviewed firefighter such a ticker can improve the coordination and communication among commandants. Additionally the prototype test showed that it also should be possible to include audio records, videos and photographs. They can be used to document the situation and to send sketches, relevant for the operation. Also Monares et al. stated that multimedia data, like photos, sketches and maps, is an important part of coordination [82]. This data should be included in an electronic coordination system because it cannot be transferred via radio.

MobileMap gives the firefighters different geographical information [107]. For example the map of an area, information about fire trucks which are involved in this operation and interesting points in the surrounding like hydrants, hospitals, police stations and schools. The system enables firefighters to stay in connect with other firefighters and the command center while inside the building. Moreover it permits the firefighters to exchange media files like short video or audio files. For the transmission Wi-Fi or GSM is used. Mobile Map helps to reduce the amount of radio calls, because data can be transmitted via the system. This is important because the radio network is often busy during operations and messages may get lost [82]. Or it is simple to noisy to understand the calls. Nevertheless today the most communication on the ground is done face-to-face or via radio [106]. The same statement was done by the interviewed firefighter. This system shows an additional advantage of the to-do list and the live ticker functionality. Similar to the features of MobileMap they can reduce radio calls and thereby may prevent the loss of messages.

Finally the functionality of the introduced prototype to store the position of fire trucks and depict it on a map is analyzed. According to the interviewed firefighter this information is important if the wind direction changes. Then it can happen that the trucks need to be repositioned. He stated that it is generally important to know the position of the cars due to coordination purposes. For example to know if there is still space for another vehicle. During the prototype test it turned out that it should be possible to position different fire truck types on the map. According to the firefighter this can help in coordination because the trucks are equipped differently.

The already mentioned system MobileMap [107] also has the possibility to depict fire trucks in the map. The position of the fire truck is received from the mobile device which runs the MobileMap application. It updates the location of the truck if the device moved more than 100 meters [82]. The difference to the prototype introduced in this work is that there the vehicles need to be placed manually. It can be beneficial to place them manually because the device may will not stay in the truck all the time. Then the location information is incorrect. Moreover it is not much effort to place the vehicle on the map.

A further idea of Monares et al. is that the system stores a list of available instruments and tools to the trucks on the map [82]. This is especially important for special equipment. This enables the command center to know where which equipment is located. If a truck is selected on the map the equipment list can be retrieved. Moreover MobileMap helps to know how long it takes until special equipment arrives. The trucks are already depicted in the map before they arrive.

It is a good idea to integrate equipment lists, also for the system introduced in this work. However it is not possible to integrate a feature which predicts the duration for an equipment to arrive. Due to the fact that the fire trucks are placed on the map manually as soon as they arrive. It could be consider integrating a functionality which shows the arriving trucks, similar to MobileMap. However, a functionality should be provided which enables the firefighter to choose a parking option as soon as they arrive. This option stops that changes of the GPS data, change the position of the fire truck.

This intensive analysis of several coordination aspects of the work of firefighters showed how important it is to support them with electronic coordination tools. Several functionalities of the introduced prototype fulfill the requirements which are necessary according to existing literature.

## 5.8 Video and Images

Videos or images are a helpful medium to get additional information of the incidents taking place on the ground. The analysis and findings according to this statement are presented below.

During the interview with the police officer it turned out that video material can provide the police with important information about a suspect. Often the description of witnesses is not explicit enough. Moreover untrained people often do not know how to describe suspects. For example a jacket or cap is no relevant attribute because it can be changed easily. In comparison to that shoes and trousers are relevant because a suspect cannot change these clothes quickly. The police officer stated that suspects wear flashy jackets or bags intentionally to distract the witnesses. A video can help the police to inspect the suspect on their own to find relevant attributes. Also a study of Christianson et al. showed that police officers are better eyewitnesses because they can remember more relevant details [108]. Moreover if the police officers already get information about the suspect before they arrive at the scene they can start looking for him or her earlier. Another advantage of video material is that the police do not have to rely on the statements of the witnesses or participants.

The firefighter stated that videos or images of the operation site can help to get a picture of the situation in advance. This helps to prepare for the operation and to alert specific organization earlier. For example if a train is involved the railway needs to be informed before the firefighters can start to work.

In comparison the ambulance man saw no application to watch videos or look at images of the operation ground in the emergency vehicle. According to him most injuries cannot be seen on a video and as soon as he arrives on the scene he has an overview of the situation. However, he stated that the material can be useful for the scheduler. They would get a better view which task forces are required at the scene. Moreover the ambulance man mentioned that it is better to use the time until arriving to read medical information about the patient. In contrast Hameed et al. stated that images and videos which arrive in the hospital before the patient can help the medical personnel [91]. They can prepare themselves and as soon as the patient arrives the therapy can start.

Valcourt et al. found out that if the officers on the ground have the possibility to get additional information via images, audio and text files they can make better decisions [109]. These files help them to collect the necessary information. Also Marsden et al. say that even a single photograph can provide additional information because it shows context information which was not even noticed by the sender [11]. Such information could for example be a warning placard. Trained personnel can see more information in such images for example a firefighter can detect through the smoke color what materials may be involved.

These findings show how video and other media data can improve the work of the task forces by providing them with additional information. Summarized this data helps the task forces to get an early overview of the situation and to alert organizations involved earlier. But another important factor is that the task forces have the chance to interpret the material with their expert knowledge. This can result in additional findings which were not considered by the sender respectively the people on the ground. This additional information can help the scheduler to assign the appropriate task forces as well as the arriving forces to be prepared for the situation.

## 5.9 Additional Information

The empirical study showed that querying data on a board computer and get detailed information of the emergency call can increase the performance of the work of task forces. The following paragraphs depict the findings.

The possibility to query dangerous goods on a mobile device is according to the interviewed ambulance man and firefighter beneficial. The ambulance man stated that it can help to behave correctly in dangerous situation. For example if you get information where to wait etc. According to the firefighter it enables to get more detailed information more quickly. He supposed that you can get more information than you get via radio. Additionally it is faster compared to the look up in a folder.

The firefighter proposed to include a telephone book into the introduced system. It should contain important numbers. This makes it easier to get in contact with other organizations involved or information centers.

According to the interviewed police officer queries about persons and license number can be improved with the use of a board computer. Today these queries need to be executed via radio. He mentioned that this is more time consuming compared to a software solution. Moreover he noted another problem: The data transmitted via radio need to be written down.

The interviewed ambulance man stated that they only get limited data about the emergency call at the moment. He mentioned that detailed information about how the questions have been answered can help him to get a better understanding of the situation. A possible disadvantage could be that the call takers need more time to note all relevant facts of an emergency call. This problem can be reduced with the use of transliteration software.

These different examples show that querying for data on a board computer can help the task forces to accelerate their work.

## 5.10 Communication with the Command Center

A feature to send important information to the command center can save time. This thesis is analyzed in the following paragraphs.

According to the interviewed ambulance man a feature which enables to send text messages to the command room can save time because no call needs to be done. The police officer stated that the communication to the command center can be improved with buttons which can send different information. So the task forces do not have to write messages. An example for such a button could be a request for additional help of a specific task force. The interviews showed that detailed communication should still be done via radio.

Paredes et al. describe an iconic touch interface which can be used to send an alert to the emergency call center [58]. A similar approach can be used by the task forces to send information to the command center. Here the icons would represent possible occurrences.

The literature shows that also video clips and images taken on the operation ground can be useful if send to the command center. Bergstrand et al. created a system which allows the task forces to send short video clips to the command center [110]. The task forces are equipped with a mobile phone and the command center has a web interface to look at the videos. The videos can provide the command center with additional information. Moreover they are useful after the incident to write the report. Another advantage of videos is that they are not only reported to one person like it is with verbal reports e.g. via the radio. Bakopoulos et al. designed a system which makes it possible to make short videos or take pictures and annotate them with graphical elements [111].

Such elements can be alert symbols, shapes and so on. These annotated videos or pictures are transmitted to the command center. The annotation is done while the firefighter watches the video after recording. This system can help reducing miscommunication.

The analysis of existing researches revealed that it is not only helpful to send text messages to the command center also multimedia data is important.

## 5.11 Speech Control and Recognition

Task forces do not need speech control because they never drive alone in an emergency vehicle. This statement is analyzed subsequently.

All three interviewed task forces stated that they do not need speech control because they never drive alone. The ambulance man additionally stated that the patients may be irritated by the speech recognition of an onboard device. He is concerned that the patient will not tell everything because they are afraid that they get recorded. Moreover they stated that the noisy environment in emergency vehicles can decrease the performance of speech recognition. Also Chittaro et al. stated that speech recognition is not suitable for the use in ambulance vehicle because of the noisy environment [69].

Today most patrol vehicle applications do not use speech recognition because they are skeptical [112]. Callander et al. conducted a study and found out that the workload to query a license number increases enormously if using a computer system with keyboard and mouse compared to the query via radio [112]. Moreover they detected that speech recognition could extremely decrease the number of glances away from the street. In contrast Vetek et al. found out that a secondary speech task while driving has a significant effect on the driving performance [113]. A phone conversation slows down the breaking reaction and increases the amount of accidents. This does not change if hands-free telephones are used. Also the research of Nunes et al. showed that the cognitive process of talking distracts drivers more than physically handling with a cell phone [114]. Additionally if problems with the speech recognition occur the drivers drive even more dangerously [115]. Speech recognition is often believed to be a good alternative because the voice is the only channel which is not already used while driving [113]. Nevertheless the distraction can be reduced with guided dialogs [113].

Although there are people in task forces which would like to have speech recognition so they do not need an assistant [107], it is not advisable to implement it due to the previously described research results. Besides the possible negative consequences of speech recognition it also needs to be considered that it could have a negative effect on the work of the task forces as described by the interviewed ambulance man.

## 5.12 Volunteers

Task forces within Austria do not see the necessity to coordinate volunteers themselves. Coordination of volunteers is nevertheless very important and needs to be improved. This statement is analyzed in the following paragraphs.

During the interviews it turned out that all interviewees do not see the coordination of volunteers in their field of duties. The police officer stated that they do not use volunteers. Moreover he believes that rather firefighters are responsible for the coordination of volunteers. The ambulance man thinks that it is senseless to integrate volunteers because they need qualified personnel. He also stated even in crisis situation volunteers cannot help them. Also the firefighter said that it is not necessary to integrate the coordination of volunteers in a system for task forces. According to him the firefighters are not responsible for volunteers as there are specialized organizations like "Team Österreich" which coordinate them. Already Fernandez et al. stated that the coordination of volunteers is often outsourced to nongovernmental organizations [5].

"Team Österreich" is an organization which helps to coordinate volunteers in crisis situations. Therefore the volunteers need to register at their web portal [116]. As soon as they are needed they are requested via SMS.

Besides the coordination of pre-registered volunteers the organization also needs to prepare for spontaneous volunteers [12]. Else it can be difficult to match the volunteers to needs. Moreover it can be problematic if there is no work for spontaneous volunteers [5]. This people will not come again and the organization gets a bad reputation.

According to the interviewed firefighter volunteers should do simple tasks to support the emergency responders. The same findings were made by Fernandez et al. [5]. They stated that volunteers should do simple work so that the trained personnel can concentrate on more specialized tasks. Moreover the interviewed firefighter said that the volunteers should not be asked to bring material like shovels. This could lead to volunteers being alienated by the requirements. In contrast to this assumption Lorenzi et al. describe a system where volunteers can enter tools they can bring with them in case of an emergency [4]. It can be assumed that there is a difference between volunteers who enter these tools by choice and a public call for volunteers bringing specific material. In the cases in which volunteers do it by choice they are not alienated because they are free not to enter any tools.

This analysis shows that all interviewees think that they are not responsible for the coordination of volunteers. Moreover existing literature already mentioned that it is usual that this coordination is outsourced [5]. Nevertheless there are many examples which show the importance of the coordination of volunteers. For example after the terror attacks of 9/11, 15,000 people wanted to help immediately. Or in 1989 60% of the population of San Francisco helped after the earthquake of Loma Prieta [5]. Also storm Sandy in 2012 showed why coordination is so important. After the disaster many people wanted to help but there was no one who could efficiently assign the volunteers to tasks [4].

## 5.13 Distraction

Finally it needs to be mentioned that existing literature mention that the use of computers in police cars increases the distraction of the drivers [112][117]. The problem is that the officers should not use the computer systems while driving. However interviews depicted that all of them use it nevertheless [112]. Generally it can be summarized that secondary task while driving distract the driver. These tasks are a security risk and can lead to accidents [113].

This shows that the task forces need to be introduced carefully to a new on board system to prevent dangers as well as car accidents.

## 5.14 Comparison and Improvements of the Introduced Prototype

In the following paragraphs the prototype which was developed in the course of this work is compared with similar already existing systems. Moreover possible improvements on the prototype are depicted.

EMEREC Pilot is a similar existing system, it is a mobile information management system for firefighters [118]. Amongst others it has the following features: Navigation, depiction of a map and electronic alarm plans, request of emergency data and dangerous goods, positioning of fire trucks on the map, watching videos of traffic and tunnel surveillance cameras as live stream and checklists for the operation. In contrast the prototype created in the course of this work is not only designed for firefighters. The EMS and the police should be supported as well. Besides that the system is quite similar, it also aims to improve the work of task forces and especially facilitates coordination issues. The introduced prototype contains more and different context information, like wind prediction and the location of hydrants, compared to EMEREC Pilot.

RescueNet also has similarities with the introduced prototype but its focus is on reporting and communication to a command center [119]. The system enables to communicate with the command center and can depict emergency data. Moreover it permits to write electronic medical reports as well as fire incident reports. Additionally medical data like vital signs and ECGs can be transmitted in real time.

Jiang et al. describe the alert-driven system Siren for the fire brigade [106]. The firefighters do not have to interact with the system directly. They get alerts which are triggered through sensors of the building or in the equipment of the firemen. The alerts are depicted on a PDA. Messages are about dangers concerning themselves, information that someone else is in danger and similar alerts. Moreover it is possible to enter alerts or messages manually. These messages are sent to all other participating firefighters.

Luyten et al. as well describe a system which uses sensors on the equipment to alert other firefighters [81]. For example if the heart rate of firefighters is low the colleagues are informed via a system on a PDA.

The great difference of these two systems compared to the introduced prototype is that they use sensors to alert other firefighters.

In [83] a study showed that a system for firefighters needs the following features: a map of the area, location tracking of the firefighters and the estimated fire status. Moreover it should be possible to allocate resources, like engine X is assigned to the first floor. Furthermore an abandon button would be useful if all firefighters have to leave the building [83]. This study has similar approaches as the introduced prototype. But it mainly concentrates on the monitoring of the firefighters and the fire status. In the created prototype additional aspects are important like the provision of contextual data.

Project54 is a system for police officers which use datacasting to receive multimedia data [109]. Datacasting is the technology which uses the remaining bandwidth of TV broadcasting for the transmission of data. It is not a two-way transmission protocol therefore requests (upstream) are sent via digital radio and the downstream uses datacasting. This technological difference already depicts the main difference to the introduced prototype. The prototype uses Wi-Fi as well as existing cellular phone network standards to transmit and receive data.

In the previous paragraphs several improvements of the prototype created in course of this work have already been described. For example the transmission of video and audio material to the command center, including more information on the surroundings, like schools and hospitals and enabling to change the status of a hydrant. The following part describes additional improvements.

At first it is advisable to store more information on the device to decrease the transmission rate as stated by Monares et al. [82].

Luyten et al. describe a system which distinguishes between the firefighters that are actively working on the ground and commandants who coordinate the other firefighters [81]. The firefighters are equipped with a PDA and commandants receive a tablet. It is recommended to adapt the designed prototype so that the fire brigade could use two different versions. One with limited functionalities and one without restrictions. Many of the features provided by the introduced prototype are not needed while e.g. extinguish a fire. During a firefighting operation it is mainly necessary to stay in contact with the commandant and to get alerts. Also Luyten et al. stated that firefighters should only have a limited amount of information while extinguishing a fire. Otherwise they could get distracted or confused by the various functionalities on the mobile device [81].

# 6 Conclusion

This work showed that during an emergency detailed context information can help to improve the work of task forces. Similar findings have been made by Valcourt et al. who stated that information needs to be *"accurate, complete and up to date in order to make the most appropriate decision involving public safety"* [109, p.1].

Moreover the analysis showed that the information provided for the task forces needs to be prepared appropriately to be helpful for task forces. A system which is used on the ground needs to have a simple design because task forces must not be overwhelmed when executing their work. Therefore a system should provide the adequate amount of information. If the system has too many functionalities and is therefore to complex it could hinder the task forces during their work.

It can be concluded that pictures or videos of the operation site provided to the task forces could improve their work. Trained personnel can interpret the material with their expert knowledge which may result in additional findings. Moreover this multimedia material can be analyzed in the command centre to improve the dispatching process. If the command centre gets an overview of the situation in advance the adequate task forces can be assigned immediately. This accelerates an operation. Moreover the videos and pictures can be used as evidence.

The analysis showed that electronic reports are important. However, more research and user tests needs to be done to identify how reports should to be processed for and depicted on mobile devices to enable quick completion. Moreover it needs to be analyzed which instruments can provide direct feedback which can be included into a report. For example the data of ECG monitors.

Another important finding is that external help could enhance the work of task forces and could even be lifesaving. Tele-analysis of medical data reduces the response time of medical help. This is especially important in case of cardiovascular diseases or strokes. These emergencies need to be treated immediately and in many cases qualified personnel for the medical attendance is required. Paramedics are not trained to make the necessary medical decisions. Therefore tele-analysis can help the paramedics to treat the patient adequately until an emergency doctor is on the ground. Also tele-translators help to simplify the work of task forces by accelerating the access to a translator in case of languages barriers. This can help to improve the anamnesis of injured patients or help the police understand statements in foreign languages.

Summarized this work dealt with several aspects which get important when creating a support system for task forces. It is important to choose the used functionalities wisely because too many features are contra productive and lead to rejection of the system.

Additionally the implemented features need to be simple to use and understand. Future work needs to be done in evaluating the prototype created in the course of this work. A bigger sample size shall improve the results and thereby the possibilities to enhance the system. Moreover it needs to be considered to implement a light version of the system to simplify its handling. Such a light version could be especially important for task forces working directly on the ground.

# Appendix A: Interview Guideline

In the following chapters the interview guideline which was used to gather information from the police, EMS and firefighters to develop a software to support task forces on the ground can be found.

## A.1 Initial Guideline

Ziel der Untersuchung: Ich versuche ein System zu entwickeln, dass entweder Feuerwehr, Rettung oder Polizei bei ihren Einsätzen unterstützen soll.

Rolle des Interviews: Sie helfen mir dabei herauszufinden, welche Probleme und Anforderungen es bei Polizisten/Feuerwehr/Rettung gibt, um ein mögliches System sinnvoll zu gestalten.

Anonymität: Alle Ihre Angaben werden anonymisiert.

Genehmigung über Tonbandaufzeichnung: Damit ich die Informationen, die sie mir während unseres Gespräches geben werden, später ideal verwerten kann, bitte ich Sie um Erlaubnis das Gespräch aufzuzeichnen und als Transkription an meine Diplomarbeit anzuhängen.

1. **Bitte beschreiben Sie Ihre Tätigkeiten bei der Polizei/Feuerwehr/Rettung?**
2. **Welche Probleme sehen Sie während Ihrer Arbeit? (besonders vor Ort)**
    a. Denken Sie über Situation im Einsatz nach die nicht ideal verlaufen sind. Wo lagen die Probleme?
    b. Welche Probleme sind während Einsätzen eingetreten?
    c. Welche Probleme haben Sie von Kollegen gehört?
3. **Was sehen Sie während Ihrer Arbeit als Behinderung?**
    a. Welche Behinderungen gibt es durch technische Geräte?
    b. Welche Behinderungen gibt es durch zu wenig Information oder falsche Information?
    c. Welche Probleme treten dadurch auf?
4. **Wie denken Sie können diese Probleme und Behinderungen verbessert werden?**
    a. Welche Maßnahmen müssten getroffen werden?
    b. Welche technischen Geräte müsste man austauschen? Wodurch sollte man sie ersetzen?
5. **Welche zusätzlichen Informationen würden Sie für eine bessere Arbeit vor Ort brauchen?**
    a. Von wem soll diese Information kommen?
    b. Warum brauchen Sie diese Information?

c. Wie helfen diese Informationen?
d. Müssen sie in einer bestimmten Form aufbereitet sein?
e. Welche Informationen die Sie schon erhalten sind für Ihre Arbeit besonders wichtig?

6. **In welcher Form würden Sie gerne zusätzliche Informationen bekommen?**
   a. Mobiles Device (Tablet, Smartphone),
   b. eingebauter Computer im Einsatzfahrzeug,
   c. Touch Device,
   d. nur Audio?
   e. Wo liegen ihrer Meinung nach die Vorteile?
   f. Wo liegen die Nachteile?
   g. Können Sie sich vorstellen, dass Sie während einem Einsatz eine Software verwenden, das Sie mit zusätzlichen Informationen z.B. von der Leitzentrale versorgt?
7. **Wie würde die Arbeit der Polizei/Feuerwehr/Rettung verbessert werden, wenn Sie Freiwillige durch ein geeignetes Softwaresystem besser koordinieren könnten?**
   a. Sehen Sie es für notwendig Freiwillige besser zu koordinieren und warum bzw. warum nicht?
   b. Welche Aspekte der Arbeit würden damit verbessert werden?
   c. Welche Informationen werden benötigt, damit Freiwillige sinnvoll koordiniert werden können? (Ausbildung, Ressourcen etc.)
8. **Stellen Sie sich vor man könnten bei einem Notruf direkt Videos vom Unfall, Gefahrensituation etc. mitschicken. Wie hilfreich könnten diese Videos bei einem Einsatz sein?**
   a. Welche Aspekte müssten im Video zu sehen sein?
   b. Wie müsste das Video aufbereitet sein?
   c. Wo müsste es angezeigt werden?
   d. Wann müsste es angezeigt werden?
9. **Für wie hilfreich halten Sie die Möglichkeit Gefahrenguttransportkennzeichen direkt über ein Softwaresystem im Einsatzfahrzeug abzufragen?**
   a. Würde es Zeit gegenüber dem aktuellen System sparen? (über Funk)
   b. Halten Sie es für sinnvoll?
   c. Welche Informationen müssten vorhanden sein um die Gefahren richtig einzuschätzen?
10. **Wie würde sich die Arbeit der Polizei/Feuerwehr/Rettung verbessern, wenn Sie die Möglichkeit hätten über einen Videochat einen Übersetzer hinzu zuschalten?**

    a. Stoßen Sie oft auf Sprachbarrieren, die direkt vor Ort gelöst werden müssen?
    b. Könnte diese Möglichkeit Leben retten?

11. **Für wie hilfreich halten Sie die Möglichkeit ein Softwaresystem das Einsatzkräfte zusätzliche Informationen und Unterstützung im Einsatzfahrzeug liefert mittels Sprachkommando zu steuern?**
    a. Sehen Sie die Notwendigkeit, dass der Fahrer des Einsatzfahrzeuges das Softwaresystem verwendet? Wenn ja, wann? (keinen "freien" Beifahrer)
    b. Wann würden Sie die Sprachsteuerung nützen?
12. **Wie würde die Arbeit der Polizei/Feuerwehr/Rettung verbessert werden, wenn Berichte über die Straftat, den Unfall etc. direkt vor Ort maschinell ausgefüllt werden könnten?**
    a. Würden dadurch Informationen besser und schneller verarbeitet werden können?
    b. Würden dadurch weniger Informationen verloren gehen?
13. **Welche Software gibt es bereits im Einsatzfahrzeug?**
    a. Welche Funktionen hat diese Software?

## A.2 Adapted Guideline

Ziel der Untersuchung: Ich versuche ein System zu entwickeln, dass entweder Feuerwehr, Rettung oder Polizei bei ihren Einsätzen unterstützen soll.

Rolle des Interviews: Sie helfen mir dabei herauszufinden, welche Probleme und Anforderungen es bei Polizisten/Feuerwehr/Rettung gibt, um ein mögliches System sinnvoll zu gestalten.

Anonymität: Alle Ihre Angaben werden anonymisiert.

Genehmigung über Tonbandaufzeichnung: Damit ich die Informationen, die sie mir während unseres Gespräches geben werden, später ideal verwerten kann, bitte ich Sie um Erlaubnis das Gespräch aufzuzeichnen und als Transkription an meine Diplomarbeit anzuhängen.

1. **Bitte beschreiben Sie Ihre Tätigkeiten bei der Polizei/Feuerwehr/Rettung?**
2. **Welche Probleme sehen Sie während Ihrer Arbeit? (besonders vor Ort) Denken Sie in alle Bereiche, zum Beispiel Probleme wo du dich geärgert hast oder wo du Verbesserungspotenzial siehst.**
    a. Denken Sie über Situation im Einsatz nach die nicht ideal verlaufen sind. Wo lagen die Probleme?
    b. Welche Probleme sind während Einsätzen eingetreten?
    c. Welche Probleme haben Sie von Kollegen gehört?

3. **Welche Geräte, Systeme, Abläufe, Koordinationsmissstände führen zu Behinderungen?**
    a. Welche Behinderungen gibt es durch technische Geräte?
    b. Welche Behinderungen gibt es durch zu wenig Information oder falsche Information?
    c. Welche Probleme treten dadurch auf?
4. **Wie denken Sie können diese Probleme und Behinderungen verbessert werden? Was müsste neu eingeführt, gekauft, erfunden werden damit die Arbeitssituation perfekt wäre, denken Sie utopisch?**
    a. Welche Maßnahmen müssten getroffen werden?
    b. Welche technischen Geräte müsste man austauschen? Wodurch sollte man sie ersetzen?
5. **Welche Informationen würden Sie brauchen um perfekt arbeiten zu können? Denken Sie utopisch!**
    a. Welche wichtigen Informationen fehlen oft?
    b. Von wem soll diese Information kommen?
    c. Warum brauchen Sie diese Information?
    d. Wie helfen diese Informationen?
    e. Müssen sie in einer bestimmten Form aufbereitet sein?
    f. Welche Informationen die Sie schon erhalten sind für Ihre Arbeit besonders wichtig?
6. **Welche Software gibt es bereits im Einsatzfahrzeug?**
    a. Welche Funktionen hat diese Software?
7. **Wie würde die Arbeit der Polizei/Feuerwehr/Rettung verbessert werden, wenn Sie Freiwillige aus der Bevölkerung in Krisen besser koordinieren könnten?**
    a. Sehen Sie es für notwendig Freiwillige besser zu koordinieren und warum bzw. warum nicht?
    b. Welche Aspekte der Arbeit würden damit verbessert werden?
    c. Welche Informationen werden benötigt, damit Freiwillige sinnvoll koordiniert werden können? (Ausbildung, Ressourcen etc.)
8. **Stellen Sie sich vor man könnten bei einem Notruf direkt Videos vom Unfall, Gefahrensituation etc. mitschicken. Wie hilfreich könnten diese Videos bei einem Einsatz sein?**
    a. Welche Aspekte müssten im Video zu sehen sein?
    b. Wie müsste das Video aufbereitet sein?
    c. Wo müsste es angezeigt werden?
    d. Wann müsste es angezeigt werden?
    e. Wie viel Zeit bleibt Ihnen im Einsatzwagen um ein Video anzuschauen?

9. **Für wie hilfreich halten Sie die Möglichkeit Gefahrenguttransportkennzeichen direkt über ein Softwaresystem im Einsatzfahrzeug abzufragen?**
    a. Würde es Zeit gegenüber dem aktuellen System sparen? (über Funk)
    b. Halten Sie es für sinnvoll?
    c. Welche Informationen müssten vorhanden sein um die Gefahren richtig einzuschätzen?
    d. An was für sonstige Abfragen können Sie denken?
10. **Wie würde sich die Arbeit der Polizei/Feuerwehr/Rettung verbessern, wenn Sie die Möglichkeit hätten über einen Videochat einen Übersetzer hinzu zuschalten?**
    a. Stoßen Sie oft auf Sprachbarrieren, die direkt vor Ort gelöst werden müssen?
    b. Könnte diese Möglichkeit Leben retten?
    c. Würde es das Leben für die Einsatzkräfte vereinfachen?
11. **Für wie hilfreich halten Sie die Möglichkeit ein Softwaresystem das Einsatzkräfte zusätzliche Informationen und Unterstützung im Einsatzfahrzeug liefert mittels Sprachkommando zu steuern?**
    a. Sehen Sie die Notwendigkeit, dass der Fahrer des Einsatzfahrzeuges das Softwaresystem verwendet? Wenn ja, wann? (keinen "freien" Beifahrer)
    b. Wann würden Sie die Sprachsteuerung nützen?
    c. Gibt es Umweltgeräusche die stören könnten, wie das Radio oder offene Fenster?
12. **Wie würde die Arbeit der Polizei/Feuerwehr/Rettung verbessert werden, wenn Berichte über die Straftat, den Unfall etc. direkt vor Ort maschinell ausgefüllt werden könnten?**
    a. Würden dadurch Informationen besser und schneller verarbeitet werden können?
    b. Würden dadurch weniger Informationen verloren gehen?
    c. Würde damit Zeit gewonnen werden?
    d. Könnte dadurch die Aufmerksamkeit vom aktuellen Geschehen abgelenkt werden?
13. **In welcher Form würden Sie gerne zusätzliche Informationen bekommen?**
    a. Mobiles Device (Tablet, Smartphone),
    b. eingebauter Computer im Einsatzfahrzeug,
    c. Touch Device,
    d. nur Audio?
    e. Wo liegen ihrer Meinung nach die Vorteile?
    f. Wo liegen die Nachteile?

g. Können Sie sich vorstellen, dass Sie während einem Einsatz eine Software verwenden, das Sie mit zusätzlichen Informationen z.B. von der Leitzentrale versorgt?

# Appendix B: E-Mail

Sehr geehrter Herr W.!

Meine Schwester besucht bei Ihnen einen Selbstverteidigungskurs und erwähnte, dass Sie bei der Polizei tätig sind. Da ich mich im Zuge meiner Diplomarbeit an der Technischen Universität Wien mit dem Thema "Emergency Management" beschäftige, suche ich für ein kurzes Interview einen Polizisten der im Streifendienst tätig ist bzw. war. Es würde mich sehr freuen, wenn Sie mir weiterhelfen könnten.

Für weitere Fragen stehe ich Ihnen natürlich gerne zur Verfügung.

Vielen Dank für Ihre Unterstützung!

Mit freundlichen Grüßen

Karoline Mattanovich

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