UNIVERSITY OF OSLO
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Exploring map-based interfaces for mobile solutions in emergency work

Master's thesis

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Abstract

The use of technological equipment as task-support in emergency response is still a fairly unexplored domain. While the current research within this field has presented some solutions, lacking understanding of user, user context and task seem to prevent these from being successfully exploited. The uniqueness and characteristics of emergency situations complicates the implementation of mobile technology, thus an in-depth understanding of the domain area is required to properly facilitate for task-support in emergency response.

This thesis investigates challenges and requirements related to both domain area and usability principles through investigating task-support for incident commanders in the police. To this end, domain knowledge has been collected through field studies, interviews and observation, and a prototype combining these requirements with state of the art mobile technology has been developed. The prototype has been developed to support tasks related to resource allocations. It combines the use of a map-based interface with icons with lists and forms, and uses direct manipulation as a part of the interaction. Evaluations have been conducted with both usability and domain experts, and results from the evaluations are categorized, discussed and finally used to put forward design implications.

The findings of this thesis include a set of design implications deduced from (1) careful investigation of the domain area, (2) usability theories and design guidelines, and (3) evaluations of a developed prototype. The study has proven that the uniqueness and characteristics of emergency situations does not allow us to rely on design theory alone, and a combination of usability and domain expert is essential.

The results from the evaluations and the design implication put forward show that the work in this field is highly feasible, yet more knowledge about the domain area is required to further facilitate for added value when solving tasks. Results also confirm that state of the art mobile devices are well-suited for decision-support within emergency response. Furthermore, the challenges, requirements and alternative solutions presented in this thesis are highly transferrable to other emergency agencies.

Keywords: *Emergency response, mobile decision support, map-based user interfaces, user interface design and evaluation.*

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List of acronyms and abbreviations

GOMS	Goals, Operators, Methods, and Selection rules
HCI	Human–computer interaction
HTA	Hierarchical Task Analysis
ICT	Information and communications technology
ISO	International Organization for Standardization
MVC	Model–view–controller
PDA	Personal digital assistant
PHE	Participatory heuristic evaluation
PO	Politiets Operative System (Operative system of the police)
OS	Operating system
SE	Software engineering
UCD	User-centered design
UI	User interface
UID	User interface design
UIM	Usability investigation method
XP	Extreme Programming

Chapter 1
Introduction

1.1. Motivation

> *"The delivery of police, fire, or emergency medical service depends on a complex communications system. Prior to the 1970s, dispatch facilities in the United States relied almost exclusively on manual – paper and pencil-based techniques and devices, essentially."*
>
> *(Thomas 1995, p. 161)*

The development of mobile technology the last decade has provided new and unexplored possibilities within countless fields. From enhanced gaming experiences to life-changing functions, new features and services are being developed consecutively. Naturally, it can be argued that some contribution's primary goal is amusement, while other focus on carrying out as contribution to society. The usage of mobile solutions for emergency response is an example of how mobile applications can enhance the field work in crisis management. For personnel and leaders involved in emergency work, new opportunities have arisen with the application opportunities that follow with new technology.

Because of the complexity of their work, along with the variation in circumstances, future applications must be thoroughly studied. This is to ensure coverage of all potential variations within tasks that may arise during the emergency processes. One thing is to introduce task support through a mobile solution, but as a part of designing the mobile, new features and possibilities can be implemented to further enhance the work of the field personnel.

Nonetheless, as cited in (Thomas 1995), the tasks have been gradually automated in emergency response as price and availability became reasonable, but the emergency response is an example of arenas where implementation of technology is not happening as fast as other public services (Brenner and Cadoff 1985). The actual usage of mobile technology as supportive equipment is still relatively narrow in emergency work compared to other lines of work. While there is a common agreement that technology is indeed able to improve emergency response, it is also no doubt that designing solutions for emergency work requires a deep insight in both who the user is, and what tasks they are solving. Proper knowledge about the users and their requirements must by gathered before embarking upon the design process. Several studies, among them (Jokinen 2008, p. 169; Norros, Hutton et al. 2009; Way 2009, p. 40), have identified a lack of understanding of the actual work carried out as one of the reasons when technological solutions are only considered partly successful.

With this in mind, we have an opportunity to explore exactly what local leaders and field personnel in emergency response require from an ICT-system supporting their tasks at hand. Also, we can combine the gathered user requirements with state of the art technology to hopefully improve the support of every-day tasks of emergency workers.

1.2. Research context

This master thesis is part of an ongoing research project at SINTEF called EMERGENCY (Mobile decision support in emergency situations). The lifetime of the EMERGENCY-project is set from November 2008 to October 2012, while this master thesis is written as a part of the EMERGENCY-project in the period December 2009 – May 2011.

> *"The purpose of the research project EMERGENCY (Mobile decision support in emergency situations) is to improve decision support in emergency situations based on systematic experience-gathering and state of the art support for real-time information access. EMERGENCY is partly funded by the Research Council of Norway, and runs from November 2008 to October 2012."*
>
> *(Stølen 2010a)*

1.3. Objective

The purpose of this thesis is to evaluate the role of mobile devices as fundamental support in a potentially life-saving situation. By combining state of the art technology with domain and usability requirements, we can hopefully discover important potentials for improvements on the decision making part of emergency situation. This will in turn benefit both the emergency agencies themselves, but also the victims of the emergency. More precisely, we focus on solutions associated with common tasks amongst incident commanders working with emergency response.

The main objectives of this master thesis are to (1) identify these design requirements and challenges for interfaces used in decision making support, (2) develop a prototype and evaluate early implementations of features that may help address these design requirements, and (3) present problem areas and derive design implications for future work. To evaluate the main objectives, this thesis investigates a map-based interface for incident commanders working with tasks related to allocation of resources.

1.4. Scope

The theme for this thesis is how to design decision support for mobile solutions in emergency response. The thesis is focused around resource handling amongst incident commanders responding to emergencies. Incident commanders are local leaders within the police operating at tactical level. Resource handling includes resource allocation, as well as both reallocation and continuous updates of information about resources.

There are several reasons for selecting exactly this task within the work of the police. First of all, it is a task well-suited for prototyping. By combining previous studies and relevant literature, along with the previous work in the EMERGENCY-project, the knowledge around this topic is mature enough to be transferred to a prototype. The task restricts my possibilities, but gives me an opportunity to explore at the same time. A second reason to select such a task is the task importance in regards to an emergency operation. This is both an important and unavoidable task in most operation. It is a central task for an incident commander. It is also a task very much similar to tasks carried out in the fire agency and to some degree also in medical response and voluntary organizations. The knowledge and experience collected in this project is very much transferable to other agencies. The final reason is the general impact of potentially improving life-saving work which would be fair to assume is in the interest of the public.

1.5. Research question

What are the most important implications of design when developing a prototype for map-based interfaces for resource allocation on mobile devices amongst incident commanders?

To answer this research question, the three main objectives are addressed. Related work and usability theory are combined with state of the art mobile technology to develop a prototype with a map-based interface. This prototype has been evaluated by usability experts, allowing us to find the most important design implications for future work within the same problem domain.

1.6. Chapter overview

The structure of this thesis is divided into to three main parts:

- Background and method (chapter 1-3)
- Problem domain (chapter 4-6)
- Solution (7-10)
- Validation (11-13)

Chapter 2 gives an introduction to the work done so far in the EMERGENCY-project, and presents a case study carried out prior to this thesis. A presentation is given of related work, and a structured presentation is given of relevant findings from related work. Chapter 3 describes the general approach of the thesis, and gives an explanation of the methods used during data collection, prototyping and evaluation. Criteria for evaluation are also presented in this chapter.

Chapter 4 – 6 gives an introduction to the problem domain by presenting the user context, the user and the task. Chapter 4 describes the user context, which is an emergency response situation. Different phases of emergency response are explained, and the characteristics and challenges related to the user context are presented. In chapter 5 the indented user is described in detail. First, an introduction of levels of leaderships is given, and then the user's persona, behavior and skills are used to describe the characteristics of an incident commander. The tasks at hand are presented in chapter 6, and they are also broken down and described in detail.

Chapter 7 – 10 investigates solutions based on design requirements from usability theory and related work. Chapter 7 present general requirements on how to design interfaces for decision by exploring different aspects of usability. Chapter 8 takes a deeper look at more specific design challenges by studying device-specific and application-specific aspects. An overview of the prototype method and scope, along with relevant design guidelines are presented in chapter 9. Chapter 10 gives a presentation of the developed prototype. First, the technical features of the prototype are explained, and then a walkthrough of the prototype is given.

The chapters from 11-13 seek validation by presenting the evaluations of the prototype and related analyses and results. In chapter 11, the evaluations are described in detail, along with theory and discussion around the evaluations. The results from the evaluations follow in chapter 12. Chapter 13 discusses the findings from the evaluation and defines four problem areas. Based on these problem areas, design implications for future work are laid out. A discussion of validity of the evaluation is given in the end of the chapter.

Finally, chapter 14 concludes this thesis by giving a summary of the work and contribution presented in this thesis, and exploring possibilities in future work.

A glossary is presented in Appendix H for translation of Norwegian terms.

Chapter 2

Background

Writing this thesis as a part of a project has provided several benefits. This chapter begins by giving an introduction to the EMERGENCY-project. Then, the advisory board is presented, and a case study conducted prior to this thesis is briefly presented. Finally, the related work is identified and presented. The related work is discussed, before the findings are group according to relevance and structured into a table.

2.1. The EMERGENCY-project

The EMERGENCY-project commenced in November 2008. By the time the work with this thesis began, data from the domain area had been collected for a year. Various contributors had provided the project with domain knowledge, and several papers and technical reports had been published. Reading this material gave a necessary introduction to the problem area during start-up. Most of these publications cover a similar topic within the exact same problem area as this thesis, rather than just covering parts of it. Therefore, prior works in the EMERGENCY-project have functioned as an important source for relevant work, and have been used actively in the work of this thesis. The most relevant work from the EMERGENCY-project is presented by the thesis supervisor Erik Nilsson (Nilsson and Brændland 2009; Nilsson 2010a; Nilsson 2010b; Nilsson and Stølen 2010).

Writing this thesis at SINTEF also allowed the work to be a part of a bigger project with resources and knowledge that would otherwise not have been available. The EMERGENCY-project also gave access to domain experts through the advisory board which would be difficult to obtain in an independent thesis. Besides, usability experts at SINTEF who were not directly involved in the project also provided relevant material, such as evaluation methods and domain knowledge. They also contributed to this thesis as members of expert groups during evaluations.

Equipment was also made available at SINTEF, including mobile devices for testing the prototype, recording equipment and mobile device camera[1].

The EMERGENCY-project (187799/S10) is funded by the Norwegian Research Council and the following project partners: Locus AS, The Directorate for Civil Protection and Emergency Planning, Geodata AS, Norwegian Red Cross, and Oslo Police District.

2.2. The advisory board

Because this thesis is written as a part of the EMERGENCY-project, other people besides the thesis supervisor have contributed to this thesis as well. An advisory board has been appointed to assist the researchers of the project (Stølen 2010b). This board consists of several domain experts, all with scientific background now working within fields related to the project. Also, professors, associated professors, researchers and doctoral fellows from SINTEF/University of Oslo are a part of either the project or this advisory board. The members of the board have been individually selected because of their unique knowledge and expertise within the problem area. This board meets a few times a year to question and validate the work done so far, and to further suggest work that can be done in the future. The advisory board has been of great importance in regards to validation of information, especially during the latest meeting December 14th 2010. Several topics mentioned and discussed during this meeting have been used in this thesis as a source of information. The data collection methods during sessions with the advisory board are further presented in Section 3.3.4.

2.3. Case study: Handling emergency response

Previous to this thesis, a smaller qualitative case study was conducted where users' technology acceptance in emergency response was evaluated. The acceptance in emergency response was measured against acceptance in general (i.e. other professions). The study was partly based on previous studies of user acceptance in similar scenarios. The main inspiration was Philip Fei Wu at University of Surrey, who had done a case study and written an article on this topic. In (Wu 2009) he presents the most important factors affecting user acceptance within emergency work in a Campus Alert-system. By using the technology acceptance model he investigated how different motivational factors were related to the intention and

[1]Noldus MDC is a mobile device camera: http://www.noldus.com/human-behavior-research/accessories/mobile-device-camera-mdc

behavior of using an emergency alert system. The *technology acceptance model (TAM)* is a model specifically meant to explain computer usage behavior (Davis, Bagozzi et al. 1989, p. 983).

The case study was carried out to explore the hypotheses: "*The user acceptance is low in emergency work relatively compared to the statically average level of user acceptance".* The final conclusion implied that the user acceptance tended to be lower in emergency work, thus confirming the hypotheses. This was one of the tendencies implying that the user's needs should be further investigated.

2.4. Related work

Several papers and technical reports from the EMERGENCY-project were used actively throughout the work in this thesis. However, it was vital to use related work to fill in the gaps and provide new knowledge to the project. This section gives an overview of the most relevant work included in this thesis. Before the related work is presented, a brief introduction is given on how related work was identified and found.

2.4.1. Identification of related work

The topic of mobile solutions for emergency response is a fairly new topic in the world of research. However, we have seen an increasing number of research papers and studies on crisis situations and the usage of mobile solutions over the last decade. Several related papers are presented on the ISCRAM-conferences, the annual conferences held by the *Information Systems for Crisis Response and Management* community. This community consists of researchers and experts from all over the world working around the topic of crisis response and management.

Other articles and papers are found on the digital libraries of *ACM (Association for Computing Machinery)*[2], *SpringerLink*[3], *The Ovid Experience*[4], *IEEE Xplore (Institute of Electrical and Electronics Engineers)*[5], *IET's (Institution of Engineering and Technology) INSPEC*[6], *ScienceDirect*[7] and *Wiley Online Library*[8]. These are either found through Google Scholar[9] by keyword search, or

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[2] Association for Computing Machinery: *http://portal.acm.org/*
[3] SpringerLink: *http://springerlink.com/*
[4] Ovid: *http://www.ovid.com/site/index.jsp*
[5] IEEE Xplore: *http://ieeexplore.ieee.org/Xplore/dynhome.jsp*
[6] INSPEC: *http://inspecdirect.theiet.org/*
[7] ScienceDirect: *http://www.sciencedirect.com*
[8] Wiley Online Library: *http://onlinelibrary.wiley.com/*
[9] Google Scholar: *http://scholar.google.no/*

recommended by supervisors. Also, through the EMERGENCY-project I've been pointed in direction of topics and authors working on related topics. Lastly, a few papers and theses from previous students at University of Oslo have been used to find related work.

2.4.2. Presentation of related work

There is much related work that can be seen in context to the topic of this thesis; however they all focus on different aspects of either mobile solutions or emergency response in general. Some papers focus on general problems identified with emergency management in disasters (Nakatani and Nishida 2007) that should be included when gathering requirements. Even though several problems are identified, some are more relevant than other. One of the most interesting one is their problem on situation recognition, both in regards to why an early overview is important and how to present information. (Norros, Hutton et al. 2009) focus on joint agencies, typically fire brigades, police officers and ambulance personnel when discussing demands in emergency response. Important factors such as cognitive, operational and collaborative demands are brought up. The authors in (Newlon, Pfaff et al. 2009) also focus on collaboration between agencies, but from a mega-collaborative perspective including several actors. These papers provide a solid foundation for identifying requirements for police officers, but don't focus on how the solutions should be implemented. Large-scale systems are often forced to spend time discussing how to overcome heterogeneous network issues and often proprietary challenge, thus having less time to discuss the implementation. In addition, even though there might be similarities, this thesis focuses on UIs for incident commanders, and not a multi-agency interfaces.

Likewise, some papers (Dilmaghani and Rao 2009; Nilsson and Stølen 2010) are interesting for a better understanding of the totality of the solutions. They discuss mobile solutions in relations to network requirements with a focus on ad hoc networks. While interesting when evaluating the design and functionality of a mobile solution as a whole, these matters are not that important in relations to UID. However, in (Luyten, Winters et al. 2006) a larger European project is used to elicit user requirements and discuss applications that can meet these demands. The focus is heavy on collective intelligence and collaboration between the emergency response personnel and community citizens, and less on the topic of designing the UI. Another related paper is (Way 2009), in which criteria for evaluation of mobile technologies are extracted based on needs from crisis responders. Instead of directly discussing the UI, the paper presents a very interesting framework for evaluation of what mobile technology that would suggest the best adaption for different criteria.

Existing research on situation awareness is more relevant and discussed in (Streefkerk, van Esch-Bussemakers et al. 2008). This paper focuses on location-based notification systems includes important topics on how mobile devices can improve situation awareness for police officers. This is similar to research on situation aware systems with context rule-based decision modules by (Luyten, Winters et al. 2006). Both these papers address important requirements for successful UIs, but lack testing in practice as they have used a user-centered approach and informal acceptance testing for validation. A study done on mobile decision support (Pérez, Cabrerizo et al. 2010) draws some similarities to these two papers. The study focuses on dynamic decision support systems. However, the paper is mostly concentrated around group decision making (GDM), and not from a user-centered point of view. Still, there are interesting elements in regards to how adaptation is an important factor when discussing UIs. The authors of (Uluca, Streefkerk et al. 2008) also bring up important related topics when presenting automated user interaction. The study of panning, zooming and other automation of navigational tasks is interesting in when designing a UI for police officers. The paper also includes the relevant topic of designing according to the user's attention span. Different design constraints and the need for simplicity is also discussed in (Nadal-Serrano 2010) which brings up fire brigades to examine advantages and disadvantages of existing solutions, and lists desired features of new solutions.

The importance of multimodality in UIs for emergency response has also been discussed in prior studies, notably by (Khalilbeigi, Schweizer et al. 2010). The paper is mostly focused around large-scaled disasters, but includes interesting discussions on how new technology should adapt to older routines. To what degree attachment to traditional equipment and work practice should be incorporated in novel solutions, is a topic also discussed by (Cohen and McGee 2004) in their paper on tangible multimodal interfaces. (Sinha and Landay 2002) also includes studies of early work practice of professional multimodal interaction designer. In their paper they have explored the design space of multimodality and they highlight several key factors in regards to what new possibilities that comes with multimodal interaction. Several of these key factors are transferrable to this thesis.

2.4.3. Findings from related work

This section gives an overview of how findings from related work affect this thesis, i.e. which part of the thesis they have influenced. The related work is divided into three categories:

1. Design requirements
2. Methodology

3. Domain knowledge

Related work from the EMERGENCY-project is not included here since it overlaps on all three categories, and the purpose of these findings is to add supplementary knowledge into the project. Each of the listed works overlaps with two of the three categories above.
Figure 2.4-1 illustrates the overlap in a Venn diagram and Table 2.4-1 gives a categorical overview of the related work and their findings. Each number in the Venn diagram refers to the elements in Table 2.4-1.

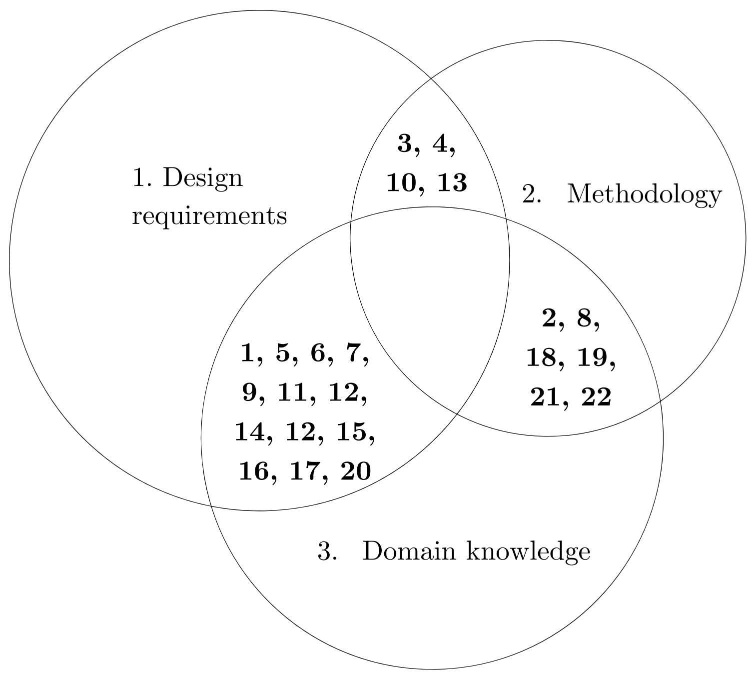


Figure 2.4-1: Venn diagram: Categorical view of related work

Table 2.4-1: Categorical overview of related work and findings

#	Source	Focus	Relevant methods	Relevant findings	Category
1	(Luyten, Winters et al. 2006)	Situation-aware mobile system	User test, prototyping	System design and functionality categories	1, 2

#	Source	Focus	Relevant methods	Relevant findings	Category
2	(Newlon, Pfaff et al. 2009)	Interface development for large-scale disaster response	User testing, experimental observation, prototyping	Interface design for prototype	1, 2
3	(Pérez, Cabrerizo et al. 2010)	Mobile decision support system for dynamic group decision making problems	Prototype presentation	decision support system model	1, 2
4	(Sinha and Landay 2002)	Multimodal applications	User and field study, prototyping and Wizard of Oz-participation	Technique for extending paper prototypes to multimodal application design	1, 2
5	(Cohen and McGee 2004)	Tangible multimodal interfaces in safety-critical applications	Development of three systems	Design implication	1, 3
6	(di Tada and Large 2010)	Real disaster emergency information system	Case study	Report of work in progress	1, 3
7	(Dilmaghani and Rao 2009)	Communization in emergency response	Observation, mesh network deployment	High-level hierarchical Petri net	1, 3
8	(Khalilbeigi, Schweizer et al. 2010)	Computer Support of paper workflows in emergency management	User study, field study	Design implications, proposed system	1, 3
9	(Lanfranchi and Ireson 2009)	User requirements for collective intelligence emergency response system	User studies	User requirements	1, 3
10	(Nadal-Serrano 2010)	Concepts for incident response preplanning	Peer review, Software prototyping	Proof of concept	1, 3
11	(Nakatani and Nishida 2007)	Prospective interfaces for emergency management	Development of advanced interfaces, qualitative simulation	Interfaces for three types of human support systems	1, 3
12	(Nilsson and Stølen 2010)	Ad hoc network and mobile devices in emergency response	Empirical studies	Design- and user requirements	1, 3
13	(Plotnick, Ocker et al. 2008)	Leadership roles and communication issues i emergency response	Pilot study	Results, implications for practitioners	1, 3
14	(Streefkerk, van Esch-Bussemakers et al. 2008)	Field evaluation of mobile location-based notification systems for police officers	Field study, empirical analysis	Recommendations for mobile systems	1, 3
15	(Uluca, Streefkerk et al. 2008)	Automated hanheld navigation support	Low-fi prototyping, relevant literature	Claims of core features	1, 3

#	Source	Focus	Relevant methods	Relevant findings	Category
16	(White, Plotnick et al. 2009)white	Online social network for emergency management	Exploratory action research, examination of existing systems, survey	Feasibility study of social network paradigm	1, 3
17	(Burstein, Holsapple et al. 2008)	Decision support in emergency situations	Design principles, literature review, Delphi method	Process model, recent advances in domain	2, 3
18	(Carver and Turoff 2007)carver	HCI in emergency management information systems	Literature review, cognitive theory	Design models	2, 3
19	(Fiedrich, Gehbauer et al. 2000)	Optimized resource allocation	User tests, mathematical modeling,	Dynamic optimization model	2, 3
20	(Kondaveti and Ganz 2009)	Decision support system for resource allocation	Prototyping	Decision support framework	2, 3
21	(Krahnstoever, Schapira et al. 2002)	Multimodality in crisis management systems	Prototyping, user studies, study of related systems	Framework for multimodal crisis management system	2, 3
22	(Way 2009)	Framework for evaluating mobile technologies for crisis response	User examination, literature review	Framework presented	2, 3

Chapter 3
Research method

> *"People don't usually do research the way people who write books about research say people do research"*
>
> *(Bachrach 1962)*

The purpose of this chapter is to introduce the approaches and methodologies used when conducting the research in this thesis. The problem to be addressed through the work of this thesis is to derive design implications. To determine this, several methods for data collection have been used, both qualitative and quantitative. First, the motivation for using a combination of several methodologies is explained through the underlying approach. Secondly, the chosen design process is presented, and the various data collection methods are described in detail. Thirdly, frameworks for prototyping and methods for evaluation are explained. Finally, the evaluation criteria used in this thesis are presented.

3.1. Underlying approach

The way that mobility is discussed and conceptualized in mobile HCI-literature is lacks consistency (Hagen, Robertson et al. 2005, p. 2). This allows certain perspectives on mobile technology use to emerge with different definitions of mobility. These perspectives, in turn, affect the selection of methods employed by researchers to understand and further investigate the domain and user experience. Relevant literature and general knowledge within this field suggest that systematic and extensive research should be done before presenting any certainties. As pointed out by the advisory board, general knowledge about users, behavior, needs and preferences cannot necessarily be transferred to the specific domain of emergency work.

Therefore, the underlying approach is to always double-check all results. In (Denzin 1970; Denzin 2006) different types of *triangulations* are presented to ensure cross-examinations of all results. The first interesting type of triangulation is *theoretical triangulation*, which involves the use of several different theoretical perspectives and/or hypotheses regarding the phenomenon of interest when analyzing the same set of data. The second type is *methodological triangulation*[10] which involves the use of multiple methods in attempt to decrease weakness and biases of each method. This would imply using different methods to gather data, such as interviews, questionnaires and observations. (Denzin 2006, p. 472; Waltz, Strickland et al. 2010, pp. 460-461).

3.2. Design process

To describe the different activities and their reciprocal relations, *lifecycle models* are frequently used (Rogers, Sharp et al. 2007, p. 444). This is necessary to understand which activities that form the design process for this thesis, and also to understand how they relate to each other. Popular alternative design processes are presented and discussed in regards of suitability for this thesis, before the selected lifecycle model is presented in detail.

3.2.1. Alternative design processes

Most lifecycle models come from other fields than HCI, such as software engineering (SE) and have less focus on the user and the user's task than usually desired in design studies. Therefore the traditional life cycles such as the sequential *waterfall model* or Boehm's *spiral model* (Boehm 1988) are unsuited for this thesis. The spiral model is similar to the waterfall model, but also incorporates risk identification, and is mostly seen in large, expensive projects such as defense projects (Boehm and Hansen 2001, p. 4). Newer agile methods of development like *Scrum* or *Extreme Programming* (*XP)* introduce several new aspects to development, such as early focus on user and continuous testing. Less documentation to begin with and rather rapid enactment of development are two other features that make these agile methods popular in SE-development.

However, in (Jacko 2007, pp. 174-175) interesting comparisons between HCI and SE are made to determine the fitness of classic and agile SE-methods in HCI-related studies. It is concluded that HCI has a high focus on UID, including ease of

[10] Methodological triangulation is often referred to as *multi method triangulation* or *mixed-method triangulation* (Waltz, Strickland et al. 2010, pp. 460-461).

use, ease of learning, user performance, user satisfaction and aesthetics. On the other hand, methods from SE focus on how to translate functional requirements to running systems. Therefore, the lifecycle models should be shaped on the basis of UID rather than functional requirements.

Three lifecycle models are presented in (Rogers, Sharp et al. 2007, pp. 458-463). The first model is the *star lifecycle model* which focuses on unordered activities star-shaped around evaluation which is the central activity (Hartson and Hix 1989, p. 484; Qureshi and Durrani 2010, p. 2). Because this model demands each finished activity to be evaluated, it limits the degree of freedom. Also, if the approach for this thesis was to evaluate an existing solution first, this lifecycle model would have been much better suited.

The second model presented is the *usability engineering lifecycle model*. This model is a detailed three-leveled lifecycle that include (1) requirements analysis, (2) design, testing and development, and (3) installation. This model is both highly complex and structured, and is often deemed too complicated for some development projects. While the author behind this model suggests that some steps may be skipped if unneeded, it is considered to be unfit for this thesis in general. Thus, while both these are in the same category of lifecycle models as the lifecycle model used in this thesis, *ISO13407*, they both had limitations and weaknesses that worked in their disfavor.

3.2.2. ISO 13407

The third lifecycle model presented in (Rogers, Sharp et al. 2007) is *ISO 13407 Human-centered design processes for interactive systems*[11]. This is an ISO-standardized guidance on human-centered design activities. Since this model provides guidance on how to design usability, it is often used in combination with ISO9241-11, which gives the necessary definitions of usability (Jokela, Iivari et al. 2003, p. 53). This is an open model as it does not cover specific design approaches. However, it identifies four key principals that are described by Rogers, Sharp et al. (ISO 1999, p. 6; Rogers, Sharp et al. 2007, pp. 462-463):

1. *Active involvement of users and clear understanding of users and task requirements.* To ensure that provided information is reliable, the standard claims interaction from the user. Also, as the level of interaction between

[11] Since the startup of this project, ISO13407 has been withdrawn by ISO, and been superseded by *ISO 9241-210:2010 "Ergonomics of human-system interaction - Part 210: Human-centered design for interactive systems"*. It would however not have affected the fundamentals of the design process; therefore this is not discussed any further in this thesis.

user and developer increases the effectiveness of the involvement increases as well.

2. *An appropriate allocation of functions between users and technology.* This decision should be based on more than just the technological constraints. Reliability, flexibility of response, and user well-being are mentioned factors that should decide the relative competence of technology and humans. This should be one of the factors deciding the appropriate allocation.

3. *The iteration of design solutions.*

4. *Multi-disciplinary design.* A wide range of potential users should be included in the team. However, one member of the team can assume different roles.

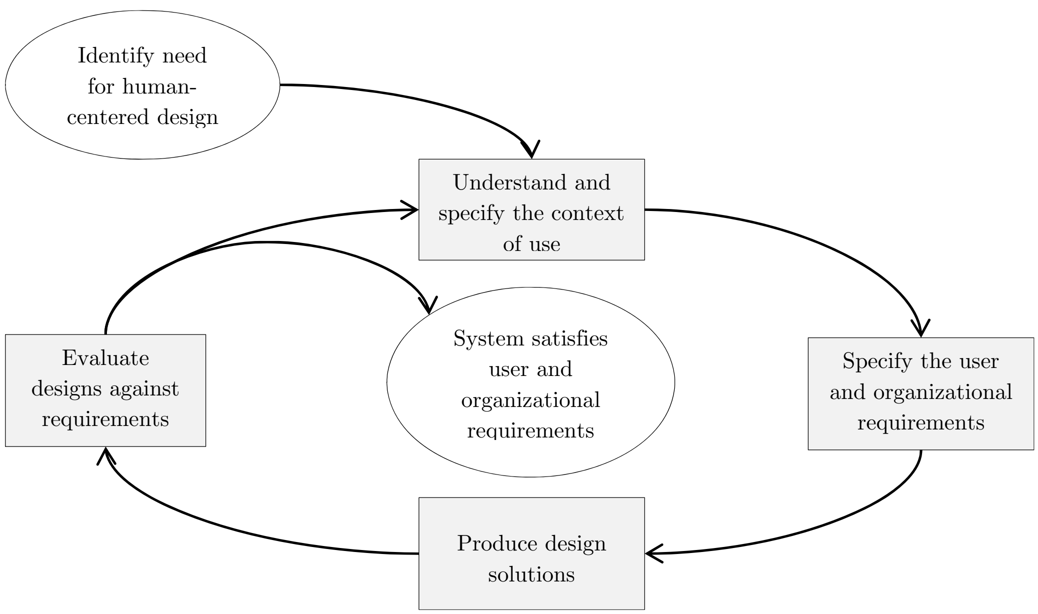


Figure 3.2-1: ISO 13407 lifecycle model

Figure 3.2-1, which is adapted from (Rogers, Sharp et al. 2007, p. 463), represents the lifecycle model as seen in the standardization. The first and uppermost activity marks the start of the lifecycle and indicates a planning phase, while the central activity is a finished system that meets the requirements of the user and organization. Besides this the model consists of four main human-centered design activities presented by Rogers, Sharp et al. (2007):

1. Understanding and specifying the context of use.

2. Specifying the user and organizational requirements.
3. Producing a design solution.
4. Evaluating design against requirements.

The focus in this lifecycle model is in line with the focus of this thesis, and can therefore be considered well-suited as design process. It is also very similar to the wok that has been carried out in the EMERGENCY-project previous to this thesis. Figure 3.2-1 defines the outline for the main part of this thesis. The structure of this thesis reflects this design process. First, requirements from the use context, user and organization, and task are described. Secondly, possible solutions and the prototype are presented. Finally, the evaluation, results and design implications are put forward.

3.3. Data collection

In this section, applied methods for data collection are presented. As a part of methodological triangulation, different methods have been used. The selections of methods for data collection were mostly based on situation suitability, and sometimes on previous experience with research method in relevant literature or in the EMERGENCY-project.

3.3.1. Questionnaire

As suggested by Rogers, Sharp et al. (2007), questionnaires can be used in combination with other methods to clarify or deepen the understanding of a problem area. To collect information about the indented user group, which is workers in emergency situations, a questionnaire with 20 questions was used in the case study prior to this thesis (presented in Section 2.3). Questionnaires can include both *open* and *closed* questions, but in this case the questionnaire represented a structured interview with exclusively closed questions. The obvious advantages of data collection through questionnaires include fast and cheap setup, easy analyzing, lesser chance of misunderstandings, and same response format. Since this data collection method is inexpensive, it usually involves a high number of respondents. This makes the cost per respondent low as well. In addition, simplicity and equivalence across studies is also mentioned in relevant literature as another benefit (Goodman 1997, p. 584). An evident weakness with this method is the respondent's limitations. Questionnaires seek answers just by asking questions, thus the structured format with predefined questions and a range of answer have already decided on the possible outcomes. The element of discovery is much reduced, and no information is given about why the selected answer was given. More importantly, what answer you would have gotten if the respondent could answer more freely (Gillham 2000, p. 2).

3.3.2. Interview

To verify and update the information gathered so far on incident commanders' characteristics and their tasks during emergency incidents, an interview was held with an operational commander and an incident commander. Interviews are often divided into categories based on the degree of control the interviewer has over the interview process. On one hand, the exploratory open-ended or *unstructured interviews* function very much like a regular conversation around a particular topic. Questions are shaped to be *open*, i.e. allowing the interviewee to answer freely and fully, and also allows the interviewee to take the lead and steer the interview (Sommer and Sommer 1992, p. 108; Rogers, Sharp et al. 2007, p. 298). Since the questions are not predetermined, unstructured interviews allows the interviewer to improvise, thereby being more independent and thereby gathering the most important and relevant information. This method typically generates large amounts of data. However, it is unstructured and often requires time to analyze and structure afterwards.

On the other hand, *structured interviews* use predefined questions that are formulated and structured beforehand. Since this technique is mostly used with interviews on larger amounts of people, the structured format and predetermined questions allows the interviewer to obtain consistency from one situation to the next (Sommer and Sommer 1992, p. 109). As this is often used in surveys or opinion polls they usually come with a set of possible answers (i.e. *closed questions*), thus limiting the freedom of the interviewee (Rogers, Sharp et al. 2007, p. 299). It also requires the interviewer to know exactly what he wants answered beforehand. Nevertheless, the most common method is to use a combination of these to ends of the spectrum, and rather go with a *semi-structured interview* which allows the use of features from both structured and unstructured interviews.

The interview conducted with the operational commander and incident commander was an unstructured interview. Although several questions were written down beforehand and a phone with prototype brought along, it was the interviewee that took the lead. Due to the open nature of the interview, the interview also withered into stories that were told as directed storytelling. *Directed storytelling* is the method were a subject is asked to tell a story about a time where they interacted or performed an action with a product or service (Saffer 2006, p. 87). The interviewees were asked to sign the interview agreement (Appendix G) before the interview began. The results from this interview have been combined with other information when presenting the user, user context and task. The interview in its entirety is presented in Appendix B.

3.3.3. Observations and note taking

Studies are often moved out from laboratory settings and to the field. To collect data from a social or cultural context, researchers often spend significant time in the field (Chittaro 2003, p. 319). Most observational data in the EMERGENCY-project prior to this thesis was collected during the TYR-exercise in 2009. The *TYR-exercise* is the annual crisis management exercise of the police. Hundreds of participants from over 30 agencies and companies partook in the exercise (Politidirektoratet 2009).

During the TYR-exercise in 2009, both shadowing and "fly on the wall" was used by the thesis supervisor, and other participants in the EMERGENCY-project, as observation methods to collect data about incident commanders. *Shadowing* is a term described as following the subjects through their normal routines, and often includes recording of what is done and said. *Fly on the wall* is a more indirectly method, where one goes to a location and unobtrusively observe (Saffer 2006, p. 86). The former method is coined as a first degree involvement, i.e. where the observer is directly involved, while the latter is categorized as second degree, where the observer is only indirectly involved (Lethbridge, Sim et al. 2005, p. 313). These methods also included note taking. This is to ensure that personal thoughts and reflections, that the recorder, photos and interviews could not include, are documented as well. The obvious advantage of such data collection methods is that they generate large amounts of rich and grounded data in relatively short time, while the major disadvantages are unknown biases, and no indication about how representative the data is (Kjeldskov and Graham 2003, p. 319). Images and documents from this exercise and other field studies were also studied to strengthen the domain knowledge for this thesis. That would qualify as third degree, i.e. studies of work artifacts only (Lethbridge, Sim et al. 2005, p. 313).

3.3.4. Informal methods of data gathering

The EMERGENCY-project involves several different partners from different emergency agencies and companies. This generates a high numbers of potential stakeholder groups wanting to have a say in the design progress. These stakeholders are distributed all over the country making meetings and gathering difficult.

While some of these gatherings have been field studies, interviews and evaluations, i.e. methods that would automatically facilitate a formal and structured process with easy documentation possibilities, other gatherings are more open and unpredictable. An example of the latter is the annual presentation to the advisory board (as presented in Section 2.3) where work done in the EMERGENCY-project is presented and discussed. Other situations also occurred where proper interviews or other data gathering methods were not or could not be prepared. Still, most of these informal gatherings with different types of stakeholders, domain experts and usability experts yielded vital answers and feedback on the work done in this thesis.

3.4. Prototyping framework

As presented in section 3.2.2, the design process requires in-detail information about user, task and context before the development can begin. Section 1.1 points to several studies that recommends severe research about these factors before embarking upon the design. Most development that projects suffer from only partial success in functionality and user acceptance, tend to have a lack of understanding of the actual work done by the users (Norros, Hutton et al. 2009).

Other reasons seem to be too sporadic involvement of the end-user when designing the interface. Because of these potential problems, a proper framework should be used when developing such task-specific mobile solutions.

Way (2009) presents a framework based on theories of *task-technology fit* (Goodhue and Thompson 1995, p. 220). The framework suggests first delving a little deeper into tasks and challenges of incident commanders, before mobile technology is evaluated to deduce an ideal mobile technological solution. The idea behind the framework in Figure 3.4-1 is to set up various criteria and weigh these according to the priorities of emergency responders. Then, technological possibilities should be evaluated by professionals to find the best fit after incorporating the criteria (Way 2009, p. 40).

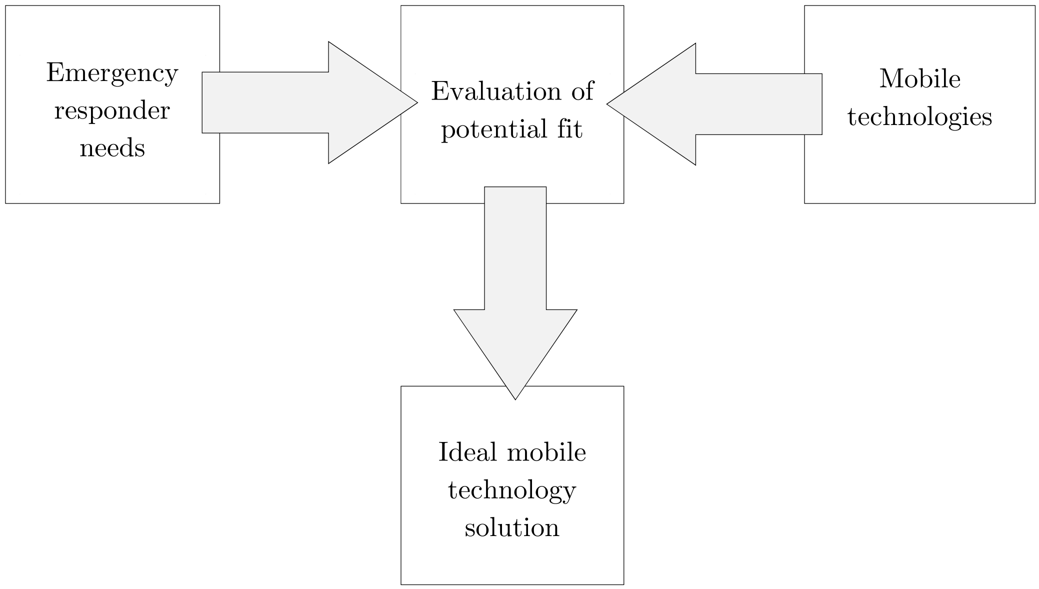


Figure 3.4-1: Framework for evaluating technologies for crisis response

Prototyping methods are explained in Chapter 9. The two main principles followed when prototyping is the *economic principle of prototyping* and *timeboxing*. The former is presented further in Section 9.1, while the latter is introduced in Section 9.1 and described in detail in Appendix A.

3.5. Evaluation methods

Two main evaluations have been conducted on the prototype, respectively usability testing and two group-based expert walkthrough. The two evaluations were held during different stages of the development. This section gives a brief introduction of the methods, and then more detailed descriptions and procedures of each method are explained further in Chapter 12.

3.5.1. Usability testing

> *"The designer can quickly see many subjects in a single day, one after the other, without having to change location, and there is only one setup."*
>
> *(Saffer 2006, p. 183)*

Usability testing is a general technique that evaluates a product or service by testing on users. Conventional usability testing is mostly conducted in laboratorial settings (Duh, Tan et al. 2006, p. 181). This approach was used in the earliest phases of the development to get feedback on the prototype functionality, more precisely the map principles. This also allowed us to test in laboratorial settings rather than in the subjects' own environment. It also gave a major advantage: efficiency. Using a controlled environment in combination with pre-planned tasks, a usability test can be rapidly repeated and measured. This early testing gave valuable feedback that allowed wrong implications to be corrected. It also allowed us to incorporate modifications of all misconceptions in rest of the development process. The full definition of usability testing and procedure used in this thesis are explained in detail in Section 12.1.

3.5.2. Group-based expert walkthrough

The *pluralistic walkthrough*[12] gathers developers, users and usability expert in a discussion after stepping through all steps of a task-based scenario (Nielsen 1994, p. 413). It is recognized as an *usability investigation method (UIM)* actively used for assessing usability (Hollingsed and Novick 2007, p. 251).

The main evaluation method for this thesis is a *group-based expert walkthrough*, an evaluation method developed by Asbjørn Følstad, research scientist at SINTEF. The method is based on various UIMs: cognitive walkthrough, cognitive jogthrough, and in particular pluralistic walkthrough (Følstad 2007a, p. 58). It also bears some resemblance to the participatory heuristic evaluation (PHE) which is a participatory extension of Jakob Nielsen's heuristic evaluation (Muller, Matheson et al. 1998, p. 13).

The group-based expert walkthrough is an UIM mainly developed to allow non-usability experts to participate as evaluators (Følstad 2008, p. 467). By allowing work-domain expert to take the place as evaluators, the group-based expert walkthrough shares their context knowledge. As pointed out by Følstad (2007a) the method is particularly suited for applications being developed for a specific work domain in an early stage, hence it is highly suitable for the prototype and problem areas of this thesis. Also, it was previously successfully utilized in the EMERGENCY-project during the evaluation of the DISKO-system (Nilsson and Brændland 2009, p. 3).

Experience gathered through empirical investigation suggests that domain experts can have far higher impact on the subsequent development processes than usability-experts when identifying problems and possible improvements (Følstad

[12] Pluralistic walkthrough is also known as *storyboarding* or *table-topping.*

2007a, p. 58). Similar to the pluralistic walkthrough this evaluation is structured according to task-scenarios, but does not utilize guidelines. Another similarity to the pluralistic walkthrough is that the UI is presented by a moderator.

A typical evaluation will be structured as a stepwise presentation of tasks where evaluators take individual notes for each step. Their notes should include what they expect the next step or action to be, along with evaluation of usability issues. The right answer is then presented, but the discussion is retained until all steps are complete. A plenary discussion after completion of all steps allows evaluators to share their thoughts on completing task-scenarios with the UI. When the evaluators have presented their ideas, the developer may also join the discussion. Hence, this UIM allows the developer to partake in the discussion without affecting the evaluation as the evaluators have already stated their opinions on usability issues. As suggested in the method description, the developer should participate in the discussion, but not prior to the plenary evaluator discussion (Følstad 2007a, p. 59). Since discussion is discouraged in this UIM, alternatives could include pluralistic walkthrough or cognitive walkthrough as suggested by Følstad (2008). The pluralistic walkthrough relies heavily on group discussions, thus represents the opposite encouragement than intended in Følstad's method. The cognitive walkthrough allows for something in between.

3.6. Evaluation criteria

During evaluation of prototypes, a list of evaluation criteria is often created against which success is measured. Since usability is a challenging unit of measure itself, the ISO 9241-11 gives us guidance on how usability can be evaluated through three aspects of usability.

3.6.1. ISO 9241-11: Aspects of usability

In accordance to the guidance on usability given in ISO 9241-11 (ISO 1998, p. 2) the three main aspects of usability are effectiveness, efficiency and satisfaction (Bevan 1995, p. 350; Frøkjær, Hertzum et al. 2000, p. 1; Jokela, Iivari et al. 2003, p. 53; Sauro and Kindlund 2005, p. 401; Meng, Zipf et al. 2008, p. 5). *Effectiveness* is understood as the user's accuracy and completeness when achieving specified goals, and is usually measured with error rate and quality of solution. *Efficiency* is defined as the relation between (1) the accuracy and completeness with which the user achieve a specified goal, and (2) the resource expended in achieving them (Frøkjær, Hertzum et al. 2000, p. 1). Learning time and task completion time are the most relevant indicators. Satisfaction is defined by the ISO 9241-11 as freedom from discomfort and positive attitude towards the use of the system. The usability framework adapted from ISO9241-11 incorporates these aspects as illustrated in Figure 3.6-1. These particular aspects can also be regarded as indicators on quality of use. *Quality of use* is defined as the result of interaction between user and product or service, while a specific task is being performed in a technical, physical, social and organizational environment (Bevan 1995, p. 5). The relation between context of use and quality of use is illustrated in Figure 3.6-2 which is adapted from Bevan (1995).

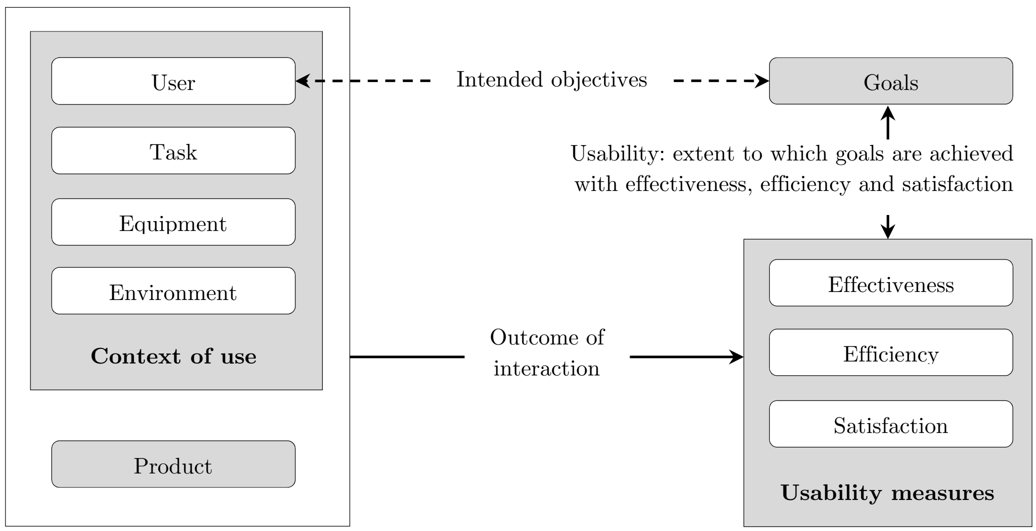


Figure 3.6-1: ISO9241-11 - Usability framework

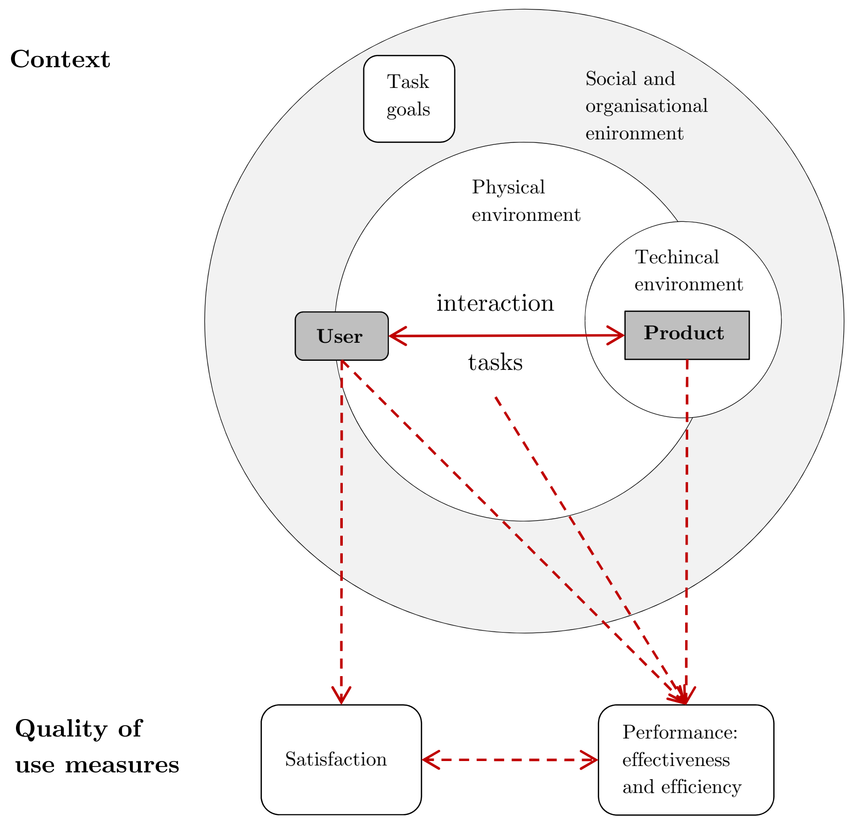


Figure 3.6-2: Quality of use measures determined by the context of use

3.6.2. Criteria scope

The essential criteria to mobile device UID can be broken down to two groups: product related criteria and user related criteria (Işıklar and Büyüközkan 2007, p. 268). *Product related criteria* can be further divided into three sub-criteria: basic requirements (price, standard parts used, standard process applied), physical characteristic (weight, dimension, shape, water resistance, solidity, attractiveness etc.), and technical features (talk time, standby time, international roaming, safety standards). Since the indented mobile device for the prototype of this thesis is a regular smartphone, the product definitions are mostly given. Thus, the product related criteria are more relevant when studying the device in addition to the design and UI. Also, it is more interesting when studying a consumer product rather than a general solution for a specific user group where the selection of device will be limited.

User related criteria may also be further divided into sub-criteria; including functionality, brand choice and user excitement (Işıklar and Büyüközkan 2007, p.

268). Brand choice is given for the prototype of this thesis, and user excitement is described by Işıklar and Büyüközkan (2007) as entertainment (e.g. games, ringing tones) rather than satisfaction with usage. The interesting sub-criteria in this division are therefore related to functionality. The criteria f*unctionality* can be understood as what the system is capable of doing, while *efficiency* in the same context can be defined as how well the system supports those tasks, or how much work is required to achieve the same outcome (Harrower and Sheesley 2005, p. 5). Hence the indicators on success will be based on the three aspects of usability, i.e. effectiveness, efficiency and satisfaction, along with functionality.

3.6.3. Criteria as guidelines

During the first evaluation, two success criteria were set up to measure effectiveness and efficiency. The former was evaluated by looking at the error rate, and the latter with total completion time. This was possible since a specific map function was being evaluated, thus it was suited for time taking and error counting.

However, the main function of the evaluation criteria was to serve as design guidelines until a proper evaluation of the prototype was conducted. Along with theories on usability, the indicators on success laid the foundation for the prototype until a second evaluation could be conducted. The process can be illustrated with Figure 3.6-3 which is the quality plan presented in (ISO 1998, p. 8).

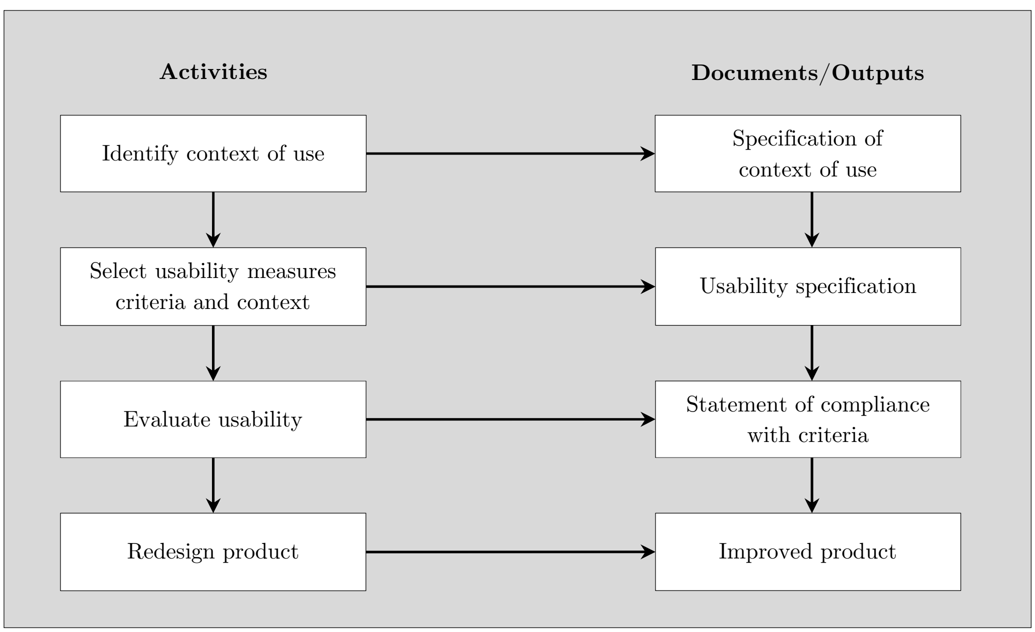


Figure 3.6-3: ISO 9241-11 - Quality plan

3.6.4. Indicators on success

While some evaluations can be done analytical, there is still a need for indicators on success (Way 2009, p. 40). This section defines the different indicators that were used to guide the design in the earlier phase, and then later used to lay the foundation for the second evaluation. The indicators on success can be divided into *overall success indicators* and *detailed success indicators*. The overall indicators were: *(1) Increase in value during task handling*, and *(2) non-intrusive ICT-support*. These were difficult to measure directly, therefore a list of detailed success indicators were created. This allowed more accurate guidance of the design, and easier evaluation of the weaknesses and strengths of the design. Some of these derive directly from data collected in the EMERGENCY-project, while others are based on (Rogers, Sharp et al. 2007, pp. 686-687).

Table 3.6-1: Detailed success indicator

Indicator	**Description**	**Aspect**
Visibility of system status	The user should always have a proper overview of the system status via appropriate feedback within reasonable time.	Effectiveness
Consistency and standards	The user should never be confused or insecure about the meaning of words, symbols or actions.	Efficiency
Error preventions	Via confirmation dialogues, input restraints and validation the system should prevent the user from making mistakes.	Effectiveness Efficiency
Recognition rather than recall	The memory load should be minimized by making information and instructions so intuitive that the user does not have to remember information between dialogues and views.	Effectiveness Efficiency
User control and freedom	To ensure a non-intrusive behavior, the user must be given possibilities to undo actions and not be irritated when handling tasks.	Effectiveness Satisfaction

3.6.5. Alternative criteria

Several papers explore and question the validity of only using the three aspects of effectiveness, efficiency and satisfaction to evaluate success, amongst them (Bevan 1995; Frøkjær, Hertzum et al. 2000; Nielsen 2003). During the case study which was briefly presented in Section 2.3, another set of quality components were used to determine the usability of UIs. These were presented by Nielsen (2003), who recommends a set of five quality components to investigate the usability:

1. *Learnability* – to what degree the user finds it's easy to solve a task the first time the interface is encountered.
2. *Efficiency* – how fast tasks can be solved once the design is familiar.
3. *Memorability* – the time it takes to reestablish proficiency when returning to the design after absence.
4. *Errors* – error count, severity and recover options.
5. *Satisfaction* – the user's perception of the design.

While these were initially developed as heuristics for evaluating usability on web, the principles have been popular amongst usability experts the last years. It was used with success during the case study where technology acceptance was evaluated, yet it was not reused in this thesis. An important reason for this was the fact that these five attributes may conflict when measuring usability. For example, learnability and efficiency normally have negative influence on each other. Therefore the usability cannot be measured as a sum of these principles; it is necessary to measure the values for each attribute individually (Ferré, Juristo et al. 2001, p. 23).

Nonetheless, the main reason for not using these criteria is the intended function of evaluation criteria in this thesis. As mentioned in previous section, the criteria have functioned as design guidelines for most of the timeline of this thesis. It was only during the analysis of the second evaluation these criteria were used to indicate success. Normally, a list of criteria is created and used as a checklist to measure success after a prototype has been developed. Since it functioned as design guideline in this thesis, it was not deemed necessary to include the additional quality components presented by Nielsen (2003).

3.7. Ethics and laws

The research methods of this thesis include both evaluations and interviews which involves gathering, processing and storing of data and sound-recordings from evaluators, testers and interviewees. The Data Protection Directive is carried out in

Norwegian law through the Regulations on the processing of personal data (Personal data regulations). The directive requires research projects to report to the Norwegian Social Science Data Services in cases where (1) processing of personal data is carried out wholly or partially by electronic equipment, or (2) manual registers of persons containing information are made (NSD 2011). The 2nd, 8th, 9th and 11th paragraph requires researcher to only collect necessary and relevant data from participants. The project should be presented, and the indented purpose of the data collection should be explained, before getting the consent of the participants. In accordance to these directives, all participants involved in this project were asked to read the informed consent form (Appendix G), and agree to participate before continuing. No sensitive data about the participants was collected, and all data was kept confidential.

Chapter 4

Emergency response situations

> *"In the field of emergency management there are natural metaphors that suggest a very specific, consistent, and unique approach to interfaces."*
>
> *(Carver and Turoff 2007, p. 34)*

To understand the user and the user tasks, it is vital to recognize the user context as well. For incident commanders the relevant context is emergency situations. In ISO 9241-11:1998, definition 3.5, the definition of context of use is given as *"users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a product is used"*. Users, tasks and equipment are described in the next chapters, but the physical and social environment is presented in this chapter.

Mobile computer systems are closely related to the physical location of the user along with the objects in the user's immediate surroundings (Kjeldskov, Graham et al. 2005, p. 51). Therefore the typical phases and characteristics of an emergency situation should be taken into account when exploring design solutions. First the different phases are explained, and then the characteristics are presented. Lastly, different bounds and the local CP are illustrated.

4.1. The process of emergency response

> *"Extraordinary events can generally be divided into the same phases, regardless of type and event."*
>
> *(Politidirektoratet 2007, p. 23)*

Emergency responses are often complicated and involve a high number of people from different emergency agencies. Therefore, different stages of the emergency response are defined. This is done to easier divide the complexity of the situation into more manageable parts. The different phases are given names, and often also a time range or time limit to ensure progress.

4.1.1. Phases of emergency response

Experience from TYR-exercises indicates that the fire brigade usually arrives at a scene of incident first. This is expected as fire stations are situated more distributed while the police stations are more centralized. In an early stage, there is often only a small amount of medical response available at the scene of incident, and they have to prioritize life-saving first aid (Vigerust, Andersen et al. 2009, p. 23). While all emergency agencies have their own areas of responsibility, the different phases in the emergency response are similar. In their guidelines for stand-by systems, the police have defined three main phases of an extraordinary event. Since these are defined in Norwegian, the original names have been included. The Norwegian translations of these phases are found in Appendix H.

1. *Preparatory phase*. This is an initial phase where general emergency preparedness is drilled through training, planning, exercises etc. The goal is to be as prepared as possible for extraordinary events. In cases of acute events this phase may be partially or completely dropped.

2. *Execution phase*. This is the main phase and may be divided into three phases:

    a. *Announcement phase*
    b. *Action phase*
    c. *Stepping-down phase*

3. *Supplementary phase*. Through supplementary work and follow-ups, this phase aims at bringing the situation back to a normal state. Investigations might be independent from this phase, but are often carried out as a direct part of this phase. Other governmental institutions and establishments might also effectuate investigations in search of causal connection.

Figure 4.1-1, which is adapted from (Politidirektoratet 2007, pp. 23-24), illustrates the relation between time and effort for the six phases mentioned:

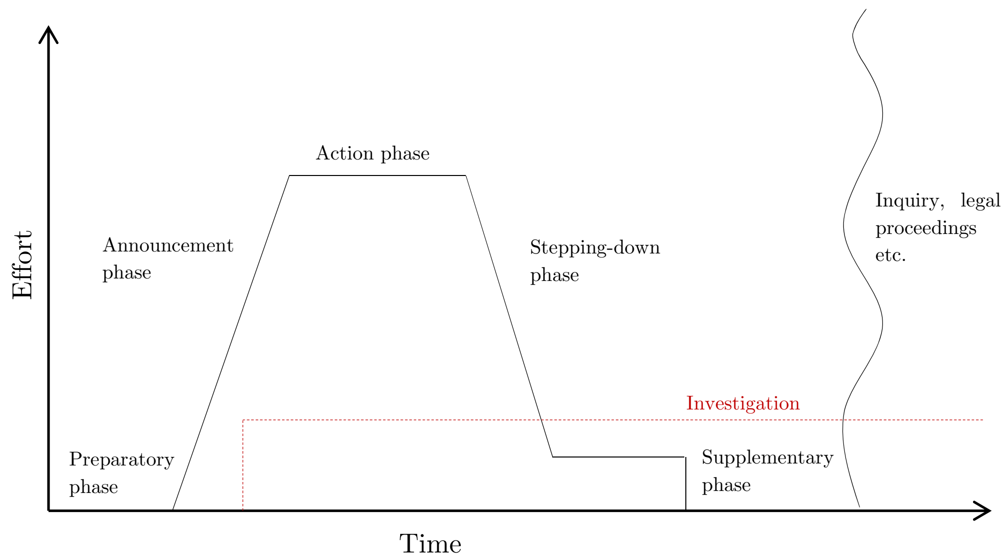


Figure 4.1-1: Phases of emergency response

4.1.2. Contradicting definitions

While the mentioned phases are presented in the official guidelines for the police, and therefore deemed the most reliable and relevant source, there are some contradicting descriptions of these phases. American research within a similar topic points *preparedness*, *training*, *mitigation*, *detection*, *response* and *recovery/normalization* as the six phases in emergency response (Burstein, Holsapple et al. 2008, p. 41). As they use major events such as the World Trade Center-attack, the Hurricane Katrina and the Chernobyl nuclear disaster in relation to these phases, it might explain their focus on the preliminary phases. The preparedness phase is additionally divided into analysis, planning and evaluation. This division might further suggest a more serious situation than indented in this thesis. This division is therefore more applicable to larger-scale disasters.

In (Vigerust, Andersen et al. 2009, p. 25) the three main phases listed above has been cited from the same source as four phases: *announcement phase, management phase, investigation phase* and *supplementary phase.* Although presented primarily for medical response, their presentation of a six-phase emergency response should be brought up to extract important situational characteristics that are common regardless of emergency agency. Vigerust, Andersen et al. (2009) present two additional phases that are not directly separated as individual phases in the police's guidelines. One of these extra phases is presented in the next section: the chaotic phase.

It is also necessary to point out that while there are defined phases for the whole operation, different personnel might have their own defined phases that are better suited for their most important tasks and needs. The higher up one is on the chain of command, the better overview of the situation is required. Similarly, the lower you are on the chain of command, the more likely is it that you are only interested in one or a few phases. An example from this can be the incident commander interviewed during our meeting with the Police (**Error! Reference source not found.**). The incident commander presented four phases that were more relevant to his work: *alarming phase, travel phase, arrival phase* and *effort phase*.

4.1.3. The chaotic phase

While the presented phases follow a strict and chronological sequence, the *chaotic phase* breaks this timeline and may occur at any given time during an emergency response. It is further complicated as it may affect different persons at different time. Based on emergency agency, geographic location in regards to the scene of incident, job description, external conditions etc. this phase may hit different people or groups of people at different stages during the emergency response. This is also individually dependent, i.e. for someone it might be a chaotic phase during a traffic accident, while others are trained and experienced, thus requires more catastrophic situations to categorize the situation as chaotic. It is important to include this phase as it affects the situation characteristics that are presented in the next section.

4.2. Situation characteristics

There are two concepts that professionals use in the planning, training, response and evaluations of emergencies. These concepts are *events* and *roles*.

> *"Events are triggered by outside occurrences or by a set of roles that are responsible to react to a specific type event (for example, reports of injuries) with appropriate counter events (such as sending an ambulance)."*
>
> *(Carver and Turoff 2007, p. 34)*

The highly event-driven development of emergencies makes the situation unpredictable and highly impulsive, and lays most of the foundation for the characteristics of emergency situations. Different roles are further presented in the user description in Chapter 5.

4.2.1. Characteristics of emergency situations

> *"Emergency situations are situations we are not familiar with – nor likely to be familiar with – and by their mere happening create acute feelings of stress, anxiety, and uncertainty."*
>
> *(Burstein, Holsapple et al. 2008, p. 39)*

Emergency responses are characterized by a high level of uncertainty. They generally *come surprisingly* and the situation *develops fasts. This* makes it hard to plan and prepare properly. There is often a *lack of control* or *lack of overview,* which can make the situational understanding ambiguous or vague. These two characteristics are also related to two other problems: *missing information* and *contradicting information.* Not all information is usually available, and when information is gathered from different sources by various actors, some information might be misunderstood. This could be either the source apprehending the situation incorrectly, or by the actor misunderstanding the conversation with the source. *Lives at risk* or *environmental hazards* usually also present a threat. This puts time pressure on the situation, and often also leads to sacrifice of human lives and/or environmental damage.

High insecurity on the *scope or direction* of the crisis is also a main characteristic of emergency situations. How long a crisis will last, or how it will spread, is always a present uncertainty. As emergency situations always affect some people, there is usually a huge *interest from outsiders* such as the media. This of course is a disturbing factor which combined with *time pressures* complicates the situation. Other challenges include *numerous actors* and *breakdown of standard decision making processes*. (DSB, Kystverket et al. 2010, pp. 4-5). For these reasons emergency situations demand fast and reliable action (Nilsson and Stølen 2010, pp. 1-2). Important information is spread over a wide range of public and private actors. As mentioned previously, there are few others present at the scene of incident when the police arrive. Therefore, little information have been centralized and sorted. It is up to the incident commander to get an overview of the situation.

Additionally, the incident commander will often move around a rather large geographical area in order to keep situational overview. However, this depends on both the size and expected duration of the operation. Since this generates variations in use context, it implicates that switching between different equipment and devices is necessary for the incident commander to keep a proper overview (Nilsson and Stølen 2010, p. 8). In mobile situations, the user's attention is not always fully focused on the device interaction, but divided between the service and other activities such as talking, moving or meeting people (Jokinen 2008, p. 183).

It is also pointed out that mobile supportive applications should be tailored to support, yet not intrude the user in accomplishing their other tasks. To achieve this, context awareness is an important requirement. This point is also brought up in studies of state of the art map-based mobile services (Meng, Zipf et al. 2008, p. 4), where the results support the idea of applications being a personalized and non-intrusive rendered service. Key situational characteristics include stress, tunnel vision and missing overview. If the preparing has been inadequate, the situation context might also cause low level of productivity and constructivism due to physiological factors, e.g. feelings of unreality (Vigerust, Andersen et al. 2009, p. 25).

There are also indications of people reacting with an overcharged level of activity, while others might enter a more apathetic state. It is certain that regardless of which factors that affect the users, they are not functioning in an optimal way. Since emergency response is often carried out outdoors, the physical environment might constraint the user context as well. Background noises and bad illuminations are two examples mentioned by (Jokinen 2008, p. 183), but weather conditions apply as well. If the weather is too cold for the finger sensors to fully function or the rain is too heavy for the device to function, the user is forced to move inside (e.g. in a car or tent) or to another partially enclosed location. If the weather conditions are too bad, it could reduce or even block the communications channels such as the mobile network or GPS-signals. The physical environment can affect, or even change, the user context and thereby disturb or complicate the interaction. Thus, the uncertainties put forward by the physical environment should also be regarded as characteristics of emergency situations.

4.2.2. Challenges in emergency situations

In (DSB, Kystverket et al. 2010) several challenges and relevant problems are presented throughout the document. While not all challenges are relevant for an incident commander, most of these are related. Thus, an incident commander often relies on other people handling their responsibilities properly in order to carry out own tasks as desired. Based on the lists in (DSB, Kystverket et al. 2010, p. 5), these are the related key challenges that might either fall under the direct responsibilities of the incident commander, or affect the incident commander's work:

- Development potential of the situation
- Different actors' responsibility, authority, certification and task delegation

- Overview of relevant actors that may be of assistance
- Routines for logging
- Ensuring that internal and external information needs are covered
- Handling the media
- System for regularly meet-ups
- Updated and mutual situation overview

Personnel-related needs:

- Need for personnel
- Competence required
- Number of personnel that should be called or given prior notice
- System that should be used for calling out personnel
- Fastest way to get an overview of available personnel
- Ensuring personnel's safety
- System for shifting personnel, ensure endurance over time
- Ensure provision and bivouac for personnel

Equipment-related needs:

- Need for equipment
- Requested equipment should always be available
- System for transporting equipment to scene of incident
- System for continuous supply

As mentioned, these are general challenges and lay the foundation for many of the incident commanders' tasks. The specific tasks of the incident commander are further presented in Chapter 6.

4.3. Defining bounds

As mentioned, the fire brigade usually arrives earlier than the police to the scene of incident. The fire brigade usually handles short-lived events within a limited geographic area (DSB, Kystverket et al. 2010, p. 4). They are therefore normally unaware of the situation scope other than what directly concerns their first priorities. The same applies to medical response. They are mostly occupied with handling life-threating situations, and do not have time to explore all impacts of the situation. However, someone must map out the geographical area that is affected by the event. This responsibility often falls on the incident commander who is responsible at tactical level.

4.3.1. Levels of interest

Emergency events often spring out from a specific geographical location. To define bounds, the incident commander scope out different levels of interest, and then defines the bounds accordingly. It is important to point out that this is more of a mental model for the incident commander rather than something officially written down and used by everybody as geographical references. While an incident commander might use this frequently and consistently, other levels of leadership might not be aware of these bounds. Levels of leadership are presented in the next chapter.

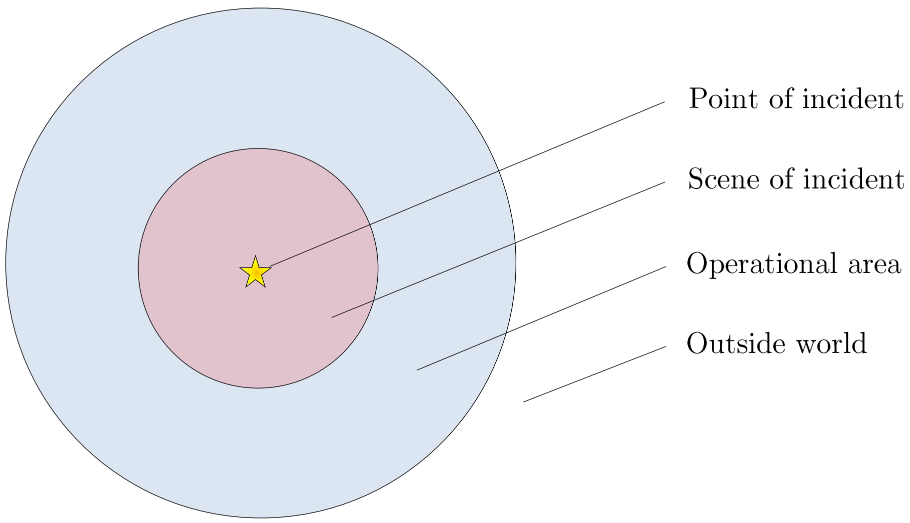


Figure 4.3-1: Levels of interest

As illustrated in Figure 4.3-1, it is natural to consider three levels of interest for the incident commander. The first is the critical *point of incident* where the accident happened. This point, which in some rare occasions may be an area, is usually automatically defined as it often confines to a limited geographical area. While this is not necessarily the most active place, or the most critical point within the area of effect in regards to resource allocations, it is the point around which the border is drawn. With this point in mind, a first level is drawn around the point of accident to indicate the geographical area within which the incident commander's main focus will lie. This is referred to as the scene of incident. The *scene of incident* is the first zone wrapped around the point of incident, and is an inner barrier within which the incident commander has a full overview of the situation and resources (Appendix B). This zone is referred to as the critical zone.

Outside this, the *operational area* is drawn. Within this area the remaining emergency response that is not active at the scene of incident typically operates. While the incident commander has no direct overview of these resources, he is aware of the available resources within this area.

The *outside world* is defined as everything outside the second circle. The border between the area of effect and the outside world is therefore the last barrier between the public and the emergency situations. Personnel that operate at this level often have clear responsibilities and job instructions that are not directly relevant to the incident commander. This could be preventing new people from entering the emergency scene, or patrolling an area. Hence, these personnel rarely report to the incident commander. But they may utilize or request different resources that might be valuable to the incident commander; therefore they cannot be ignored completely.

4.3.2. Circular bounds

A common way to illustrate geographical map coverage is by the use of circles. Especially in situations where the midpoint is used as a base for defining the circumference (e.g. wireless networks), a circular shape is frequently seen (Siqueira, Ruiz et al. 2007, pp. 21-22). Since the interviewed incident commander in (Appendix B) also defined these levels of interest as circular areas, they have been kept in the same shape. This also illustrates the fact that the different areas are defined around the basis of a point of incident.

However, gathered domain knowledge in the evaluation of Red Cross' DISKO-system (Nilsson and Brændland 2009, pp. 7-8) exemplifies how these areas are not always circular, but rather shaped as a freehand polygon around a point of incident. Photos taken during field studies of the TYR-exercise in 2009 also indicate the same pattern, where maps of the area are filled with bounds of different shapes. The interesting point here is not how the different areas are shaped, but rather what each area indicates, and how they relate to the incident commander and his tasks.

4.4. Local control post

During emergency situations, operations are usually led from a *local control post (CP)*. The local CP is situated close to the scene of the incident, usually outdoors or in a car, caravan, tent etc. (Nilsson 2010a, pp. 17-18; Nilsson and Stølen 2010). Figure 4.4-1, which is adapter from (Nilsson 2010a, p. 3), illustrates how various sources and local CP are positioned within and outside an operational area. Based on a combination of the situation's duration and size, the persons in the CP also move around more or less frequently. In addition to leaders at tactical level, support personnel are typically also present at the local CP. Nilsson (2010) points out that the characteristics of a local CP and the responsible leaders make portable computers and/or mobile devices suitable for ICT-equipment.

Task performed at the local CP require high attention, and large amount of information is considered. Typical requirements include proper overview of the situation, priorities on information and optimal visualization of relevant information. Relevant sources of information and description of tasks at the local CP is given in the next two chapters.

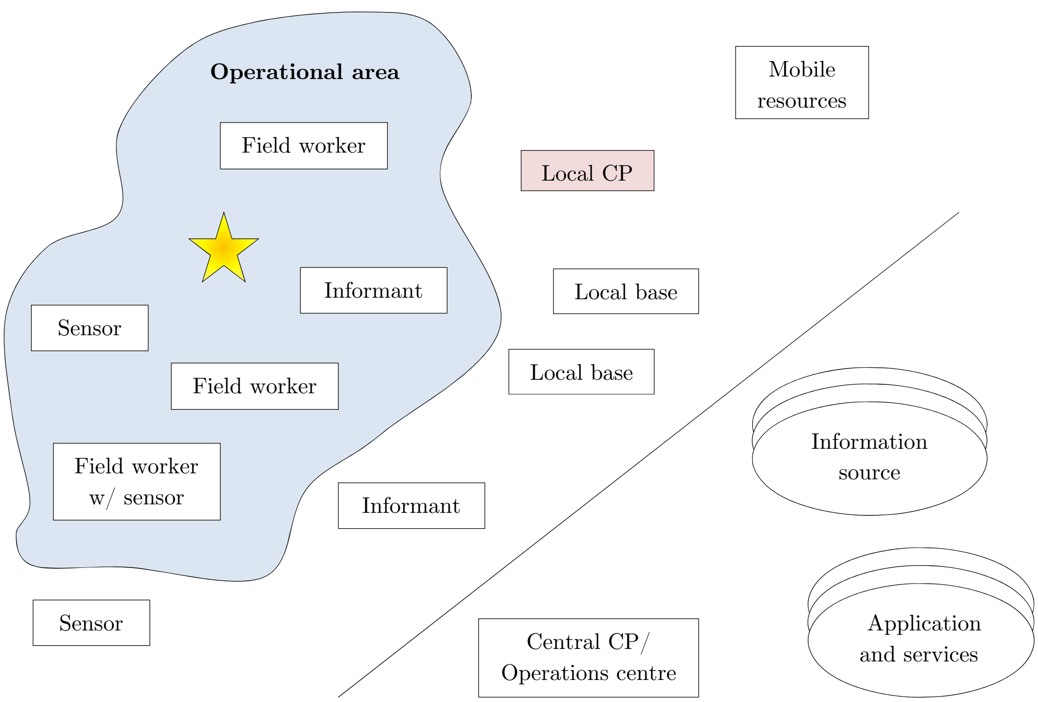


Figure 4.4-1: Local CP in relation to operational area

Chapter 5

User description

The purpose of this chapter is to give an in-detail description of the main user of our system. Many user roles are involved in emergency response, but for this thesis, our main role is the incident commander who operates at tactical level in the police. First, the whole hierarchy of leaders within the police is described to give an overview of the organizational structure. Then, the topical user role is presented in detail, and the field personnel are described to illustrate the difference between the incident commanders and personnel. Finally, a clarification is given of the usage of leader terms between agencies.

5.1. The levels of leadership

When extraordinary situations occur, the police work should operate with three levels of leadership (Politidirektoratet 2007, pp. 24-26):

- Strategic level: *Police commissioner*
- Operational level: *Chief of staff with staff*
- Tactical level: *Incident commander with staff*

These three levels are acknowledged as standard classification within crisis management, both domestically and internationally. These classifications are important because they mark the division between types of tasks and grade of decision making. This hierarchy is illustrated in Figure 5.1-1, which is adapted from (Politidirektoratet 2007, p. 25). Translation on the various roles is given in Appendix H.

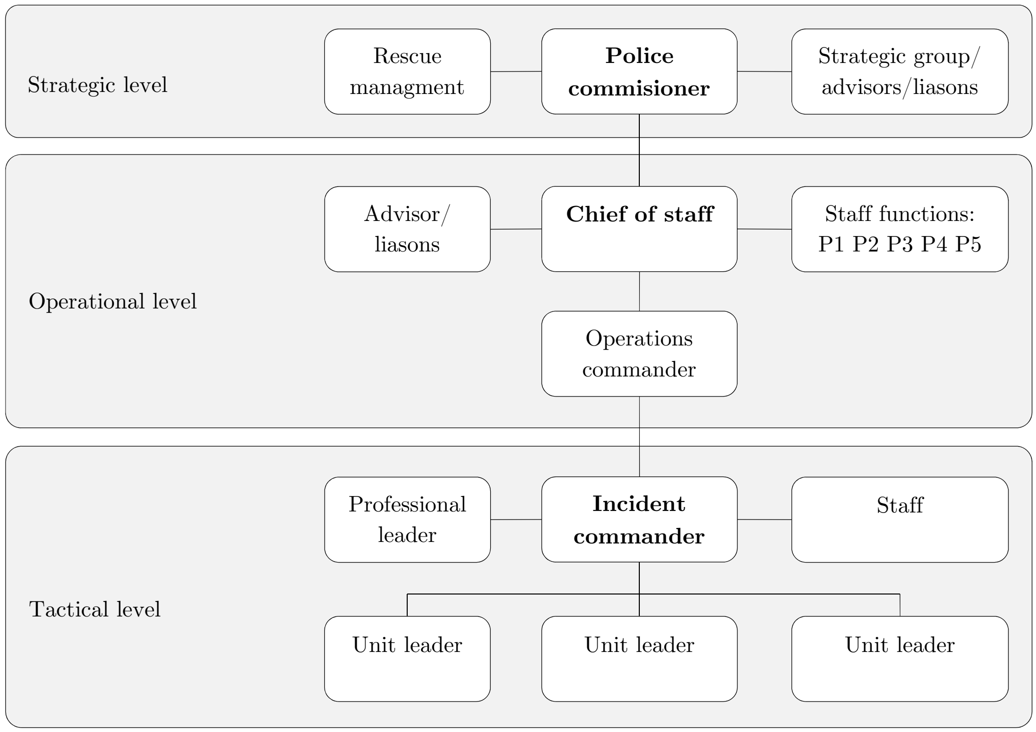


Figure 5.1-1: Levels of leadership

5.1.1. Strategic level

The *strategic level* consists of the leader of the enterprise, most typically the police commissioner. Work at this level involves setting the overall goals, along with setting focus areas and overall usage of resources. Method of operation is also among the tasks at strategic level. Work at this level requires both high insight and an ability to reflect. General knowledge, along with creativity and foresight, is necessary to perform work of this measure. Therefore the work is often carried out at a distance from the actual incident.

5.1.2. Operational level

The second level of leadership is the *operational level*. It is the staff of the police commissioner that forms this level. Their work mostly consists of planning and coordination of the tactical level in accordance to the overall goals set at strategic level. Also, their purpose is to act as a connecting link between strategic and tactical level. According to the advisory board, the staff is also only set in bigger operations; hence the level often exists without a staff.

5.1.3. Tactical level

The *tactical level* is the lowest level of leadership. The incident commander, and appointed staff and leaders, work at this level of operation, which is closest to the incident. They carry out the actual operation handed down to them by operational and/or strategic level. Their work mainly consists of direct leadership and handling field personnel, equipment, resources etc. If the operation is of a larger scale, the incident commander can point out leaders in charge of minor parts as they need to maintain a certain level of overview at all time. If necessary, a strategic leader must also be able to make decisions at both operational and tactical level.

Likewise, the operational level must be prepared to handle both strategic and tactical decision making in certain situations. It is therefore necessary to scope the definition of tactical leadership in this thesis to only include incident commanders and associated officers. This excludes possible leaders that steps down from higher levels to work at a tactical level.

It should also be mentioned that tactical level can fully operate without involving the two levels above. In some cases operational level can be represented by only one role, e.g. the chief of staff. However, an operational level is not required to carry out an operation. The tactical level can also operate without setting a staff. The combination of size and expected duration also determines in whether the operational and strategic level is necessary and whether to set staff or not. In major emergency situations involving all agencies, a staff is typically set. This was also the case in the TYR-exercise.

5.2. Incident commander

> *"The incident commander is the police district's highest ranking leader on tactical level in operations that require coordinated leadership"*
>
> *(Politihøgskolen 2007, p. 2)*

When several police officers carry out an operation together, an incident commander must always be designated (Politidirektoratet 2007, p. 99). Even though the user characteristics between incident commanders and other field personnel may overlap in certain occasions, the normal user characteristic for an incident commander is typically not similar to the user characteristics of field personnel (as described in Section 5.3).

5.2.1. Definition

The *incident commander* is the highest leader at tactical level for an operation that requires coordinated leadership. The incident commander typically has many years of service, carrying valuable operational experience and competence. It is strongly suggested by the National Police Directorate that police districts always have officers with this competence available. Their responsibility is considered both difficult and important, and their presence is often crucial to the outcome of the operation. The main task of the incident commander is to lead, coordinate and assure the overall quality of the operation. They lead the tactical force and carry out professional police assessments.

There is only one incident commander per operation regardless of operation. However, situations might occur where the incident commander appoints unit leaders responsible for specific parts of the operation. He can the then delegate works to them. This could be second in commands, communications units, loggers, drivers or support personnel. Even though the incident commander hands over the work, the responsibility is always his. So there is only one responsible for an operation at tactical level, and that is the incident commander.

5.2.2. Persona

While detailed descriptions of tasks are presented in the next chapter, some user characteristics of the incident commander derive directly from their task at hand. The main distinctiveness of their tasks is the attention span required. Proper task performance demands highly attention. Also, the tasks are often very time critical which brings extra pressure into play and requires concentration. Much information is being considered, often simultaneously, and it is often challenging to get a proper overview of the situation. As a part of the decision making process, the local leaders have to distribute information about decisions affecting involved personnel as well. This is further confirmed by the Norwegian Police University College in their own description of the incident commander job (Politihøgskolen 2007; Ladstein 2009, p. 2).

The most characteristic features of an incident commander can be mapped out by looking at their key attributes. Field studies of rescuing operation presented by Nilsson and Stølen (2010) identifies several key characteristics of incident commanders. The key attributes of incident commanders include the following:

1. *Close to the scene of incident* – While field personnel are at or inside the scene of incident, the incident commander stays outside, yet close to the scene of incident. Their main tasks are usually related to coordination and their direct involvement at the scene of incident is unnecessary, and may in some cases be distracting for both themselves and others.

2. *Often outdoors* – When emergency situations occur outside, the incident commander is usually outside as well. Situations could force an incident commander outside in order to get a full overview, or to communicate with involved personnel. Situations that take place in remote settings, such as avalanche rescue missions, could also unintentionally create environments where only outside facilities are available for the incident commander.

3. *In car, caravan or tent* – Certain situations allow the incident commander to stay inside police vehicles while coordinating and assessing an operation. Also, the use of temporary facilities such as caravans or tents is normal for an incident commander. As their tasks require a high attention span, reducing external factors (weather, temperature etc.) or disturbing factors (noise, danger etc.) would imply a better work environment.

4. *Move around more or less frequent* – Since incident commander are not working directly at the scene of incident, they are able to move more freely according to own tasks. They are not bound to certain locations either. A fireman would necessarily have to be at the scene to extinguish the fire. An incident commander usually performs coordinating operations via radio, intercom or other communication, allowing them to do their tasks from a more remote and independent location.

5.2.3. Behavior and skills

Firstly, the incident commander is normally an experienced official with good knowledge about the domain. This includes knowledge about incident commanding, leading the scene of incident, and overall good leadership qualities (Politidirektoratet 2007, p. 99). Another central ability of the incident commander is proactivity, which means the incident commander must be able to look forward and always stay one step ahead. During the early stages it is challenging to look at the big picture and imagine worst-case scenarios. This is vital for successfully giving prior notices and premonition of additional resources, receipt of resources and transferring competence and/or resources from other involved parts (DSB, Kystverket et al. 2010, p. 10).

Additionally, in (Carver and Turoff 2007, pp. 33-34) several necessary behavioral skills of an emergency manager are listed. All these elements are relevant for an incident commander as the on-site manager of the emergency:

- Absorb information rapidly
- Judge its sense, its meaning, its relevance, and its reliability
- Decide what the options for action are and make effective decisions
- Deal with plans that were prepared with little knowledge of the reality at the 'coal face' (where the pick meets the coal).

Based on the presented skillset of an incident commander, it is reasonable to assume the user to be an *expert* in regards to domain knowledge and accompanying tasks. However, an ICT-support solution should be designed to disallow the user to make errors. During the interview with the incident commander (Appendix B) the word *"police proof"* was used to describe a system that was even more user-friendly than a "foolproof" system, i.e. not allowing any mistakes.

5.2.4. Incident commander's sources of information

The cohesive nature of teams, and the attitude of the responding units, is critical to the success of the effort. The individuals responding must feel they have all relevant information available to successfully make a decision that can reflect the reality of any given situation (Burstein, s. 40). To perform his tasks, an incident commander must maintain close contact with several information sources. Nilsson defines five sources of information (Nilsson 2010b). The different types of sources generate different types of information. The different sources are first illustrated in Figure 5.2-1, and then listed in Table 2.4-1.

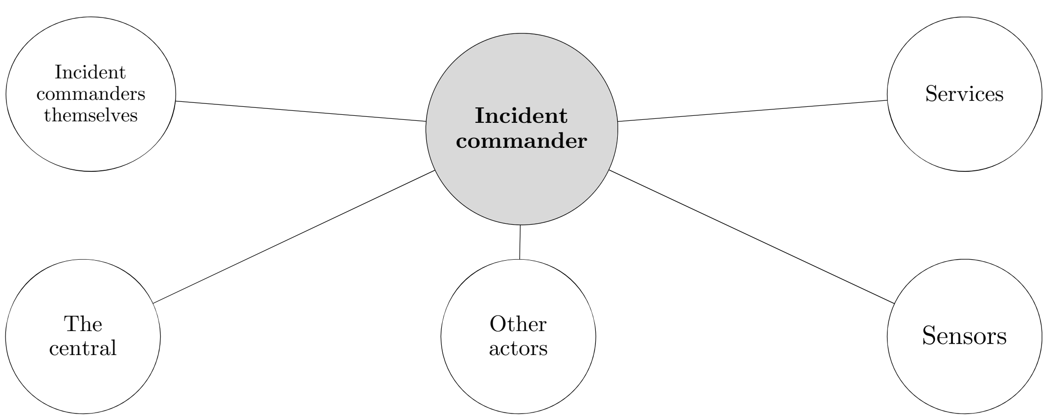


Figure 5.2-1: Overview of sources related to the incident commander

Table 5.2-1: Overview of information flow from sources

Source	Information
Incident commanders themselves	- Information about the extent of the operational area. - Information regarding location of various bases. - Logs of actions and events.
Services	- Information from external services such as weather (forecast). - Information regarding dangerous substance.
Sensors	- Information is gathered from sensors already available before incident. - Information from sensors put out during operation.
Other actors	- Information about involved people, both field workers and external people. - Information in regards to dangerous substances.
The central	- Information about critical concentration of people. - Information about available resources (both personnel and equipment). - Information regarding dangerous substances.

5.3. Field personnel

As mentioned in the previous sections, the main user is an incident commander. Before continuing on with the user role of an incident commander, it is interesting to look at the field personnel as well. This is especially important because overview of field personnel and allocation are defined as two of the operational tasks at hand. This is further presented in the next chapter. The key attributes of field personnel include the following:

1. *At or inside the scene of incident* – The incident scene is usually confined to a smaller area with emergency personnel working both inside and outside of this defined space. Field personnel are typically working inside this area, and are directly involved with the situation and/or involved people.

2. *Mostly moving around* – Field personnel move around most of the time. This is due to tasks being performed at different locations within the scene of

incident. Also, all factors of an emergency situation are rarely fully mapped out before entering the scene. Unforeseen development of the situation or general uncertainties, forces the field personnel to often move around within the scene.

3. *Highly focused on primary task* – Field personnel are often handed designated tasks within a scene defined as their primary task, e.g. placing roadblocks on roads leading to the scene of incident. This does not only separate different organizational personnel (e.g. police officers and ambulance workers), but often also distinguish different personnel within each agency.

4. *May operate in very hostile environments* – An emergency situation usually involves a hostile environment. This could be hostile people involved in the incident, or hostile environmental factors such as fires, avalanches or floods. This introduces an unwanted, and often distracting, stress factor for the involved field personnel.

5.4. Usage of leader terms between agencies

In the literature, many names are given to the different types of leaders that operate within the area of effect. Since each agency have their own terminology and hierarchy for the different types of leader roles involved in an emergency response, one often sees the term local leader as a common way to refer to all these different leader roles.

5.4.1. Local leader

The term *local leader* is only a generic term for someone that serves a certain function, or has a specific responsibility that puts him in a "leader role". It is too general as a term to distinguish one local leader from other local leaders within the same agency, or other involved agencies. It cannot outline any tasks or responsibilities either. In general, the term would refer to a ranking leader present in an emergency situation (e.g. the *incident commander*). However, this might be confusing in some contexts as we only have one incident commander, yet the term local leader is often used in plural.

If an incident contains clearly separated tasks, such as isolation or arrest, it is expedient to appoint subordinate leaders (Politidirektoratet 2007, p. 99). As seen in

Figure 5.1-1 the incident commander might delegate responsibility to second in commands, professional leaders or unit leaders. There will almost certainly be several local leaders at tactical level in an emergency response; however this thesis will only focus on one of them, namely the incident commander. Experience from previous work in the EMERGENCY-project confirms that certain situation includes several local leaders within one agency. During an avalanche rescue training mission observed by the thesis supervisor, the Red Cross had at least three or four local leaders. The incident commander appointed a *second in command* who also assumed the position of local leader. Then, as the incident commander had to move around the scene of incident, different local leaders were appointed to the different points of interest (e.g. rallying point for wounded people or the counting turnstile). These people were appointed by the incident commander and were on a lower level than him, yet still considered local leaders.

In (Politidirektoratet 2007, p. 164) the glossary lists the term *tactical commander* as the proper translation for the local leader we want to study. As seen in Section 5.1, the term *tactical commander* is the definition for the highest ranking leader at tactical level. In this case, that would be the intended incident commander. However, using the term tactical commander may lead to confusion in cases where several commanders exist at tactical level, even though only one is the incident commander. In cited documents, especially the more general and unspecific in terms of agency, there are several occurrences of the term local leader. When such terms are used as a source in this thesis, it is ensured that the term is used in a context where the information is transferrable to this thesis.

5.4.2. Situational uniqueness

Emergency situations mostly include variables that make each situation unique and not necessarily applicable to the default hierarchical structure. The involved personnel have not necessarily seen a similar situation before, and they might not have relevant experience. In general, it is difficult to define an explicit number of local leaders and hierarchy that is best suited. Situations do not have to be of large scale to contain leadership issues. An example is given in (Plotnick, Ocker et al. 2008, p. 29) where a traffic incident involving several agencies lacked clear leadership.

> *"However, there were no plans for who should be "in charge" in such a situation, and no guidelines for how those assuming leadership roles for one of these subgroups should communicate and coordinate with leaders or members of different subgroups."*

(Plotnick, Ocker et al. 2008, p. 29)

As certain situations develop unexpectedly and ambiguously, clear instructions on the appropriate leader are not always present. The traffic incident presented by Plotnick, Ocker et al. (2008), illustrates how the leadership structure change from situation to situation, and how some incidents may involve more local leaders than others. It also demonstrates how some incidents require local leaders that are not required elsewhere. Thus, the term local leader is very general and unspecific in relation to the otherwise hierarchical structure in the emergency response agencies. Also, operations of larger scale often involve additional agencies such as military services (e.g. the coast guard) or the Red Cross. This may include other definitions and hierarchies that may conflict with the general definition of a local leader.

To avoid misunderstandings in this thesis, the term local leader is never used. The intended user is an incident commander; hence that term is used where the end-user is described. Other roles are described with a precise title rather than the general term local leader.

Chapter 6

Task description

In this chapter, the tasks of an incident commander are described. First, the general tasks of incident commanders are presented. Then, six task categories are introduced, which allows us to give an in-detail description of the main tasks category. Finally, details regarding required information to perform the tasks are presented.

6.1. Tasks for incident commanders

During emergency response it is necessary to handle different situations and related tasks in a professional, effective and safe manner. To make sure all essential tasks are carried out in a proper way at a right time, the decision maker (i.e. the incident commander) relies on a predictable, structured and well-organized support network (DSB, Kystverket et al. 2010, p. 5). Some tasks are common for all local leaders during emergency situations, and will be applicable to an incident commander, while other tasks are fundamental specifically for incident commanders in the police.

6.1.1. Textbook responsibilities

As mentioned in the last chapter, the incident commander is responsible for leading the whole operation at tactical level. The first phase of operations is usually chaotic and complex, which can be limited with appropriate and predictable organization. Until support functions and different roles are established, the incident commander needs to keep control of leadership, planning and surroundings, operation, logistic, safety, information, economy and legal tasks (DSB, Kystverket et al. 2010, p. 10). This makes the list over the incident commander's responsibilities and tasks long. In (Politidirektoratet 2007, p. 99), a list of nine tasks is presented:

- Choose the appropriate leader style in the situation under consideration.
- Establish staff with the necessary leader groups.
- Plan the execution of the mission with other leaders I line with directives and guidelines.
- Organize the tactical troop so that they can accomplish the mission in the best way possible.
- Select the personnel that are best suited to solve the different parts of a mission. It is also important that the incident commander also evaluates the mission risk against the crew's dexterity.
- Coordinate and lead subordinated staff while carrying out the mission.
- Hold the police commissioner's staff oriented about the situation at the scene of incident.
- Assist the police commissioner's staff with advices during planning and give own assessments on the decisions being made.
- Suggest and recommend different ways on how to solve the mission. This is done by presenting a plan to the staff, eventually present an alternative plan.

6.1.2. Task categories

The tasks mentioned in the previous section are the superior textbook tasks associated with incident commanders. Thus, they are very wide-ranging and unspecific. Some of the tasks do not require ICT-support, such as choosing the appropriate leader style. Therefore only tasks that could benefit from ICT-support are studied further. These tasks can be divided into groups that reflect the overall purpose of the task. For example, organization, coordination and selection of personnel can be regarded as parts of resource handling (as personnel are considered resources).

In previous work done in the EMERGENCY-project, Erik Nilsson has identified six main categories to represent the tasks of an incident commander (Nilsson 2010b):

1. Handling location
2. Handling information about the incident
3. Handling the incident
4. Handling resources
5. Communication
6. Handling the rest of the world

Because these categories each include different tasks, each category should be studied individually. Each task within each category could be further subcategorized using task analysis methods such as *HTA (Hierarchical Task Analysis)* or *GOMS (Goals, Operations, Methods and Selection rules).*

There is a reason for wanting to go deeper before starting with the prototyping. First of all, the tasks differ not only between categories, but also between tasks within the same category. To get a sufficient understanding of the user and the user context we should scope down to a lower level. Hence, the thesis scope defines resource allocation as the relevant topic, and only tasks associated with handling resources are studied in this thesis. This is in line with previous studies by (Norros, Hutton et al. 2009) which makes it clear that the designer needs a clear understanding of user, task and context to increase the likelihood of success. Therefore, the selected category for this thesis is the handling of resources.

6.2. Main task category: handling resources

The main category of this thesis is resource allocation amongst incident commanders in the police during emergency operations. This includes resource allocation, as well as both reallocation and continuous updates of information about resources. Information exchange about resources and requisition of new resources should also be integrated as possible tasks (Nilsson 2010b, pp. 8-9).

6.2.1. Task category breakdown

There are several tasks within this category presented by Nilsson (2010b):

1. Allocating resources, reallocating resources and keeping track of resources
2. Exchange information about resources
3. Requisition of new resources

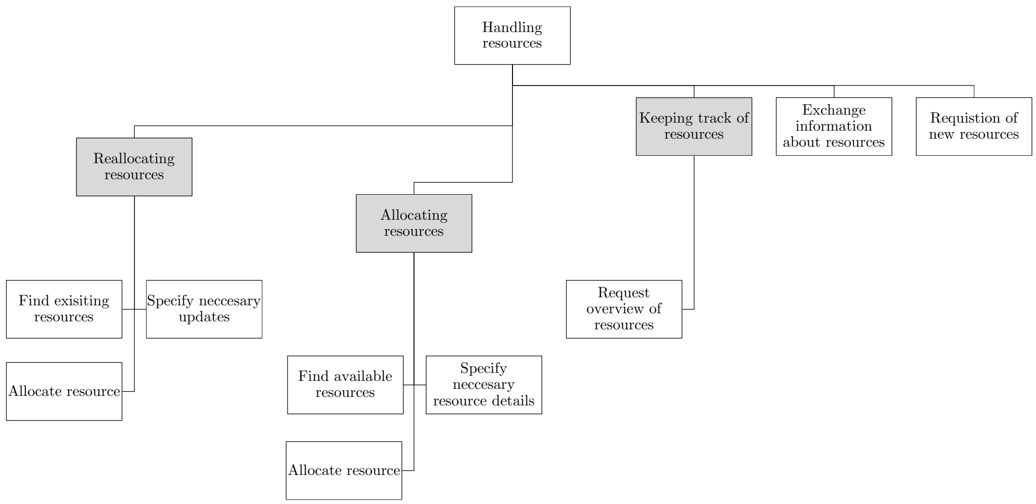


Figure 6.2-1: Handling resources: main tasks

Since Nilsson (2010b) defines the tasks of allocating, reallocating and keeping track of resources, as the central task of resource handling, those task can be further broken down with the use of a HTA (Figure 6.2-1). The tasks consist of finding available resources, continuously (re)allocating resources to the other tasks being performed, and keeping an overview of resources. Each task is dependent of different type of information. This requires cooperation with different sources; hence the user interaction might be different. The suggested user interaction for each task is also presented by Nilsson (2010b). The Table 6.2-1is adapter from (Nilsson 2010b, p. 8).

Table 6.2-1: Appropriate UI styles based on task.

Task	**Appropriate UI style(s)**	**User interaction**
Allocate, reallocate & keep track of resources	List/forms/map based	- Info on resources available from services - Status automatically from central or enter - Select allocation/priority - Location automatically from services, tracking or enter
Exchange information about resources	List/document/forms/map based	Share or send

Requisition of new resources	List/document/forms/map based	Select from info available from services

6.2.2. Domain models

Nilsson (2010b) further goes on to describe and conceptualize the tasks with a domain model[13] expressed with a domain class diagram (Appendix C). Based on these domain models, most notably (Figure C.2), we can extract the required information related to task allocation:

1. *Category* – the availability and allocation status of a resource.
2. *Type* – whether the resource is of type personnel or equipment.
3. *Status* – the status of the resource selected from a list of predefined statuses.
4. *Owner* – the personnel owning a certain resource.
5. *Priority* – the priority of a resource from a list of predefined priority grades.

6.2.3. Details about the required information

This work is done by the incident commander in cooperation with several other units and information sources. To allocate, reallocate and track resources the incident commander needs certain information about the involved resources. Status and ownership is always important during allocation. For reallocation especially, priority is essential.

Information	Details
Category	The category can be broken down to the following three types: - Known, but unavailable resources - Available, but not yet allocated resources - Available and allocated resources

[13] Domain model*: "an analysis class model that is independent of any particular use cases or applications, and that typically contains only entity objects"* (Bennett, McRobb et al. 2005).

Information	Details
Status	The current status of the personnel or equipment. The status for personnel can be broken down to the following four types: - Reserve - Not on duty - On duty, allocated - On duty, unallocated
Owner	The owner of a resource in case of equipment or the leader of that unit in case of personnel.
Priority	The priority the allocation of equipment or personnel has both in regards to general priority and priority amongst all other equipment and personnel.
Type	There are two types of resources: personnel and equipment.

It is important to point out that it is not the equipment or personnel itself that has a priority, but rather the allocation. The roadblock itself does not have a priority, but when placed in a certain context, it serves a specific function which can be graded with a priority. It is therefore the allocation of the roadblock that has a priority, not the roadblock itself.

6.2.4. Task frequency and size

As presented in this chapter, the incident commander has several responsibilities both onsite and offsite during emergency operations. The uniqueness of each situation forces designers to work with very little specific information about the use context. More importantly, the frequency and size of tasks may vary from one situation to another. In regards to validity and triangulation, this is probably the most uncertain and unpredictable information used when developing the prototype.

It became a motivation itself to select resource handling because it is central in most emergency situations. This is especially important since our scope of resources also include personnel and tracked equipment, which is fundamental in all situations. Therefore, task frequency and size is problematic to predict; however the combination of resource scope, assumption of medium-sized operations (see Section 9.1.1), and expert users as intended audience, allows us to build prototypes that can explore the problem area.

Chapter 7

Design requirements

This chapter will discuss general design requirements presented in relevant literature. Previous work presented in Section 2.4 points out different aspects of the design phase that requires attention. Since the term "design" often include more issues than just the UI (physical size, shape etc.), the first section begins by defining what type of requirements we want to study. Then different design requirements are presented based on related work on the particular topic.

Several requirements have been identified as important when developing mobile solutions for crisis response. The topic of requirements for mobile technology is discussed and presented by several papers (Lanfranchi and Ireson 2009; Way 2009; Pérez, Cabrerizo et al. 2010). However, they all have in common that they focus on either external criteria or direct hardware requirements. While these papers are both relevant and interesting, they often forget to analyze the UID-requirements of a successful solution. Steven C. Way (2009) has made requirements an important part of his paper on criteria for evaluating mobile technology. Mentioned requirements in his paper include infrastructure, bandwidth, scope and location, availability, robustness, standards, security, durability, networking, location identification, timeliness, applications and power. These are all important topics when considering the overall requirements. In this thesis however, the main focus will be on requirements directly related to design of the UI.

7.1. Intuitive user interface

An important topic when it comes to designing UIs is how intuitive the system is for the end-user. It is emphasized in several studies that regardless of the complexity and context-awareness of a system, it should always be predictable and reliable in all conditions at all times (Luyten, Winters et al. 2006). It is also pointed out that to maintain best possible decision making support, neither the structure nor the interface should change, only the content. Other studies also support this principle.

Firefighters in Madrid have been used as example to illustrate how experience and knowledge combined with a less complex interface, would prove the process both more easy and effective (Nadal-Serrano 2010). The field observations also concluded that visualizing information, e.g. direction to the scene of incident, made the task handling much easier than presenting information as textual directions. This was done by comparing traditional written direction to a visual alternative, either map or sketch.

In (Khalilbeigi, Schweizer et al. 2010) the authors discuss how users, especially in field work, tend to remain attached to traditional workflow and artifacts, such as pen and paper. The article refers to studies on multimodal interfaces in (Cohen and McGee 2004) when describing reluctance to digital solutions as an important challenge. One important matter presented is how hardware and UIs don't necessarily tend to fit the current work practices. There needs to be a correlation between the conventional work practice known to the user and the novel digital systems, to avoid confusion and delay during decision making processes. Such a significant modification of every-day tasks and routines will also introduce an increased amount of unknown risks. An intuitive UI is therefore a key necessity when it comes to minimizing, or perhaps eliminating, the challenge of reluctance and risk. This is further backed up by a study from San Diego (Rogers, Sharp et al. 2007) that stresses the importance of simple and very user-friendly interfaces. Further pointed out, is that stressful situations, typically associated with police work, reduce the attention span one can expect from a user. To illustrate their point, they use an example from a situation where police officers under fire are trying to communicate. Instead of looking for a small button on a touch screen, they would rather prefer having the big red button. It is therefore suggested that in certain situation s, simple solutions might be the best solutions.

7.2. Multimodal interface

Humans communicate with each other through several different modalities. In emergency response, this is no different. An important goal for a successful interface should therefore include the possibility to extend the bottleneck within traditional HCI where one can only communicate through one or few modalities (Krahnstoever, Schapira et al. 2002). Mentioned modalities include audio- and video streaming, and also hand gestures and speech recognition. Both in regards to comprehending the extent of the situation and maximizing decision making support, a multimodal interface is suggested to give a better overview of reality.

Other studies (Nakatani and Nishida 2007; Lanfranchi and Ireson 2009) have also suggested that multimodal implementations, such as images, audio and video clips and speech recordings, will improve the situation recognition. This can be crucial during time-critical operations. Also, it will allow situation awareness and real-time information to be gathered and shared more easily. In (Sinha and Landay 2002), several reasons for the growing popularity of multimodal systems are presented. Increasing accuracy of perceptual input systems (speech recognition, handwriting recognition, vision recognition, etc.) is especially mentioned as one of the two main reasons. The other reason pointed out by the authors is the increasing ubiquity of heterogeneous computing devices (cellular telephones, handheld devices, laptops, whiteboard computers).

Cohen and McGee (2004) have also pointed out that safety-critical application should include a multimodal interface to maximize decision making (Cohen and McGee 2004). They suggest that instead of trying to change the user, the system design could be adapted to match the key aspect of the user's practice. By using tangible multimodal (TMM) systems, the users have the possibility to employ physical objects and knowledge of their workspace when communicating and sharing information with other users. This could be simple physical objects such as pen and paper, or other natural input modalities such as spoken language, sketches or gestures. In general, several papers points out that emergency response require multimodality for easiest understanding and sharing of information.

Nilsson and Stølen's (2010) paper on Ad hoc networks and mobile devices (Nilsson and Stølen 2010) also points out several tendencies that support the usage of multimodal design. The high-frequent usage of GPS and other deployed sensors indicate different methods of presentation. Other topics that suggest multimodal visualization are illustrating direction and distance, along with live-feed from mobile cameras.

7.3. Dynamic interface

A mobile solution for emergency response can potentially make large amounts of information directly available to incident commanders. This could be direct information gathered about the current event in an emergency response, or indirect information such as local landmarks and background information collected from a centralized database. When designing UIs, one should take into account that incident commanders may experience the interface as too complex or too comprehensive. Especially when performing time-critical task at maximal stress-level, the information presented should be easily understood and provide a supportive decision making interface. Most information is only necessary and relevant in certain situation or at specific locations (Streefkerk, van Esch-Bussemakers et al. 2008).

In general, while all information should be accessible, the information directed towards the incident commander should be carefully filtered (Burstein, Holsapple et al. 2008, p. 47). The interface should also be able to adapt to the severity of the situation. As mentioned, the attention span is usually low when situations escalate, and an interface should be able to adjust according to whether the system has the user's fully focus, or whether he is only partly focused (e.g. driving a car while interacting with a GPS). The example with the police officers in San Diego looking for the big red button while under fire is once again a good example of how different situations require different presentations of the interfaces.

(Nakatani and Nishida 2007) also identifies a problem related to when and how information should be presented to avoid confusing situations. Only including the necessary amount of information, and adapting presentation to the situation, are regarded as important factors for proper situation recognition. This implies the usage of a dynamic interface able to present the proper amount of information, and perhaps also in different ways, based on the situation. This topic can be seen as contradictory in regards to section 7.1 where factors such as stability, reliability and predictability suggested a more static and familiar interface to make the interaction more intuitive.

7.4. Public-aware interface

Another topic regarding this matter is the importance of including information from external users. A system for emergency response should always be prepared to collect information from unexpected sources of all kinds. In major crisis such as the World Trade Center-attack, or the hurricane Katrina, it has been shown that the public are usually the first to respond (Newlon, Pfaff et al. 2009). The public usually possess important information that could not be gathered elsewhere. It was further confirmed during the case study prior to this thesis, that the involvement of the public cannot be neglected because their information might be too important and relevant for the outcome of the emergency response to ignore. While emergency responses are on their way, the public present at the scene of incident often collect vast amounts of information. Also, the public are often partially involved themselves or connected to either the situation or people involved. Experience shows that during crisis, both individual and unplanned groups volunteered to aid their fellow citizens (Way 2009).

In (Vigerust, Andersen et al. 2009, p. 23) it is recommended by daily emergency responders to always include related persons, volunteers and spectators as resources. In medical response this could benefit the situation as these additional resources may carry patients around allowing medical personnel to use more time on treatment and assessment. A third reason presented to include the public is to acquire their general knowledge, such as local events or recent activity. This information is often unknown to the response team. This will in turn strengthen the basis on which the decision making process is done. Theoretically, this is further backed up by the research done in association with the WeKnowIt-project, a European project bringing response personnel and community citizens closer together in emergency incident monitoring (Lanfranchi and Ireson 2009). Other reasons to bring the community citizens into the monitoring include faster and more precisely collect relevant information from collective intelligence. Mentioned factors that could influence the work of emergency responders are affected locations, transport issues, potential threats etc.

However, this public information includes several new challenges, among them both organizational and legal matters, which should not be included in such a thesis. Also, it includes the topic of potential incorrect information. It requires several steps in regards to sorting out correct and relevant information before the sharing can even begin. Filtering, processing and identifying important information is necessary before the editorial process of editing, verification and translation can begin (di Tada and Large 2010).

Another paper that investigates and discusses how the social network paradigm allows individuals to communicate and collaborate with organizations is (White, Plotnick et al. 2009). The paper presents the social network as a place for sharing information and finding potential collaborators with needed expertise. This is interesting in regards to how to treat the information shared in such a social network. If it becomes necessary at some point to allocate more resources, social networks can be utilized to reach resources. Local police leaders in the need of volunteers for an organized search could use social networks to recruit nearby volunteers. For example, if there is an acute need of power, they could benefit from social networks by tracking down local people with access to generators that can provide power. However, as pointed out by the White, Plotnick et al. (2009), there is a limitation in regards to how information that has yet not been verified should be handled. (Vieweg, Palen et al. 2008) describes how names of victims during the 2007 Virginia Tech (VT) shooting were collected and made available on Facebook long before any proper list of victims was released. As an organizational unit, the police are limited to only using unverified information as indications or possibilities, rather than confirmed information they can present to the public.

7.5. Stability-aware interface

A stable network is fundamental to guarantee a channel for communication. This is especially the case when field personnel or moving personnel are dependent of communication with local control points or centralized points. Emergency teams are often forced to set up their own infrastructure during crisis. This could either be because general networks are unavailable at the emergency scene, or because they need to set up an infrastructure to acquire maximal reliability. Previous studies indicate that several network issues are likely to occur during the establishing and accessing of a reliable infrastructure (Dilmaghani and Rao 2009). Wireless mesh network is one of the solutions that have been tested, and they are amongst recent papers deemed the fit solution for such an ad-hoc infrastructure (Nilsson and Stølen 2010). Other studies have researched and experimented with mesh networks as well (Luyten, Winters et al. 2006). This is interesting in relations to design requirements because the designing of the interface should take into account that network problems might arise.

Research around automated handheld devices have proven that when navigation, or other similar features, are not supported, the user suffers (Uluca, Streefkerk et al. 2008). Not only does this include taking inefficient routes or making minor navigational errors, but it could also be as severe as finding themselves unable to reach hot-spots or incapable of finding specific location. Thus, several papers have made a point out of the fact that reliable interfaces should be able to display information even after signal is lost. This is not only a matter of presentation, but also includes other design-related topics such as temporary storage of information. This is also interesting because an ad hoc infrastructure might enable multimodal feature that might not be available with existing infrastructures, such as audio and video recording and sharing. This would better both the total overview of the situation, and the safety of involved personnel. However, an ad hoc network might introduce network problems when dealing with interconnectivity between different personnel and contributors. Unless especially designed to cope with communication in a heterogeneous environment, this could represent a bottleneck within the communication. If this were to be the case, this should be taken into account when designing the interface.

7.6. Context-adaptive interface

Another important topic is automation of response tasks through contextual behavior. This could be deployed sensors collecting contextual data making the interface perform an automatic reasoning of for example how to present information.

A GPS with sensors could automate panning and zooming of locations on a map, providing us with an automated interface adapting to context. However, it is important to remember that adaptation can include more than just collected information from sensors or other external sources. Flipping a phone 90 degrees can make the interface change, and that is also considered an adaptation.

While new technology allow us to partially automate tasks, it is not always clear which parts or which features of a solution that should be automated (Streefkerk, van Esch-Bussemakers et al. 2008). When selecting which feature to automate, both the type of task and the end-user should be taken into account. It is pointed out that the success of mobile solution partially relies on the system's ability to adapt according to task complexity and priority. This is based on identification of different roles an incident commander might take during a navigation task, and how dependent the user is of the system. If an incident commander is driving to an unknown location, an auto-panning and auto-focusing navigation interface would be preferred; hence the panning and zooming of the interface could be automated. But as soon as the incident commander exits the car and continues on foot, his preferences to automation changes as well. Now he is more likely to prefer panning and zooming himself. Not only do these different user scenarios have to be identified, they should also be separated (Luyten, Winters et al. 2006).

Other studies also stress the importance of real-time information (Luyten, Winters et al. 2006; Nadal-Serrano 2010). Firefighters are used to present the need for real-time information. The direction of the wind or the heart rate of the firefighters, are examples of factors that are so dependent on accurate real-time information, that they can cause fatal outcomes if not presented accurately. Therefore, in addition to using contextual information to gather relevant knowledge about an incident from external sources, in this line of work it is utterly important that the presented information is both accurate and in real-time.

Another paper discussing the presentation of real-time information is (Nakatani and Nishida 2007). They begin by pointing out how operations and tasks within emergency work often tend to differ from how they were intended to be. This is a result of many factors, e.g. situations and circumstances that are not fully mapped out or necessarily predictable. As a potential solution to this issue, the paper suggests a visual presentation of the gap between the intention of an operation, and a real-time monitoring of the situation. This would allow detecting and prioritizing different operations. Also, by identifying reasons or subtasks that generates this difference between expectations and actual progress of an operation, problems can easier be identified.

Chapter 8

Design challenges

The previous chapter introduced several requirements for interfaces used in emergency work based on relevant literature. The purpose of this chapter is to combine the knowledge from last chapter with more factors specific to this thesis, and thereby further lay the implications for the design. This includes device-specific aspects such as small-screen impact and applications-specific aspects such as icon language and cluttering. Lastly, the interface control is discussed to determine what interactions that provides the best UI for solving map-based resource handling on mobile devices.

8.1. Small-screen impact

In 2006, Jones and Marsden said that *"while resolution and color quality continue to improve, an aspect that will remain a very real constraint is the size of the viewable screen"* (Jones and Marsden 2006, p. 250). Five years later, their statement is still valid. Over the last few years tablets have been filling the gap between mobile devices and laptops for those who find either mobile devices too small or laptops too large. However, mobile devices remain the same size still fulfilling the need to remain pocket-portable.

Looking back at the evolution of smartphones, one can find similar patterns. Ever since IBM's first attempt in 1993 to create a smartphone with touchscreen, several companies have followed with devices that can be regarded as a precursor to today's smartphone generation. Being a personal digital assistant (PDA) without mobile phone features, thus technically not qualifying as a smartphone, the Palm Pilot (and also HP iPAQ), still popularized mobile data use through enterprise users during the nineties. While the next wave of smartphones became available in 2002 with RIM's Blackberry (Davis 2011), the current generation smartphones with exclusively touch-screen interaction, such as the iPhone, did not show up until 2007.

With the iPhone smartphones were brought out to the masses presenting a whole new dimension within user-friendliness. Today the iPhones are still the measuring sticks to which all new smartphones are being compared. Thus, while the smartphones have integrated successful factors from both the PDA and mobile world, their physical size and screen size have remained generally consistent even though key features such as stylus and keypads have mostly gone extinct.

8.1.1. Restrictions

The most obvious challenge when designing map-based applications for small-screen devices is handling the constraints set by the device. Knowledge from desktop scenario cannot automatically be adapted to small-screen device design. Techniques and practices effective in desktop scenario must be redesigned to achieve usability and performance goals on small-screen devices, as they simply cannot be adapted (Burigat and Chittaro 2008, p. 13).

Specific issues might require novel solutions. As presented later, icon cluttering is one of the issues that would not be deemed equally problematic in a desktop scenario. This exact issue of desktop vs. small-screen applications is also mentioned by (Paelke, Reimann et al. 2003, p. 57) through their presentation of key constraints with mobile devices relatively compared to desktop applications. Paelke, Reimann et al. (2003) present these constraints in a list with short descriptions. Since their article is from 2003, some of these points are somewhat outdated and not relevant anymore. Based on their list, Table 8.1-1 has been made with updated and supplemented descriptions.

Table 8.1-1: Small-screen device restrictions

Restriction	**Description**	**Restriction type**
Limited screen resolution	With the best models ranging from 480x320 to 960x640 pixels[14], the limited screen resolution is still a key constraint for mobile devices.	Visual

[14] The screen resolution refers to the Apple iPhone 4 (Apple 2011)

Restriction	Description	Restriction type
Small display size	The small physical display size is another key constraint. The best models have up to 4.3 inch screens[15]. Paelke, Reimann et al. (2003) also mentions this potentially interfering with universal design as people suffering with vision problems are especially affected by this.	Visual
Limited number of available colors	While this has definitively been an issue hitherto, new phones such as the Apple iPhone 4 provide retina display making individual pixels undistinguishable and everything sharper and clearer.	Visual
Limited processing power	For complex graphical display generation and real-time animation the limited processing power of modern mobile devices can still represent a bottleneck.	Visual
No standardization	Desktop applications mostly require standardized input units to fully function such as mouse or keyboard. Mobile devices are often device specific. Skill-transfer between different types of devices, both in regards to models and brands, is more difficult with mobile devices.	Interaction
No full keyboard	Most new mobile devices provide an on-screen option to a full QWERTY-keyboard, but this is not nearly as effective as a regular keyboard. The function and numeric keys are also not so easily accessed.	Interaction
No mouse	A 2D-pointing device, most notably the mouse, is normal in most desktop environments. Some devices have support for styluses, but not in the same manner as a mouse (or touchpad, graphic tablet etc.) provide for a desktop application.	Interaction

[15] The screen size refers to the HTC HD (HTC 2010)

Restriction	Description	Restriction type
Specific interaction technique	Mobile devices provide interaction options and techniques that are often unavailable or irrelevant in a static desktop setting, such as location-sensing, multimodal interaction etc. Since experience with interaction of these sorts is limited, this can make the user interaction challenging.	Interaction
Auditory environment	Two good examples are given by Paelke, Reimann et al. (2003): (1) since mobile devices are often used outside, background noise can disturb the interaction, or (2) sound out might be undesirable (e.g. in a library setting).	Context
Visual environment	Desktop applications are mostly used indoor under controlled lighting and stabile temperature. Mobile devices are used in different visual environments. Being used in both in glaring sun or in complete darkness, this is an important context restriction.	Context
Level of attention	The amount of devoted attention is much lower for mobile devices where the user is often combining several activities. Also, interruptions are likely to occur due to external events.	Context

8.1.2. Reduced efficiency

A last topic related to challenges with small-screen devices that should be mentioned is Fitts' law. *Fitts' law* was first presented in (Fitts 1954) and uses a formula to state the time it takes to move from a starting position to a final target, typically a target on display. The formula uses two factors: the distance to the target and the size of the target.

> *"The larger the target, the faster it can be pointed to. Likewise, the closer the target, the faster it can be pointed to."*
>
> *(Saffer 2006, p. 134)*

Based on this understanding it is reasonable to regard the small-screen devices to be more time-consuming in use than larger screens as the targets size also scale up. As a tool mostly used to decide size, position and relative placing for buttons and other interaction mechanisms without delaying the user interaction, Fitts' law is also helpful in estimating efficiency of task handling methods. This is relevant since Fitts' law might be useful when evaluating systems where the time to physically locate an object is critical to the task at hand (Rogers, Sharp et al. 2007, p. 714).

This can also relate to the time-critical and intensive tasks performed by incident commanders. The small-screen size once again suggests reduced efficiency compared to larger devices. User studies in other literature researching mobile devices with built-in projectors have generated similar results. The following quote by Hang, Rukzio et al. (2008) illustrates this point:

> *"The results clearly show that the higher resolution and display size improved the task completion time, reduced the time needed for scrolling, leads to a lower error rate and a very positive user feedback."*
>
> *(Hang, Rukzio et al. 2008, p. 207)*

8.2. Icons

> *"An icon is something that looks like what it means; it is representational and easy to understand"*
>
> *(Marcus 1984, p. 87)*

The map interface allows the incident commander to navigate around the spatial area of operation. As presented in Section 6.2, resources are allocated to different positions within the area of operation. The most natural method of visualizing allocated resources is by placing out map markers, i.e. icons in a specific map location. This provides an overview of allocated resources, and visualizes the spatial relations, i.e. distance and position, among different allocations (Chittaro 2006, p. 41). Two challenges with using icons as markers are discussed in this section.

8.2.1. Icon language

In general, it is important to design UIs for mobile devices by considering difference based on disability and nationality. (Jhangiani and Smith-Jackson 2007, p. 517). However, since the prototype is meant to function as a *localized* application rather than an *international* application, it is safe to use local references and language. Hence, we do not have to worry about our icons, words and images not being able to properly translate into other languages. In (Wang 2007) the authors explore the relationship between icon identification and language skills. It was concluded that familiarity with using computers is more important than the language skill set. They further point to a congruent study, which states that computer experience impacts the identification and interpretation of metaphors. Since we are designing for expert users in this thesis, we can assume that their skillset is good. We can also assume they properly understand English.

Based on this, it is reasonable to use a combination icon to represent different types of resources on the map. A *standard icon* is an icon that is found in international versions of software, and a *concrete icon* only depicts material objects existing in the real word. A *combination icon* is a mixture of these two (Wang 2007, p. 199). This means that combination icons include both abstract elements and real world material objects. For this thesis it means that resources placed on a map should be represented with familiar symbols or illustration. However, they are not bounded to only real world material objects; they can be metaphors as well. The icons should give an independent and distinct meaning regardless of whether it is a material object or an abstract representation, or even if there is no supplementary text description. This is an argument for having different types of resources being displayed as the type of resource, and not just as a resource. The icon should reflect the resource type to distinguish from other adjacent, yet different, resources.

8.2.2. Icon cluttering

A common problem for map application is *icon cluttering* where several icons touch and overlap. There are several options on how to deal with visualizing a large number of icons on a map. On small-screen devices especially, the probability of cluttering icons is high. If the interface has support for zooming out, the probability increases as icons begin to touch and overlap. There are two reasons for wanting to avoid cluttering: (1) it may degrade the effectiveness of even a close-up view, and (2) it might cover or mask important map symbols or features such as roads or landmarks (Burigat and Chittaro 2008, p. 13).

Two common methods for avoiding icon cluttering include either limiting the maximum number of items displayed on a map, or allowing the user to select which items they want to display. A third, yet more uncommon way, could be to lock the level of zoom allowed to such a level where chances of icon cluttering are practically reduced to zero. While these methods may solve some of the issues with cluttering, it does not guarantee any improvements, and such techniques are only suitable for the simultaneously display of map contents (Burigat and Chittaro 2008, p. 13). The use of powerful and computationally intensive algorithms to unclutter icons is also discouraged. In the conclusion, Burigat and Chittaro (2008) mentions that the requirements for proper icon placement and grouping is not trivial, and that none of the propose algorithms can be regarded as optimal for all map-based applications. It is also stated by the authors that such algorithms lead to long response time unsuited for devices with limited computational resources and for interactive environments. Therefore the prototype developed for this thesis will not deal with icon cluttering. This can be justified by looking at item 4 from the list of assumptions presented in Section 9.1.1. Item 4 state that we can assume the scale of the operation to be of middle size. This limits the numbers of involved personnel and equipment. Since these are typically geographically spread within the operational area, the chances of icon cluttering are small. It is vital for the functionality of the application that the whole screen is not filled with icons since this would limit the degree of freedom when panning and zooming. This is also assumed avoided when the size of the operation is suggested to be of medium size. Another reason for not choosing to deal with this is tied to the user's needs. The user, in this case the incident commander, wants to keep an overview of the situation at all times. It is highly unlikely that he would ever need to zoom out to such a scale that icon uncluttering becomes necessary. There are no indications that he benefits from looking at the situation from such an angle, and the purpose of this prototype is to study professional and performance enhancing solutions, and not explore the unessential possibilities. Also, it is not likely that several icons of the same type are within a smaller portion of the map. Since equipment and personnel are spread, and often in movement, the pattern of spread is very dynamic and arbitrary, thereby making algorithm exploration more difficult than with static items.

A last, yet very important, point is that icon cluttering prevents much vital information within the context of this thesis. If a resource which is part of a grouped representation is unallocated, how does this show up in the grouping? Or if a resource is reallocated to a different location, most likely falling under a different group, how is this represented? These questions would strongly imply a grouping based on logical assessments rather than automatically grouping based on location.

To illustrate these arguments for not dealing with icon cluttering in the prototype, Figure 8.2-1 is presented. The left illustration in Figure 8.2-1 represents resources of two types (e.g. personnel and equipment) within an area of operation. At this point icon cluttering is not a problem, thus grouping of icons is not needed. The right figure in Figure 8.2-1 is the same area of operation, but seen from further away (zoomed out). This would place the icons closer together creating several overlaps. As seen, it is no easy way to group these icons and still keep their relative position to the operational area in order. Also, the equipment is often tied to a person; hence two different types of resources are often geographically adjacent. This make the icon clustering problematic as it is desirable to have resources separated at type level, while persons are only separated at occurrence level. It should be mentioned once again, that the operational area would in most cases be defined as a freehand blob (as explained in Section 4.3.2) rather than a perfect circle which was only meant figuratively to clarify the problem.

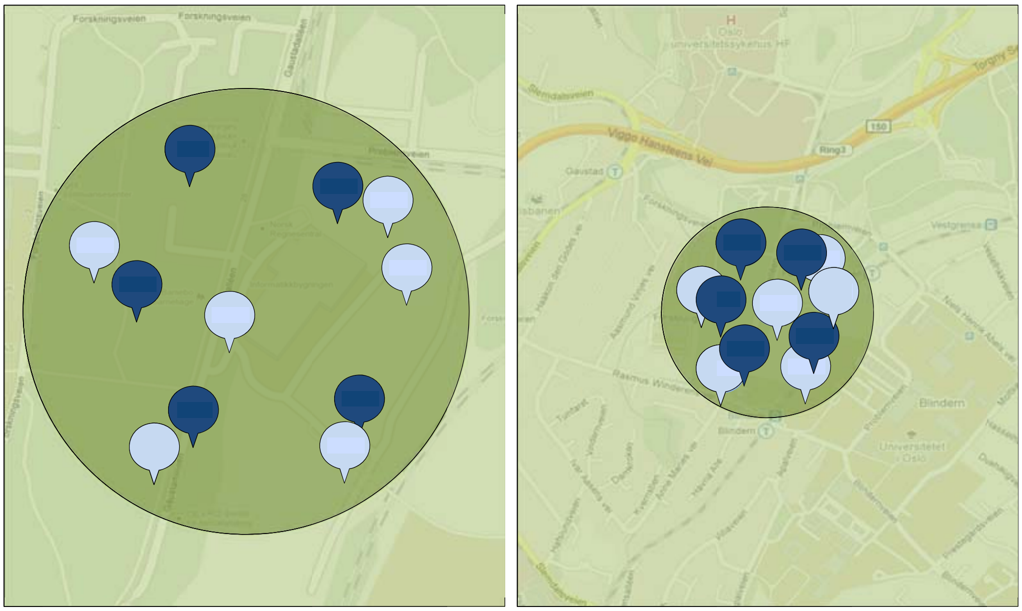


Figure 8.2-1: Cluttering of markers

> *"Placing text labels on maps while avoiding overlaps with cartographic symbols and other labels is a fundamental problem in the field of cartography."*
>
> *(Burigat and Chittaro 2008, p. 15)*

A topic related to this is *label placement* in map-based application. Since the allocation of resources, especially those that are automated and non-verbal such as biosensors, are dependent on accurate positioning, the placement of icons cannot be too arbitrarily. Otherwise this could confuse the user. Burigat and Chittaro (2008) suggest using a set of four squares shaped around a *point of interest (POI)* in the center. Algorithm can then be used to determine which of the four squares that is best suited for holding an icon or description thus filling the region of the map covered by the square.

A strategy like this was used when the prototype was first developed. To display details associated with an allocated resource, the user had to click the resource icon to reveal the details. Since the development began with few items, the information box with resource details was initially deliberately placed in such a manner that it did not cover the icon. The information box was initially drawn on the opposite half of the screen. To begin with, it was sufficient as only a few icons were placed within a plausible area of effect, in this case an operational area. As the numbers of icons grew, this method became inadequate. The screen was then treated as four separate quadrants, but this limited the maximum size of the popup-box due to the restricted size of a small-screen device. The solution became to accept that parts of the map and other icons were covered, but allowing popup-boxes that contained all the information. Trying to fit the information box in-between all icons on a map requires algorithmic investigation. As mentioned, this is not suited for devices with limited computational capacity. Furthermore, since this necessary information about the map layer is controlled by the map provider, in this case Google Maps, this topic is not further investigated in this thesis.

8.3. Interface control

The initial approach for designing the interface was to design an intuitive interface according to known theory and common sense. There are two main benefits for designing in such a manner: (1) the learning curve could be flatten, and (2) the user productivity could increase (Harrower and Sheesley 2005, p. 79). (Luyten, Winters et al. 2006) studied the topic with empirical user tests and practical use which indicated that the interface should be intuitive and easy to use. Their solution combined different user roles, tasks, situations and contexts, and was designed to focus at task at hand without losing overview of the situation. This is very similar to the desired qualities of the prototype of this thesis. (Rogers, Sharp et al. 2007; Lahlou 2009) also underline the importance of a user-friendly and intuitive interface. The interfaces studied in the mentioned literature are not map-based and the knowledge might not always be transferrable to other types of interfaces. However, the similarities in regards to desired functionality, and interaction between their solutions and the prototype of this thesis, are so alike that it is plausible to assume that the same guidelines apply. Furthermore, (Harrower and Sheesley 2005) studies map interfaces by examining approaches to panning and zooming in interactive maps. They define three basic questions for developing interactive mapping systems:

1. *Kind of control* – what type of interactivity is needed.
2. *Degree of control* – how much interactivity is needed.
3. *Method of control* – how should this interactivity be implemented.

8.3.1. Kind of control

Panning and zooming are the two most obvious functionalities of a map interface. These were the subject of the first evaluation (see Section 12.1). *Panning* is defined as a stepwise move towards desired direction, while *zooming* is enlarging or reducing the display window without content change (Meng, Zipf et al. 2008, p. 5). This is needed for users to navigate through a digital map which is represented in a substantially smaller size relatively compared to physical map. Observational reports and photographs of police officers during the TYR-exercise (Nilsson 2010b) all include usage of traditional maps for both navigation and situation overview[16].

An interesting point presented in (Harrower and Sheesley 2005) is that best-suited methods for implementing panning and zooming rely on the size of the information the user is trying to navigate. They further suggest that good mapping systems should present multiple options for panning and zooming. However, for maps with several points of interest, and a higher level of interaction, several more possibilities are relevant. In (Meng, Zipf et al. 2008, p. 45) a total of nine potential operations are presented. Based on this list, panning and zooming along with three additional sorts of interaction are present in the prototype for this thesis.

Hiding and revealing objects is a third interaction used in the prototype. This is an important function because not all points of interest are relevant at all time. Also, due to the critical time and low attention span, it is significant to implement support for selective adjustment to always get the best and most relevant overview. It can also be used to filter out unessential information when wanting to give focus to one or more particular items. Likewise, if an item is to be distinguishable in a set of similar items, highlighting that item can be a way of achieving that without hiding the rest.

The fourth interaction is *focusing*. This will allow the user to retrieve additional information about an item besides its location in a geographical context. This is necessary within the prototype to allow one more level of information which is invisible until requested. This will complement the highlight feature from a hiding and revealing interaction.

The last interaction is the *tuning of visualization parameters*. This would allow the user to change his viewing angle (e.g. from a 2D to 3D environment as seen in car navigation systems), or change graphic variables in terms of color, texture, symbol size and figure-ground contrast etc. within allowed ranges for value or input (Meng, Zipf et al. 2008, p. 5). Since we are using Google Maps for this

[16] The only usage of electronic map-based support was in their vehicle where GPS navigation systems were used to support wayfaring. Since this is a part of the phase where the emergency response is on their way to the scene of incident, and not during the emergency response itself, it can be considered less relevant to this thesis.

prototype, there are built-in alternative for representation. The most obvious feature of the application is the user's ability to change view from the standard flat view to a satellite view enabling new representations of buildings, streets and landmarks. In regards to symbolisms, several abstract representations (e.g. square boxes to represent buildings) are now replaced with satellite images, thereby eliminating the abstraction. This would imply switching from using standard icons to combination icons or in some cases exclusively use concrete icons.

To summarize we can gather these six interaction options in Table 8.3-1 which is adapted from (Meng, Zipf et al. 2008, pp. 4-5).

Table 8.3-1: Overview of interactions used in prototype

Interaction	**Description**	**Interaction trigger**
Panning	Stepwise move to the map towards different directions.	Finger gesture: using fingers to drag or swipe towards edges.
Zooming	Enlarging or reducing the display window without content change.	Finger gesture: using built-in zooming controls or pinching or spreading[17] the screen with fingers.
Hiding and revealing	Visually hiding or revealing certain objects.	Menu option: either automatically specified through desired task, or button pressed to hide/show item.
Focusing	Clicking a certain item to retrieve its detailed information.	Item clicked: the desired item is clicked to display detailed information.
Tuning of visualization parameters	Changing the viewing angle or graphic variables (color, texture, symbol size, figure-ground contrast etc.)	Menu option: set by pressing the menu option to switch view.

[17] In their development kits neither Apple nor Android separate the continuous gesture of moving two fingers towards each other (pinching) from moving two fingers away from each other. The latter is referred to as *spreading* in this thesis (Apple 2010).

8.3.2. Degree of control

In Chapter 7, several suggestions on levels of automation were discussed. However, the majority of studies agreed on a low level of automation as the optimal approach to achieve non-intrusive decision support. It is also stated in (Meng, Zipf et al. 2008, p. 4) that the user's interaction should be kept to a minimum, suggesting that several automated features should be included. The application should possess the largest adaptability and require the least interactivity.

Since screens of mobile devices with map interfaces only display a portion of a map, jumping automatically between different portions of the map may cause the user to lose sense of place or experience discomfort or frustration with the zooming or panning space (Harrower and Sheesley 2005, p. 82). This phenomenon is called *navigational trauma* and should be avoided by regulating the degree of control the system has. Therefore the system has no automatic panning or zooming included.

Usually, map-applications that are solely meant for navigational interaction (e.g. panning and zooming) rely on swipe, drag and pinch gestures alone. This application however, will have several touchable map markers spread over the map that restrict other map features from using the same the physical screen area. This reduces the total physical area available for the user to perform other actions, such as panning and zooming. This implies that small screens can potentially get too overcrowded if the map marker count is too high, thus preventing others interactions mechanisms from functioning properly. It should be mentioned that implementation of other gestures may allow interaction even though the screen is overcrowded. The map marker count should therefore be regulated under normal circumstances where additional interactions mechanisms are not implemented.

However, this problem will automatically be regulated by the assumption that limits the size of the operation to a middle-sized operation (see Section 9.1.1), which would never include a map marker count that would clutter the screen. It is also assumed that the user is an expert not making novice errors. The zoom level that follows with default map interfaces for mobile devices, such as Google Maps, does not restrain the user from zooming too far in or out. If the user zooms too far in or out the overview can get either too detailed or too unclear. If novice users were enlisted as potential users as well, this feature should have been regulated, e.g. by only allowing zooming in or out to a certain level. This would force users to always maintain a proper overview of relevant information. Another important topic is error prevention. This is explained in previous chapter as a necessity to maximize effectiveness and general usability, while reducing irritation and required attention at the same time.

Whether an incident commander manages to geographically allocate resources in the indented position is not possible to verify for the application. However, the input of resource type or resource count can be controlled based on centralized data, such as availability count. Only available resources should be presented as selectable (e.g. on a list form), to prevent the incident commander from allocating unavailable resources. Simultaneously, when defining the number of resources to allocate, the interface should be presented as a drop-down or spinner to only allow the incident commander to select a valid count. This way, the user will never try to allocate more resources than available. It is considered necessary to let the system take control over user input in this prototype, as both the nature of the situation and the user's attention span suggests that errors are plausible.

Since the prototype will switch between different views from time to time (e.g. map views and list-based views), the user should always initiate these view switches himself. If the system switches between views automatically, navigational trauma may occur. Automated switches might also cause confusion for the user. Therefore no switching between views should be done automatically. Likewise, if any filters are activated or deactivated automatically, the user should be notified. In general, the user should always be made aware when the system is in "automatic"-mode, e.g. where the map might automatically pan or zoom. This way the user always knows when to expect automation and when to interact, thereby bringing up feedback as a suitable design principle (see Section 9.3.1).

8.3.3. Method of control

In (Rogers, Sharp et al. 2007, pp. 64-78) four fundamental interaction types are defined to help conceptualize the design space:

1. *Instructing interaction* – where instructions are issued by users to a system. This could be done by typing or verbalizing commands, selecting options from menus, pressing buttons etc.

2. *Conversing interaction* – where the interaction between the user and system is dialog-driven. Through an interface or typed-in questions/answers the user interacts with the system and receives responds via text or speech output.

3. *Manipulating interaction* – where manipulating (e.g. opening, holding, closing and placing) objects in either a virtual or physical space allows the user to interact with the system.

4. *Exploring interaction* – where interaction is driven by movement in a virtual environment or physical space.

The main interaction for this prototype is an *instructing* interaction – an interaction where users issue instructions to a system. This is the preferred interaction for two main reasons: (1) interaction based on instructions issued from the users is quick and efficient; (2) it is fitting for tasks where the actions are frequently repeated (Rogers, Sharp et al. 2007, pp. 64-65). Even if this is not necessarily the most efficient way to handle the interaction, it is still most likely the preferred interaction. It is well-known that interface skills are mostly acquired through exposure and repetition, and the instructing interaction is probably the most natural interaction. Thereby, it is likely the most preferred interaction as well.

This is illustrated by (Harrower and Sheesley 2005) with an amusing example: the QWERTY-layout for typewriters and keyboards is unquestionably the most preferred layout. To some people it is the only known option. However, since QWERTY was originally designed as a layout to avoid mechanical hang-ups, several QWERTY-variation and other layouts (such as Dvorak and Colemak) exists. But they are still very uncommon even though they theoretically offer ergonomic benefits, better productivity and reduced chances of strain or carpal tunnel syndrome (Baker 2010). This is an excellent illustration of how something that was clearly invented to make typewriting *intentionally inefficient,* is still the preferred option amongst users today. It is also pointed out how this was a machine-centric solution because it was not the needs of the users that dictated the work mode, but rather the limits of technology (Harrower and Sheesley 2005).

In addition, a map-based interface provides possibilities for *exploring* interaction by allowing the user to interact simply by moving in a physical space registered by GPS-tracking or other location-based sensors. The built-in map applications on modern telephones have interaction options for default actions, such as panning and zooming. Since this prototype is developed for the Android OS with their built-in Google Maps-component, map handles for general users are predefined. These rely heavily on finger gesturing. Using dragging, swiping or pinching the map reacts accordingly. For mobile device with trackballs, those can be used as well to control respectively panning and zooming. The prototype is built as an independent application; however it utilizes Google Map Services to render maps and thereby inherits the default map handles. These handles are retained and function in the same way in the prototype. There are many desired features that are not provided by Google Map Services, and as a result several features have been implemented on top of the map.

Hiding and revealing items are not default features, and these features are made available through the use of menus and menu options. By allowing the user to press button to either hide or show an item, this interaction is layered on top of the map. The same goes for tuning of visualization parameters. This is also handled by menu options to make it easier for the user to control the options. Instead of setting options before entering the map view, or in a separate control panel, this is controlled by the user within the application. This is also done with the map visible so that all changes are done in front of the user. The user will observe all changes as they happen. This is done intentionally to reduce the user's confusion.

Multimodal interfaces have been discussed previously in this thesis, and multimodal interaction possibilities do exist. However, it is not implemented as a part of this prototype. This thesis presents a prototype exploring a mobile support application in a domain relatively unfamiliar with the usage of mobile devices for task-related support; therefore it is seen appropriate to not include this in such an early stage. But multimodal interaction, such as speech gestures, is very relevant and tangible topic for future work within this field.

Chapter 9

Prototype theory

> *"(1) Prototypes are for traversing a design space, leading to the creation of meaningful knowledge about the final design as envisioned in the process of design, and (2) prototypes are purposefully formed manifestations of design ideas."*
>
> *(Lim, Stolterman et al. 2008)*

Within the fields of HCI and design, the roles of prototypes are well established. Prototyping has been recognized as efficient and effective way to develop UIs for some times (Rudd, Stern et al. 1996). The term prototype has been used for centuries, but the modern definition presented in Encyclopedia of Small Business (Gale 2010) as *"working models of entrepreneurial ideas for new products"*. This is a general definition, but a more relevant definition is presented in (Lim, Stolterman et al. 2008). The authors define *prototype* as a specific kind of object used in the design process. They further go on to saying that the necessity of prototypes within this field is both obvious and unquestionable. So while the concept of prototyping might be ambiguous, it is still a vital part of the design process.

The authors also cite (Floyd 1984) to point out an important difference between prototyping amongst designers and general software engineering (SE). While software engineers in general use prototypes to identify and satisfy requirements, designers use prototyping to communicate the rationales of their design decisions. Designers explore solutions in a design space by framing, refining and discovering possibilities. By referring to (Schön 1984) they also point out that the non-requirement-oriented prototyping carried out by designers is flexible rather than rigid, reflective rather than prescriptive, and problem-setting rather than problem-solving. A final principle defined as *the fundamental prototyping principle* is presented:

"A design idea that satisfies all the identified requirements does not guarantee that it is the best design since a number of ways can meet each requirement. If the focus of prototyping is framing and exploring a design space, what matters is not identifying or satisfying requirements using prototypes but finding the manifestation that in its simplest form, filters the qualities in which designers are interested, without distorting the understanding of the whole."

(Lim, Stolterman et al. 2008)

9.1. Prototyping method and scope

To determine the manifestation dimensions of the prototype, the *economic principle of prototyping* is used in this thesis. It is defined in (Lim, Stolterman et al. 2008) as the most simplest and efficient way to make possibilities and limitations of a design idea visible and measurable. By using this principle as a guideline, the prototype can be scoped in a systematic and rational way to best suit the size, area of interest and time limit for this thesis. Since we are only interested in exploring certain parts of the design space, we can filter out the unnecessary features. The term *filter* is defined by the authors as screening out unessential aspects to extract knowledge from the interesting parts more precisely and more efficiently.

This is also in line with timeboxing. The practice of timeboxing is used only in project where the schedule is the most critical factor. The term *timebox*[18] is presented in (Ambler 2000) as: *"the basic idea being that you set the end date of your timebox (your iteration) and reduce the scope of your efforts to meet the schedule"*. While this is a common practice used to get project back on their tracks, it can also be a good way of scoping the prototyping according to the time available.

9.1.1. Prototype assumption

To scope the prototype created for this thesis, several assumptions are made. This means several aspects of the possible design space are neglected:

1. It is assumed that *information about resources* is available to the incident commander at all time. This means that the prototype will not be exploring issues such as network instability, database failures, storage capacity limits and similar matters that might affect the availability of resource information.

[18] The practice of timeboxing is further explained by a figure in Appendix A.

This way we can eliminate handling of unexpected problems with the information flow.

2. It is assumed that each application will only be *used by one person at a time*, in this case the incident commander. This means each involved incident commander will have his own device. Whilst the traditional maps are printed at high resolutions and may be unfolded to a large physical size, the mobile screens are of very limited physical size and often have low resolution. In (Hang, Rukzio et al. 2008) it is clearly concluded that lower resolution and lower physical size both affect the user experience and productivity negatively, hence it should be noted that this is only meant to be used by a single incident commander.

3. It is assumed that *some resources are already allocated* when the incident commander either arrives or begins using the application. The information about resource allocation done prior to the incident commander's arrival, is available when he first begins his interaction.

4. It is assumed that the scale of the imagined emergency is set to require a *middle-sized operation*. This means approximately 20 units of personnel involved, and a limited size of both resources in use and resources available for allocation. This is done to prevent our prototype to cover the scale from minor trifles to major crisis, and rather focus on a more plausible and typical situation.

5. It is assumed that certain resources are meant to be *permanently allocated*, therefore not supposed to be moved. This is primarily deployed equipment with tracking devices. This way we can limit the necessary functionality of moving and delete allocations to only concern certain resources.

6. It is assumed that incident commanders will *not be using the prototype simultaneously*. To specify, the resource allocations performed by incident commanders will never result in *race conditions*[19] or other problems related to concurrency or synchronization.

7. It is assumed that *resources know when they are being allocated or reallocated*. In an actual emergency situation the resources (e.g. field personnel) must be notified when the incident commanders make new

[19]*Race Condition:* "A cause of concurrency problems. Multiple accesses to a shared resource, at least one of which is a write, with no mechanism used by either to moderate simultaneous access." (Levi 9 2011)

allocations or updates (either status updates or reallocations), so that they can adapt accordingly. For this thesis it is assumed that the sending and receiving part of the notification is successfully accomplished, which implies that when the incident commander performs resource related updates, the resources will in fact change to the desired state or location.

9.1.2. Types of prototypes

Based on a chart presented in (Borysowich 2007) we can describe the different types of prototypes explored in this thesis.

Table 9.1-1: Types of prototypes explored in this thesis

Type of prototype	Desired purpose	Fidelity and characteristics	Intended evaluators
Concept prototype	Study of technology acceptance amongst the intended user group.	Low-fidelity. General screenshots and paper prototypes.	Domain users
Feasibility prototype	Determine which interfaces, interactions and tasks are most relevant for scope.	Low-fidelity. Task-specific paper prototypes and walkthroughs of steps.	Thesis supervisor, Advisory board
Horizontal prototype	Explore possibilities with device and interface. Scope the needed functionalities.	Mixed-fidelity. Representative images on a mobile-driven solution.	Thesis supervisor, HCI-students
Vertical prototype	Framing and refining functionalities. Discover technological limits and possibilities.	Mixed-fidelity. Programmed prototype running in an emulator.	Thesis supervisor, analytical experts
Vertical prototype	Final prototype for this thesis. Evaluate the increase in value amongst the intended user group.	High-fidelity. Prototype running on an actual device in context.	Usability experts, domain experts

The first *concept prototype* was made during the case study prior to this thesis. It was very low-fidelity paper prototypes with screenshots not particularly representative for the specific scope in this thesis (Joshi and Torp 2010, p. 18), but focusing more on the whole concept of mobile devices being used in emergency response. Since the purpose was to focus on technology acceptance amongst users within the emergency agencies rather than the usability of the prototype, the prototype remained at a basic level to be used only as *proof of concept*[20]. In (Rudd, Stern et al. 1996) the objective of low-fidelity prototypes is described as *"to depict concepts, design alternatives and screen layouts, rather than to model the user interaction with a system"*. Instead, a proper explanation of imagined functionalities was thoroughly presented and manifested with a paper prototype.

After scoping the problem area for this thesis the prototype evolved into a *feasibility prototype* as related tasks were defined and desired functionalities became clearer. Looking back at experiences documented in (Norros, Hutton et al. 2009) where lack of understanding prevented the development of a successful solution, this prototype was evaluated by the advisory board to collect necessary feedback before deciding upon which interface and interactions were best suited for the problem area. During the evaluation, a simple scenario was presented to the advisory board and a walkthrough of screenshots was presented and discussed. This prototype was also continuously discussed during meet-ups with the thesis advisor.

After spending time on low-fidelity prototypes the *horizontal prototype* represented the horizontal aspects of the prototype in relevance to the task of resource allocation. When comparing the prototype to mobile solution that meets all requirements presented in the TYR-rapport (Nilsson 2010b), it does not cover all features; however, for the scope of this thesis, and when looking at resource handling isolated, it can be regarded as an horizontal prototype. Therefore, this was the first step into a higher level of fidelity.

By using the Android-emulator[21] to show static maps, simulated markers and screenshots, the prototype became mixed-fidelity. The primary purpose of this was to explore what possibilities laid within the Android OS, and which of these options were relevant and realistic in relations with the time constraints of the thesis. Through this process the needed functionalities to evaluate the hypothesis through the prototype were scoped down. During this process several of the assumptions mentioned in previous paragraph were drawn. This process reflected the practice of timeboxing being used where limited functionality is working quickly is preferred rather than waiting for a comprehensive system to develop (O'Dell 2011). This was

[20] *Proof of concept*: evidence that demonstrates that a business model or idea is feasible (InvestorWords 2011)

[21] The Android-emulator is a part of the *Android SDK and AVD manager* which is a part of the SDK Tools that comes with the Android SDK (Android 2010b). This is further explained in Section 10.2.2.

also discussed and informally evaluated by HCI-students[22] during a similar walkthrough as done with the feasibility prototype.

The first *vertical prototype* was the most time-consuming prototype as it required a fully developed interface. Programmed for the Android OS it was aimed for a wide range of mobile devices, however none specific in mind (see full description of the technical platform in Section 10.2). Since this was still just being prototyped to be used in an emulator, several features could not be implemented such as positioning of user by GPS-coordinates, map loading over mobile network, finger interaction etc. However, it was the best solution for framing and refining the main functionalities as well as exploring technological aspects, both positive and negative. The positive aspects being unknown possibilities and the negative being enforced restrictions. The time spent in during this phase was justified as the step over to the final high-fidelity prototype would be small if everything was developed for mobile devices from the beginning. Discussions regarding functionality, development and challenges were carried out with thesis supervisor during weekly meet-ups, but this was also evaluated in two rounds: first in a usability test, then analytically by experts (see Chapter 12).

Some modifications were done after the two rounds of evaluations, yet by the time all feedback from the last evaluation was analyzed and structured, it was not time enough to further develop the prototype. However, Chapter 13-14 presents the results from the evaluation, and design implications are laid out to describe the findings from the evaluations.

9.2. Prototype fidelity discussion

There were several reasons for developing a high-fidelity prototype in this thesis. As mentioned, the primary reason was that the gathered knowledge from relevant work and the EMERGENCY-project made this problem area highly suitable for a prototype evaluation. This is in line with the next reason, which was that the knowledge gathered in the EMERGENCY-project could not be justifiably evaluated with a low-fidelity prototype. It was time for a proper prototype; hence a high-fidelity prototype was the preferred option in regards to feedback, evaluation and validity.

[22] HCI-students from the two HCI-courses INF1500 (Introduction to design, use and interaction) and INF4261 (Human-Computer Interaction) at Department of Informatics participated in an open discussion of the prototype.

9.2.1. High vs. low fidelity prototyping

Some studies try to prove that both fidelities have a place in the design process (Rudd, Stern et al. 1996; Petrie and Schneider 2007), but it is mentioned in (Rogers, Sharp et al. 2007) that paper prototypes can be used as core tools in development of mobile solutions. (Heaton 1992) suggest that up to 80% of interface and design problems can be solved with low-fidelity prototyping. However, this is also contradicted by several other studies such as (Sinha and Landay 2002) claiming that high-fidelity prototypes generate the best results for devices and problem areas similar to this thesis.

In (Rudd, Stern et al. 1996) a neutral table is presented with the advantages and disadvantages of the two types of prototyping, from which it can be argued that high-fidelity is the better option for this specific thesis. The mentioned table is used as basis to present relevant advantages and disadvantage in Table 9.2-1, hence only the relevant items from the original table are kept:

Table 9.2-1: Advantages and disadvantages with different fidelity types

Type of fidelity	Advantages	Disadvantages
Low-fidelity prototype	- Evaluate multiple design concepts. - Useful communication device. - Address screen layout issues. - Proof-of-concept.	- Limited error checking. - Poor detailed specification to code to. - Facilitator-driven. - Limited utility after requirements established. - Limited usefulness for usability tests. - Navigational and flow limitations.
High-fidelity prototype	- Complete functionality. - Fully interactive. - User-driven. - Cleary defines navigational scheme. - Use for exploration and tests. - Look and feel of final product. - Serves as a living specification.	- More expensive to develop. - Time-consuming to create. - Inefficient for proof-of-concept designs. - Not effective for requirements gathering.

It is obvious that the two major columns of this table are the advantages of the high-fidelity prototype, and the disadvantages of the low-fidelity. Nonetheless, it is still interesting to look closer at what exact benefits one can achieve with high-fidelity prototyping and how that can relate to this thesis. The first advantages are the benefit of *complete functionality and interaction*. These are vital to emergency response, especially due to limited time and low attention span combined with a high level of stress and distraction. Exactly what the system can do, and how it is done, should therefore be clear to the incident commander.

To illustrate the process through solving a task, the *well-defined navigational scheme* is also an important factor. Since incident commanders are carrying out their work with pen and paper today, their knowledge of task solving on the mobile device medium is limited. They should therefore be exposed to mobile devices to get the *look and feel of the final product*. Combining these advantages with the most obvious advantage, the fact that high-fidelity prototypes are *user-driven*, makes the case for high-fidelity very strong for this thesis.

As previously mentioned, it will undoubtedly also elevate the evaluation since the number of systems function and behaviors that can be simulated with-low fidelity are limited. And if they are simulated, how realistic are they? Also, several potential evaluation criteria such as accuracy, reaction time, system delay, interaction etc. are not up for evaluation without a high-fidelity prototype. This is also backed up by (Sinha and Landay 2002) who concluded that *"for each of the designers, the sketched designs were difficult to evaluate"*.

9.2.2. Wizard of Oz

Before moving onto higher fidelity prototyping, the *Wizard of Oz*-method for prototyping was considered as the final prototype. *Wizard of Oz-prototyping* is defined as experiments where humans take the place of a technology (Bradley, Mival et al. 2009). More precisely, it refers to experiments where humans, either with or without the participant's knowledge, simulate the desired automation of a system. The technology is usually yet to be developed, but sometimes not mature enough to perform at the desired level. Since the simulation itself is not dependent on the restrictions or capabilities of currently available technology, future technology can also be investigated experimentally. Therefore this technique has been used for a long time, and while the practice has evolved with the technology, it is important to point out the old roots of this technique.

Modern studies utilizing the Wizard of Oz-paradigm date back to at least 1991 as presented in (McInnes, Jack et al. 1997). This technique is also popular when exploring user's preferences as seen in (Sinha and Landay 2002). Several researches have successfully used the Wizard of Oz-method during data gathering experiments (Sinha and Landay 2002; Höysniemi, Hämäläinen et al. 2004; Kato, Fukumoto et al. 2006; Lee and Billinghurst 2008).

It was obvious that this prototyping method carried several benefits, one of which to avoid implementation of multimodal interaction, such as hand gestures or sound-driven commands. However, the mentioned advantages of high-fidelity prototyping were still the strongest. While this was not relevant for the prototypes of this thesis, it is still a relevant paradigm for parts of the functionalities of this prototype. Although it is assumed that the position of resources (e.g. field personnel) is given in the prototype, this could have been further explored by using Wizard of Oz. If a working prototype had the tracking and live-feed portions of a solution up and running, but yet not implemented the geographical positioning of a resource, it could have a person manually updating the position data. The rest of the functionalities of the application would function as desired as the parser does not know or care about the origin of the data, i.e. whether it was enter manually or automatically fed by satellite tracking. This way the limitation of not having all functionalities working 100% would not prevent testing and evaluating the working ones.

9.3. Design guidelines

Before looking at the design guidelines, design principles are presented to help identify what features and aspects of the design that should be provided. As presented in Section 6.2.1, the tasks should be solved with list interfaces in addition to the main map interface. This implies that guidelines should be followed when shaping the lists and accompanying components. The map layout comes with colors predefined, hence it is important to follow guidelines on how to present information with colors in relation to theoretical guidelines, and in relation to the map colors as well. First, the design principles are presented and explained, before detailed descriptions of the design theory used in the prototype in presented.

9.3.1. Design principles

Four main design principles have been used during prototype development as a result of the considerations presented in Chapter 4–7: visibility, feedback, constraints and consistency. *Visibility* allows the user to see all possible options when solving a task, i.e. not overwhelming or distracting with redundant information, yet still visualize all possible actions. Visibility indicates crucial distinctions (Norman 2002, p. 422). A related topic is to also keep navigation visible, i.e. presenting where the users are within the user system and how they got there (Constantine and Lockwood 2002, p. 4).

The second design principle is *feedback*, where the system immediately gives a response to input or other interaction. If the incident commander uses a finger gesture to pan the map, the system should respond right away. This could be done by either panning the map immediately, or by indicating that the gesture is understood and that the system is working, e.g. with a progress indicator. If the system responds several seconds later, the delay would be unbearable. This principle also allows the user to know when the system is working, and when it is just waiting for input: *"A system is insistent if feedback to the user is sustained and demands some user reaction"* (Gram and Cockton 1996, p. 84).

Consistency is important to make the system predictable and structured. Consistency is about allowing user to transfer knowledge, information and metaphors from one part of the system to another, i.e. generalizing from specific situations to similar situations (Gram and Cockton 1996, p. 41). However, as mentioned by Gram and Cockton (1996) it is difficult during design or development to know for certain which situations that the user will consider similar.

The final design principle is constraints. *Constraints* as a design principle are understood as methods for restraining the interaction possibilities for any given situation (Rogers, Sharp et al. 2007, p. 31). This implies only presenting a selection of permissible actions by either removing illegal options, or disabling them by shading them out. This is related to the concept of visibility, i.e. only displaying valid options. This is an important principle when minimizing user errors as explained under Section 8.3.2.

9.3.2. List

In (Brown 1999, p. 41) several guidelines are presented to ensure that lists are clear and easily usable. In accordance to these principles, lists should be redesigned to provide the best interaction possibilities, while still maintaining the intended structural benefits of divided presentations. The following list sums up the design modifications related to lists in the prototype:

1. *List headings* – the lists are made with headings to define the list content. While only two types of resources are defined in this prototype, this would factor in more if two levels of lists were used or additional types were added.

2. *List form* – items in the list are listed only once per line. Some structures provide list-resembling appearances, but to properly divide and distinguish each list element from each other, only one element is presented per line. If the list

element has following description or illustrations, it is much easier to remain coherent if each line has its own line.

3. *Option listing* – the options in the list are arranged in such a manner that the most frequent option appears at the beginning of the list. This is to provide an efficient structure. The idea behind this is similar to features seen on mobile phones where the last called person appears at the top of the phone list when making outgoing calls or the person you last sent a text message appears at the top of the recipient list.

4. *Variable-length listing* – for lists where the data extend beyond one display screen, the user should be informed that the current view is not covering the whole list. It can be represented with text, icons, screen numbering or scrollbars.

9.3.3. Color

Using colors properly can aid the user interaction by allowing the user to easier locate or identify classes of display information. This will result in both increased speed and reliability.

> *"Color is a highly salient feature of a stimulus in human visual perception. Variations in colors are therefore highly effective in drawing attention."*
>
> *(Brown 1999, p. 66)*

Brown presents a total of 27 guidelines for color principles. However, most of them are neither relevant nor necessary for this prototype. The following list defines the key principles and gives a description in detail for each principle that was used in the prototype:

1. *Overuse of color* – colors should be used conservatively to maintain structure and overview. There are three reasons to why this is an important point: (1) arbitrary usage of color coding may cause screens to appear busy or cluttered and may overshadow truly useful information in color codes, (2) high frequency of color coding may reduce the likelihood of appropriate and quick interpretation, and (3) as the number of color coding goes up (e.g. in highlighting), the effectiveness of the color coding goes down. In this prototype the colors other than the two primary resource type colors are only used when

the user changes the view. This way color is only brought up as an aid in specific scenarios.

2. *Color for emphasis* – as variation in colors attract considerable attention, colors can be used to highlight related data spread around the map. To distinguish the two types of resources (i.e. equipment and persons), the colors black and blue are used. These colors were selected for three reasons: (1) they are in contrast to the lighter colors of the map, (2) they are not of same type, but they are still of the same category; hence their coloring should not be radically different, and (3) they still offer the possibility of highlighting (e.g. new entered data, attention-requiring data or out-of-tolerance data). Also, when reallocating a resource on the map, all other resources are tuned down to a grey color to allow focus on the particular resource being reallocated.

3. *Color for status* – as an aid to provide contextual or temporal status information, coloring can provide additional overview. All resources have a parameter for level of priority, and upon request this can be illustrated with color codes. For example, the prototype could include mapping of priority by color: green for low priority, yellow or orange for medium priority, and red for high priority. This way priority can be represented with color as well.

4. *Consistency of color coding* – as there are several different tasks that can be solved with this prototype, and more as the prototype gradually becomes more functional, it is important to ensure consistent use of color coding between screens and tasks. All color codes are defined globally within the code of the prototype; henceforth it is not possible for two instances of a color to represent contradicting information.

5. *Use of blue color* –the use of blue is avoided. While the resource color for persons is dark blue, it is much closer to black than to the lighter variations of blue (i.e. powder blue, light blue and baby blue). The reason for wanting to avoid the usage of is primarily because of its low contrast and inherent problems in visual focusing (Brown 1999, p. 75). It is also a principal color in maps for water indication. Hence the exception would be to symbolize water or cold, but that is not relevant in this prototype.

6. *Color contrast* - color contrast should also be taken into account. Contrasting background colors helps focusing on the important part of the marker. White colors are consequently used inside the black or dark blue markers to create maximal contrast between background and foreground color. Thirdly, black or dark blue is used as a base color.

Based on these six principles, several decisions were made in the prototype in regards to coloring. It was important to avoid contradicting use of colors, so modifications were used as more and more features were added. These decisions are presented in Table 9.3-1.

Table 9.3-1: Color decisions in the prototype

Component	**Color**	**Description**
Type-based coloring	Dark blue and black	For each resource type a different color is assigned, in this case dark blue and black. These are in strong contrast to the map without being of warning or alerting color such as yellow or red.
Selection	Teal	To easily distinguish selection from everything else, selected resources must stand out from the rest. Highlighting is therefore colored teal.
Priority	Red, yellow and green	When the user wants to display markers colored on priority rather than resource type, an option allows for red, yellow and green coloring of resources based on the level of priority.
Availability count	Grey/Red	In lists or information boxes where the resource count is displayed it is vital to alert the user if the availability count is less than a certain level. Dangerous levels or conditions should be alerted with the color red (Brown 1999, pp. 74-75).
Marker repositioning	Red and grey	When the user initiates a reallocation the map marker enters a drag-and-drop mode. The selected marker is colored teal while all other (less important) markers are colored grey.

A point should be made regarding color-weak users. For users with *abnormal color perception*[23] variations in color might not be noticeable. Map providers, such as Google Maps, provide color coded information about terrain and infrastructure in maps. It is common practice to color code different layers or details to distinguish them from each other. As these colors often derive from intuitivism to provide easy associations, open areas (e.g. forests, parks and fields) are often colored green. Google Maps[24], Finn[25], Gule Sider[26] all follow this principle. This is also common practice for most other map providers. Yahoo Maps[27] and Bing Maps[28] can be seen as exceptions with a more beige color for this terrain.

However, this is only applicable for 2D map renderings. Most map providers offer terrain view or satellite view, two options that would yield massive green-colored areas. Since the prototype of this thesis utilizes Google Maps, it is challenging to incorporate principles of universal design as 7 % of all male people suffer from red-green color blindness (Montgomery 2008). The color red is used in the prototype for several reasons as presented in the section above, thus it is not easily replaceable. To still ensure full usability for those with abnormal color vision a general principle should be followed: "*critical information should not be presented by color code alone"* (Brown 1999, p. 71).

9.4. Navigation

> *"Menus are easy to use as they facilitate recognition rather than recall."*
>
> *(Jones and Marsden 2006, p. 224)*

Designing for recognition rather than recollection is a well-used principle in general design guidelines. In *10 Usability Heuristics,* Jacob Nielsen present the memory phenomenon as one of his general guidelines for interface design (Nielsen 2005). *"How information is interpreted when it is encountered greatly affects how it is represented in memory and how easy it is to retrieve subsequently"* (Rogers, Sharp et al. 2007, p. 101). Thus, if we can use recognition (smell, touch, see, hear or taste) to trigger memory instead of only recalling it, we have a better chance of remembering.

[23] Brown (1999) purposely uses the term *abnormal color perception* instead of color blindness to emphasize that color-deficient people only have trouble perceiving certain colors hence the term color blindness could be inaccurate and misleading.
[24] Google Maps: *http://maps.google.no/*
[25] Finn Kart: *http://kart.finn.no/*
[26] Gule Sider Kart: *http://kart.gulesider.no/*
[27] Yahoo Maps: *http://maps.yahoo.com/*
[28] Bing Maps: *http://www.bing.com/maps/*

To exemplify this we can look at another division of the police department. When a victim or witness is asked to identify a perpetrator, they are often presented with several mug shots or line-ups with suspects. This is to aid them remembering the perpetrator by allowing them to recognize instead of recall. Now if they were asked to describe the perpetrator so that the police could draw a facial composite[29] without seeing any suspects upfront, they would have to rely only on recalling memories.

Since the prototype will be running in an Android-environment, it follows some restrictions put forward by the OS interface. The main menu is limited to contain a maximum of six buttons. If there are more than six menu options, then one of the six buttons are reserved for the MORE-button (which would reveal the rest of the options). Exactly why this is decided is uncertain, but it could be explained with *Miller's law* (Miller 1956, p. 81; Rogers, Sharp et al. 2007, pp. 105-106). George Miller presented his theory on short-term memory over 50 years ago, and his paper on working memory capacity is one of the most cited papers in psychology. His theory state that one can only store 7±2 items simultaneously, so any more elements than this might overload the memory of the user. While this might be beneficial to the user, it also raises some negative practicalities. First of all, designing a menu with two levels such as this places another burden on the user. Some tasks or functions might now be a part of another task's submenu; hence the user is forced to remember the location through a two-dimensional navigational structure (Jones and Marsden 2006, p. 225). Table 9.4-1 gives an overview of the different navigation mechanisms implemented in the prototype.

Table 9.4-1: Different levels of navigation

Menu	**Menu type**	**Text or icon**	**Description**	**Visibility**	**Necessary navigation**
Overlay menu	Icons	Icons	Two icons always present at the top of the map layer. Allows user to modify the visual components of the map.	Visible	*(none)*

[29] Facial composite: facial images drawn after eyewitnesses rendition

Menu	Menu type	Text or icon	Description	Visibility	Necessary navigation
Main task menu	Buttons	Text and icons	Bottom-aligned menu that allows user to navigate between tasks.	Hidden	Pressing the MENU-button will reveal the main menu.
Secondary task menu	List	Text	List-menu with remaining options that appears when clicking the last button in the main task menu.	Hidden	First pressing the MENU-button, then selecting the option MORE to reveal.
Resource context menu	Pop-ups	Text and icons	Popup-window that appears on top of the map layer to reveal resources handles when clicking a single resource.	Hidden	Clicking on an allocated resource on the map layer.

Chapter 10

Prototype presentation

The main purpose of this thesis has been to produce a prototype that can be evaluated and thereby validating and updating the information collected in the EMERGENCY-project so far. The prototype is the result of information collected about the context of use, and identification of the requirements for the indented user and organization. This chapter gives an in-detail presentation of the prototype. First, the technical platform and implementation is presented, and then a walkthrough is given of the features and functions of the prototype. Lastly, a set of screenshots are given to illustrate the functions described.

10.1. Why mobile phones?

> *"But in many situations a local leader need to move around outside the local control post from time to time, in which case the local leader will also benefit from using mobile devices."*
>
> *(Nilsson and Stølen 2010)*

The main motivation for using mobile phones is the need to include ICT-support with familiar, easily accessed and highly portable equipment. The mobile phones as computing platforms are both pervasive and personal. They tend to have an intimate relationship with their owner, and they are almost always on (Raento, Oulasvirta et al. 2005). Raento, Oulasvirta et al. (2005) further suggest that the personal nature of mobile phones make them suited for context-aware computing, and especially smartphones as they are highly programmable. Emergency responders already do much work over mobile phones, and mobile phones are more susceptible to uncertainty and unplanned (Way 2009, p. 40).

However, it is obvious that some tasks are better supported on portable computers rather than mobile phone as screen sizes may become too small (Nilsson and Stølen 2010, p. 8). A perfect device for such tasks would be something in the emerging tablet-category, e.g. Apple iPad or Samsung Galaxy. During the startup of the EMERGENCY-project, such tablets were not available. But as presented earlier, most challenges lie in the impact of the small screen size. Therefore, if the problem is solved on mobile phone it is most likely solved for tablets as well. We are designing for mobile phones, but the principles and interactions should be transferrable to other equipment as context may change several time during an emergency response, and different equipment is likely to be used (Nilsson and Stølen 2010, pp. 8-11)

10.2. Technical platform

Before presenting the prototype, the technical aspects of the prototype are presented to give insight about platform, tools and compatibility. Several platforms for mobile device development exist, and this section gives an in-depth presentation of the developer environment.

10.2.1. Android OS

The prototype developed in this thesis is made for the Android OS. This was recommended in regards to the research context, and was also topical for future master students in the project. The thesis supervisor was also familiar with the Android OS which was helpful in the early stages of the development and convenient when the prototype began to take shape. Also, for future work it allows for exploration on all types of Android-driven devices with only small modifications. This could include evaluation of the prototype on other mobile devices from different brands with different properties, e.g. physical size, screen size, interaction etc. Also, it allows for easy porting to tablets running Android. However, the purpose of this prototype is to support the thesis objectives and research question, which are to explore resource allocation with map-based interface; hence the operating system is not of most importance. The functional properties of the prototype could easily be transferred to another operating system such as the iOS on iPhones and iPads, so this study is not platform dependent.

The prototype utilizes the built-in Google Maps to create a map-based interface. The Google Maps component provided by the Android OS is a standard map application featured on all Android-running devices. In regards to both appearance and interaction it is also very similar to the default map on iOS which is also Google Maps. Simultaneously, it resembles the online desktop version of Google

Maps which is familiar to most Internet users. The EMERGENCY-project has partners that can provide more accurate and more locally adapted systems and solutions for map and location-based services such as GeoData. However, the prototype is not dependent of detailed map layers. A fully functioning prototype has been built with the use of Google Maps. Also, GeoData's support for the Android OS is currently limited; therefore it was deemed the safest to use Google Maps. Lastly, since the Android OS is open-source the Internet is a huge resource for both inspiration and support, which is always helpful when developing on new platforms.

10.2.2. Eclipse IDE and Android SDK

A plugin has been made for the Eclipse IDE[30] that allows developers to work in an integrated environment when building applications. This plugin is called the *Android Development Tools (ADT)*[31], and allows Eclipse to integrate references, classes, error checking, logging and tracking possibilities, debug panes, custom XML-editors and many other helpful tools.

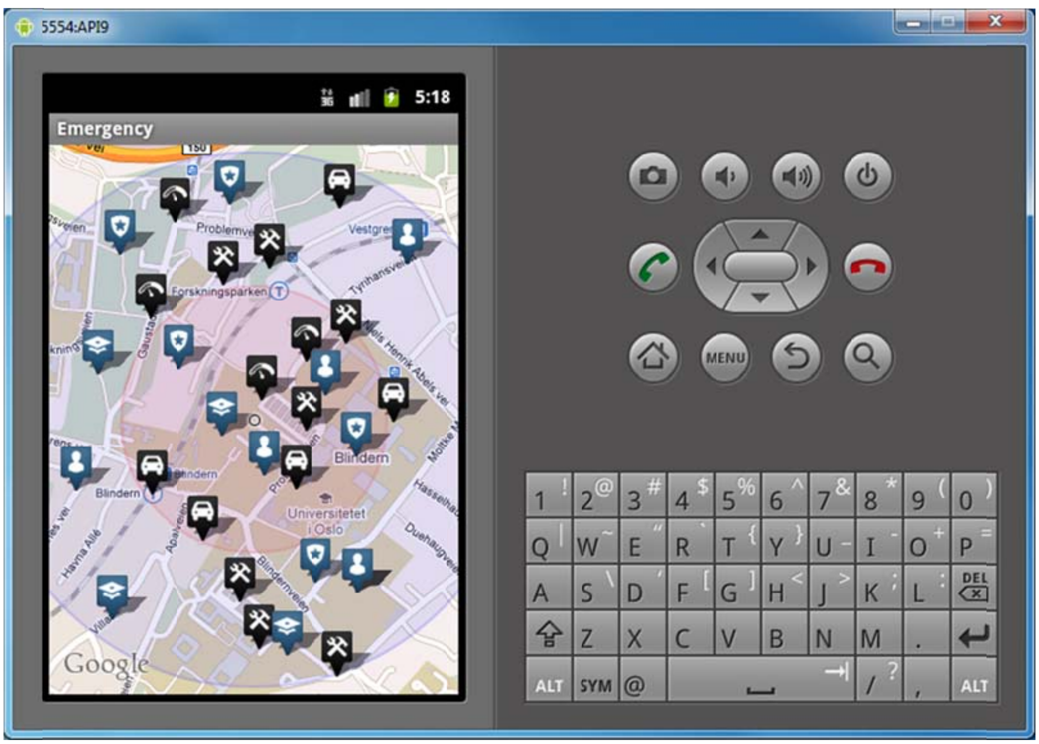


Figure 10.2-1: Screenshot of the emulator running the prototype

[30] Eclipse IDE: *http://www.eclipse.org/*
[31] Android Development Tools (ADT): *http://developer.android.com/sdk/eclipse-adt.html*

Via the Android SDK and AVD manager applications can also run directly on an Android-emulator (Android 2010b). The developer can adjust screen resolution, memory card capacity and OS-version, making it highly flexible and well-suited for functionality testing. Figure 10.2-1 illustrates how the emulator allows the user to interact with the prototype without using a physical mobile device. While this serves an important feature when developing, it can also be misleading as the appearance in the emulator may vary from the appearance when running mobile devices. This is partly due to different OS versions, but also because the custom skins mobile vendors puts on top of the OS. Also, it does not allow the developer to test features such as rotation gestures, touch sensitivity, GPS-positioning and phone functionality. A third disadvantage is the hardware requirements from the computer running the emulator. It runs very slowly on most machines, and the interaction and experience cannot be properly evaluated in an emulator.

10.2.3. Version and compatibility

The prototype was developed for the newest version of Android OS available when the development began. The prototype is made for version 2.2 or higher with target Google API level 8 and 9. The screenshot of the emulator (Figure 10.2-1) is running Google API level 9. The prototype has been tested on three devices: HTC Desire (Figure 10.2-2), HTC Hero and LG Optimus 2x, which was a state of the art telephone at the moment.

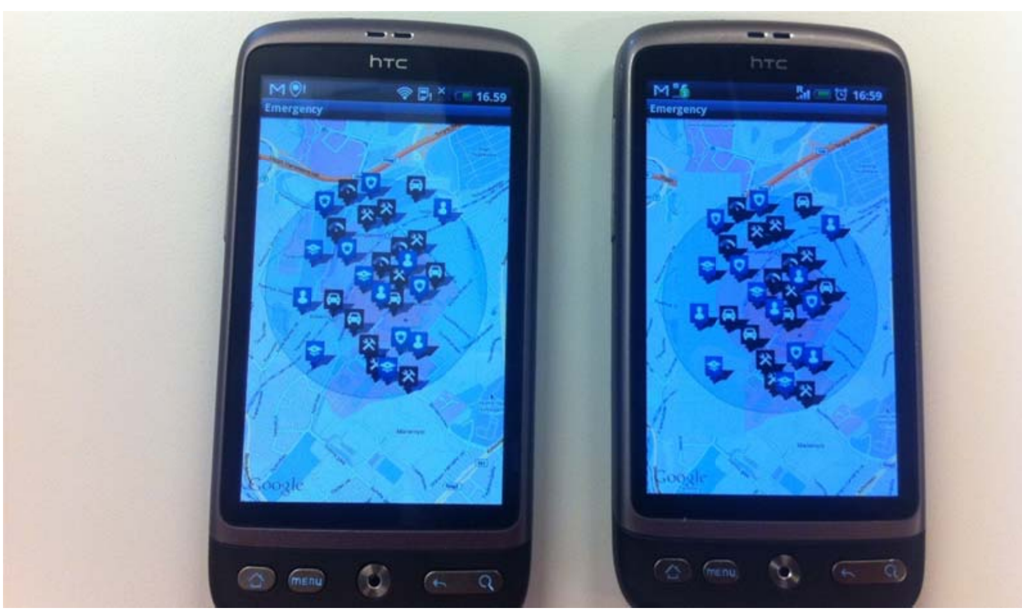


Figure 10.2-2: Two HTC Desire-phones running the prototype

10.3. Implementation

While the Android-core is programmed in C, applications are typically programmed with Java. That is also the case for this prototype, more specifically Java SE 6. The code is compiled with Android SDK Tools along with data and resources files. The code in its entirety can be found in Appendix I. The code itself is mostly straightforward Java, with the exception of some concurrency handling with *ReentrantLock*[32]. However, an outline can be drawn of the structure of the code to understand the relation between the different files and folders.

The design pattern followed is based on the *Model-View-Control (MVC)* paradigm. The MVC architecture divides the structure into three major components: model, view and controller. This way, input, processing and output are separated. This allows the view to be built only as a presentation layer upon rest of the structure, thereby not doing any processing itself (Kotek 2002; Morse and Anderson 2004, pp. 192-194; Eckstein 2007). It can therefore easily be modified or replaced, which is a very desirable and supportive quality in a prototype such as this. Figure 10.3-1 gives and overview of the structure:

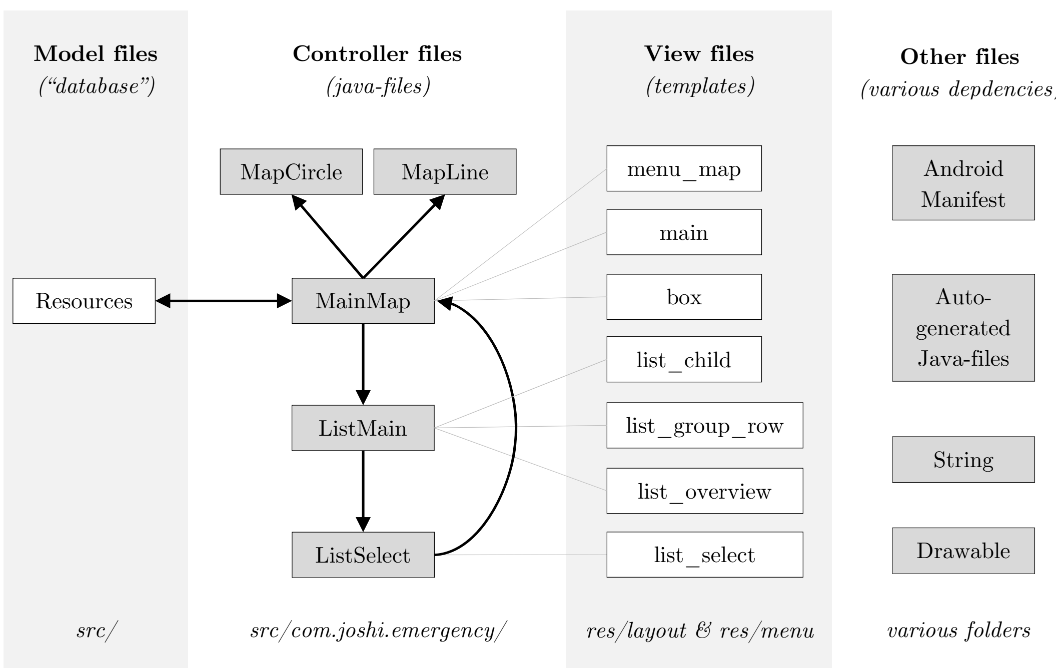


Figure 10.3-1: Structure outline of implementation

[32] *ReentrantLock* is a mutual exclusive lock found in *java.util.concurrent.locks.ReentrantLock*.

To simulate the external data being read into the system, all information about allocated and available resources, their details, and their positioning is defined in *Resources.java*. All data is stored in dynamic data structures, thereby making the rest of the code more flexible and scalable. The main file is named *MainMap.java*. It fetches the necessary details from the "database" (in this case just Resources.java), and draws the main screen (Figure 10.5-6), with all associated interaction event listeners, such as touch and gesture recognition. It also handles all filters and reallocation. To draw circles for operational area (Figure 10.5-3) and lines after reallocation (Figure 10.5-17) two other files are included: *MapLine.java* and *Resources.java.* For allocation the main two other separate files are used: *ListMain.java* and *ListSelect.java*. All these files reside in *src/com.joshi.emergency/*, while all .xml-files and graphics are located in *res/layout/* and *res/menu/* and text is mostly stored in *res/values/*. The rest of the prototype can be further explored in a used-friendly environment by importing the project into Eclipse IDE with Android SDK and developer tools installed (see Appendix I).

10.4. Prototype walkthrough

All mobile devices running the Android OS are obliged to include three buttons regardless of otherwise modifications to the OS (Android 2010a, p. 16): HOME, MENU and BACK. These buttons are essential to the Android navigation paradigm, and must be implemented via software, gestures, touch panels etc. In general, most modern mobile phones use physical buttons on the phone. Thus, it is assumed that these buttons always are available. The HOME-button is used to switch between applications and the OS, and cannot, or at least should not, be overruled by the application. However, the functionality of the MENU- and BACK-button can be adjusted.

10.4.1. Map and bounds

To ensure maximum utilization of the screen no menus are visible as default. As specified the function-buttons MENU and BACK are available as physical buttons below the screen. As the application is meant to present real-time automated and centralized information, various resources may, and likely will, be allocated and tracked before the application is launched. Therefore the default screen already has resources displaying. The map is the base layer of the application. It uses the MapView from the Google Maps external library to draw maps according to geographical positions of markers and operational area. While a future solution probably will include a more detailed and dedicated map solution, it is sufficient for the evaluation of this prototype. Also, it provides features that are desirable in a future version such as switching between different map views, e.g. satellite mode or hybrid mode. Switching between map views is done by using the secondary menu (Figure 10.5-11). On top of the map layer two circles are drawn (Figure 10.5-3). These indicate the *scene of incident* and *operational area.* The former is the inner red circle, and the latter the outer blue. As presented in Section 4.3.2, these bounds are mostly meant as guidance or assistance rather than strict borders, however they are visualized. They can easily be disabled if deemed superfluous (see Section 10.4.4).

10.4.2. Resources

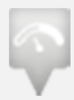
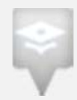
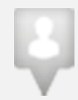
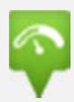
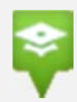
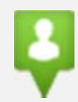
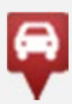
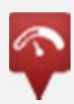
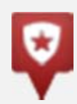
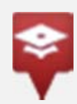
Each allocation includes one or more resources. Since all resources are either tracked or report their location manually, they can be linked to a physical location. The resources are shown in the map with a marker indicating where the resource is geographically located. Each of the two resources types is given a color, respectively black for *equipment* and dark blue for *people*. Within each resource type, three subtypes are defined to allow further visualization about the resource. Equipment may be divided into three subtypes: *vehicles* (e.g. cars, command trucks and motorbikes), *sensors* (e.g. speedometer, thermometer, biosensors, and lasers), and *miscellaneous* (everything else, e.g. road blocks, cordons, shields and floodlight). Human resources are split into *regular* (e.g. police officers and search party), *experts* (e.g. bomb experts, entry team and professional expert), and *others* (e.g. volunteers, dog patrols and humanitarian organization such as Red Cross). Based on these classifications, a total of six markers may occur in the map:

Table 10.4-1: Presentation of marker icons

Equipment			**Persons**		
Vehicles	Sensors	Miscellaneous	Regular	Expert	Other
					

When resources are either highlighted during *"find similar"* (see Section 10.4.3) or highlighted due to press, the color of the marker change to a teal color to indicate highlighting. Each marker may have up to six different colors, depending on what view or filter the user has selected, and whether the marker is highlighted or not. A full overview of all possible markers is given in Table 10.4-1. The rest of the color indications in explained further out in this chapter.

Table 10.4-2: Overview of all possible marker states

State	Equipment			Persons		
	Vehicles	Sensors	Misc.	Regular	Expert	Other
Default						
Greyed out						
Highlighted						
Low priority						
Medium priority						
High priority						

10.4.3. Resource details

Each resource allocation contains details that can be brought up. Common for both resource types is the need of *priority* to indicate the relative importance of the allocation. Equipment resources also include the *count* and whether the equipment is *staffed* or not. Person resources include *status* based on four predefined statuses, and *telephone number* in case the person needs to be contacted. While all people are assigned a telephone number in the prototype, it is also possible to not include a phone number. When a marker is pressed, these details about that particular allocation are presented in an information box.

Equipment	Persons

Figure 10.4-1: Resource details for persons

Figure 10.4-2: Resource details for equipment

In Figure 10.4-1 and Figure 10.4-2, the header defines the resource *[Kommandobil]*, while the subheading refers to the subtype of the resource *[Kjøretøy]*. The two next text fields are different since equipment and persons include different details, but the priority is a common detail for all allocations. As presented in Figure 10.4-1, priority is indicated with a *red* color when priority is at the highest level, and the other way around for lowest level which is colored *green* (Figure 10.4-2). For allocations of medium priority the color is *yellow*. This coloring based on priority corresponds with the priority coloring of markers which is explained in detail in the next section. Each information box also includes buttons for further actions connected to the resources in the selected allocation:

Table 10.4-3: Overview of buttons and actions

Button	Action	Description
	Find similar	Allows the user to highlight all other resources of the same subtypes, e.g. if the button is clicked while a motorcycle is selected, all other vehicles in the area will be highlighted (Figure 10.5-9). This is further explained in the next section.
	Reallocate resource	Pressing this buttons asks the user to confirm before initiating a reallocation. If the reallocation is cancelled before completion, the resource stays the same place.

Button	Action	Description
	Cancel allocation	This button is for canceling allocation, meaning the allocation is removed both from the map and from the centralized database. This action requires a confirmation from the user as it cannot be reversed. Resources in this allocation will immediately be available for new allocations after cancellation.
	Call resource	It is possible to assign a telephone number to persons. This button allows the user to call the selected person. Pressing this button will bring up a confirmation box before initiating a phone call. This button is only available for person resources, thus it is not visible in Figure 10.4-1.

10.4.4. Filters

The first two filters allows the user to only display resources of a certain type, hence the *"show/hide equipment" ["skjul/vis utstyr"]* and *"show/hide persons" ["skjul/vis personer"]* may be regarded as *resource type filters*. If the screens gets too overcrowded, or the incident commander only needs information on a certain resource, these filters may be used to reduce the amount of information the user has to process. The filters are accessed via the main menu (Figure 10.4-3 and Figure 10.5-10). The filter *"find similar"* is accessed via the information box that pop-up with the details about a specific resource. When pressed, all similar resource types are highlighted in a similar fashion as selection highlighting (Figure 10.5-9). This filter may be used in combination with other filters. This filter was activated via accessing a single allocation, but it is disabled by pressing the *"hide marked allocation" ["skjul merkede"]* that resets the highlighting and bring the view back to the default state. All allocation must be assigned a priority. Priority is an important factor in emergency situations in general, but especially important in the context of handling resources. Resource availability is often scarce, hence reallocation becomes a necessity. For reallocation, relative information on priority is vital to properly evaluate the situation and decide which resource to reallocate. Priority is therefore given an important function in the prototype. By selecting *"show priority" ["vis prioritet"]* in the main menu, each marker is colored according to the priority of the allocation, regardless of type. If no resource type filter is enabled, both equipment and personnel will have same coloring, thus only being separated by icon. However, if used in combination with either resource type filter or "find similar" it can show priority for only a scope of the allocations. All the mentioned filters are accessible via the main menu (Figure 10.4-3).

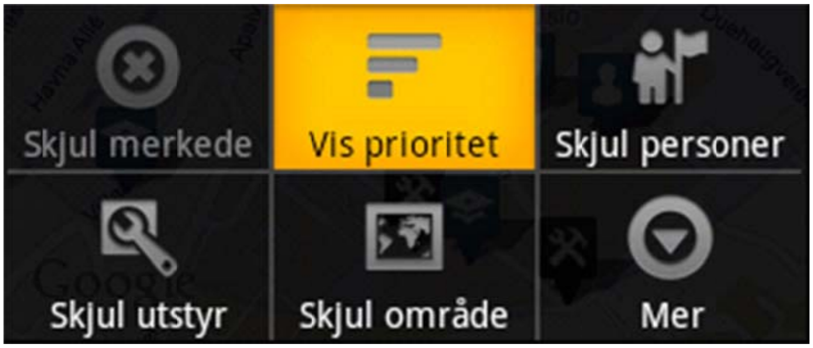


Figure 10.4-3: Extract of the main menu

10.4.5. Dialogues

Since some of the actions may cause severe trouble for both the incident commander and to the operation if accidentally initiated, some actions have dialogues that require the user to confirm before continuing. This is also a good way to minimize the chance of accidentally initiating undesired actions without noticing (e.g. phone in pant). These dialogues are very similar and block all other interaction until either "yes" or "no" is pressed. They occur in various parts of the system depending on user's action. One example of a confirmation dialogue is given in Figure 10.5-12.

10.4.6. Allocating resources

The functionalities presented until now mostly concerns with keeping overview of resources and gaining information about allocated resources. There are two other main functions of this prototype: allocating and reallocating resources. To initiate a new allocation the incident commander must access the *"allocate new resource"*-button *["alloker ny ressurs"]* (Figure 10.5-11). This button takes the user to another view, thus leaving the current map view. Since both previous studies (Nilsson 2010a, p. 8) and relevant theory suggest using lists to display overview of available resources, the first part of the task includes selecting the desired resource from an expandable list (Figure 10.5-14), and then specifying the details (Figure 10.5-15). Figure 10.5-15 might seem distorted and unpolished, but the screenshots are taken from the emulator, and unfortunately the emulator does not give an appropriate representation of the display when running on a mobile device. The user selects details by using radio buttons, check box and drop-down menus. This is to prevent the user from making input mistakes. After all details are specified the user skips back to the map view where the allocation is placed on the map to assign the location. Coordinates are fetched automatically. When the user has defined the location a confirmation pop up and repeats the details of the allocation (Figure 10.5-18). A new maker is automatically drawn where the user selected to place the resource. The BACK-button is always operational; hence the user can go back one or more steps anytime during this process. However, after placing the marker, the user cannot undo the allocation and must delete the marker (see Section 10.4.3) to cancel the allocation.

10.4.7. Reallocating resources

Reallocating resources is the third and final main objective of the prototype. When the incident commander wants to reallocate a resource the first step includes finding the desired resource. In contrast to allocating a new resource, the view does not change to a list-based presentation as staying in-map allows for more visual filtering options. As mentioned earlier, this action is often combined with a filtering process. When the user initiates the reallocation-process by pressing the *"reallocate resources"*-button *["realloker ressurs"]*, the system enters a "drag-and-drop"-mode (Figure 10.5-16) where the user can drag the resources from current position to the desire location. In this mode all other resources are greyed out to avoid disturbance. Then the system brings up a confirmation dialogue, and then draws a line from current position to destination to indicate that the resources need to geographically relocate.

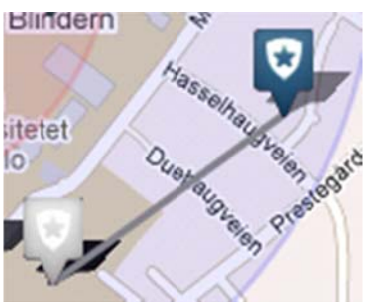


Figure 10.4-4: Extract of the line after reallocation

The marker for the current position turns grey to indicate that it is only a current position while on its way to the destination (Figure 10.4-4). For tracked equipment or personnel the line will always draw a straight line between the current position and destination, thus the line is not symbolizing the actual path (which would probably be along roads or tracks etc.), but just where the resource is, and where it is supposed to be. This also ends the task of reallocating resources. If either marker is deleted, the system returns to the previous state, i.e. only marking the resource at the current position without knowledge about future positions.

10.5. Prototype screenshots

This section includes screenshots of the different views in the prototype. They are only explained with a caption and title, but all screenshots have been referred to in the previous section where an in-detail description is given.

10.5.1. Map and markers

Figure 10.5-1: Bottom layer: the map layer

Figure 10.5-2: Markers without bounds

Figure 10.5-3: Bounds over operational area

Figure 10.5-4: Filter 1: Person resources hidden

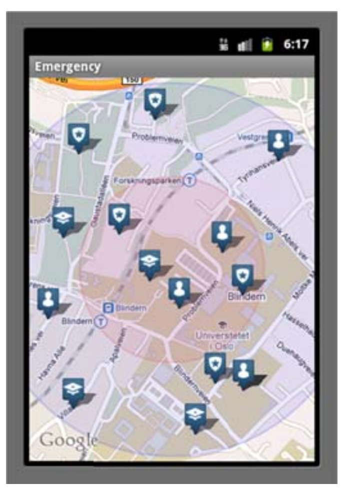


Figure 10.5-5: Filter 2: Equipment resources hidden

Figure 10.5-6: Main view: all markers and bounds

Figure 10.5-7: Map layer in satellite-mode

Figure 10.5-8: Filter 3: Markers colored according to priority

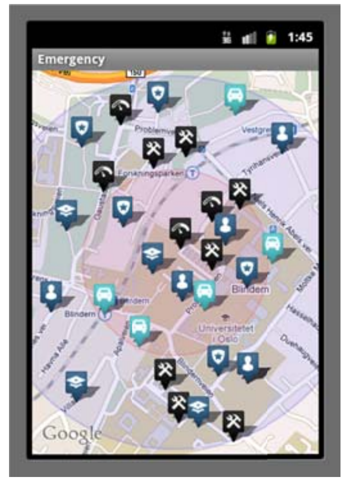


Figure 10.5-9: Filter 4: "Find similar"

10.5.2. Navigation

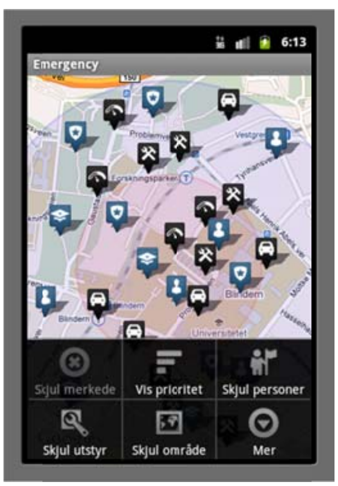


Figure 10.5-10: Main menu

Figure 10.5-11: Secondary menu

Figure 10.5-12: Example of confirmation dialogue

10.5.3. Task handling

Figure 10.5-13: Resource allocation: resource types

Figure 10.5-14: Resource allocation: Expanded lists

Figure 10.5-15: Resource allocation: detail specification

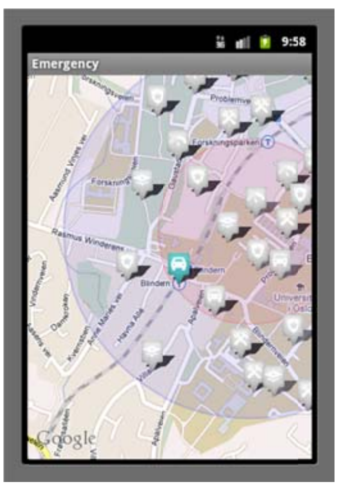


Figure 10.5-16: Resource reallocation: "drag-and-drop"-mode

Figure 10.5-17: Resource reallocation: Completed reallocation

Figure 10.5-18: Information box with allocation details

Chapter 11

Evaluation

Before design implications could be presented, the prototype had to be developed. The first two sections of this chapter describe the two evaluations carried out in this thesis. The two evaluations were conducted at different stages in the development process, and they used two different approaches. The former used an empirical approach, while the latter used an analytic approach. The main focus of the two evaluations was usability. The last two sections present a discussion of the evaluations.

11.1. Evaluation 1: Usability testing

> *"Usability evaluation has proven to be an invaluable tool for ensuring the quality of computerized systems."*
>
> *(Kjeldskov, Graham et al. 2005, p. 52)*

In (Rogers, Sharp et al. 2007, pp. 646-683), three main approaches for evaluation of prototypes are presented. The first approach is *usability testing*. To explore the error rate of the first prototype, an evaluation was carried out by conducting a usability test. This was during the early stages of the prototype, yet it was still possible to reveal potential problems with the projected future development of the prototype.

11.1.1. Definition

Usability testing was defined in Section 3.5.1 as a general technique for user testing. More precisely, it involves testing a prototype on users and producing direct feedback from potential users. The main purpose is to explore the user's response to the prototype, and to evaluate how well the user's requirements are being fulfilled by the prototype. It is defined as an *"approach that emphasizes the property of being usable"* (Rogers, Sharp et al. 2007, p. 646). In literature, usability testing is often termed as user testing. As pointed out in (Saffer 2006, p. 181) the synonym *user testing* should be avoided as it can be confusing or misleading by suggesting that the user is being tested and not the product. The application of this evaluation form varies, not only between companies of approximately same size, but also competing within the same field of interest. Microsoft is known to perform extensive usability testing and research. On the other hand, Apple, who is known for its innovative interaction design, have no such testing (Saffer 2006, p. 5). There are definitely still disagreements on the effects of such an evaluation approach. However, the one thing everyone can agree on is that evaluation is necessary regardless of approach. In usability testing the two main measure units are time and number. The *time* refers to the required time to complete a given task, while the *number* represents how many errors the participant make during the test.

11.1.2. Evaluation procedure

The usability testing was set up following a similar pattern as presented by Rogers, Sharp et al. (2007) in their description of the MedlinePlus website. There were three steps through the evaluation: (1) Brief information was given about the project, prototype and tasks, (2) the user was allowed to explore the prototype freely for five minutes, and (3) the user was given three tasks to complete. The user was told to "think aloud" while each task was carried out individually. Since this was an early prototype on a mobile device only the most basic features were tested. The three given tasks were:

1. Use panning to find a specific resource.
2. Use zooming to get an overview of all resources.
3. Use tapping to display resource details.

A total of eight participants were engaged in this testing. The users were all HCI-students with knowledge about usability and design principles, but also mobile devices and touch screen interface. While the intended user is not an expert on usability, experience with touch-screen interaction is something that can be expected from an incident commander.

For each task the number of errors made was noted. A maximum of ten minutes were given to perform all of the tasks without restricting time for each individual task. However, if the error was critical (e.g. did something entirely different that intended), then the user was notified and that particular task was restarted to avoid double-count of errors. The time for each task was not taken, but the recorded time was the time required to complete all tasks. The reason for this was that while these were presented as three individual tasks in the evaluation, they may all be part of one larger task in a final prototype. Let's say a user is told to *find a resource*, *read the information* about that particular resource, and then finally *update the information*. In this case that would be considered three separate tasks as this was an early phase and each tasks was split to minor tasks (see Section 6.2.1), but combined they amount to the main task *updating resource details*. The results were listed in one table for each task (Appendix D).

The evaluation criteria were related to effectiveness, measured by error count, and efficiency measured by completion time. Time was clocked and numbers of errors were split into two categories: *deliberate error* and *accidental error*. The former counted how many times the system responded as the user desired, but the action was not right in regards to completing the task. The latter is a count of all the times the user unintentionally interacted with the system thus producing an undesired interaction. Then the mean and the standard deviation were calculated.

11.2. Evaluation 2: Group-based expert walkthrough

> *"The method is developed to capitalize on the expert knowledge of a group of evaluators, in order to identify usability-problems, possible design improvements and successful design solutions in a given user interface."*
>
> *(Følstad 2007a, p. 58)*

Another evaluation method presented by Rogers, Sharp et al. (2007) is analytical evaluation where inspection methods with experts are used instead of directly involving users. As mentioned in Section 3.5, the evaluation is structured according to task-scenarios where experts evaluate the UI of a prototype in regards to the given task-scenario.

11.2.1. Evaluation goals

The main purpose of this evaluation was to collect information about how well the prototype developed was suited for task related to resource allocation amongst incident commanders in the police. The intention with the user-centered evaluation was divided: (1) reveal user problems, and suggest improvements, and (2) reveal general problems and sources of irritation, and suggest alternatives.

11.2.2. Organizing

The UIM recommends a group of 3-5 experts. The evaluation was carried out in two individually sessions with three evaluators in each session. Each session lasted between two and two and a half hour. Before beginning, each user was given time to read the interview agreement (see Section 3.3.2, Section 3.7 and Appendix G). They were only allowed to participate after agreeing with the terms and signing the consent (Appendix G). First, an introduction to the EMGERGENCY-project, the problem area for this thesis, and the purpose of the prototype was given. Information about how the UIM was normally conducted was presented, and the evaluation process was explained thoroughly. Description of usability evaluation was given, along with keywords and topics to keep in mind during the evaluation. The two task-scenarios were also presented:

1. *Allocation of road blocks* – Five road blocks are requested to prevent traffic from driving off the main road (bypass) and into the cordoned area. The road blocks must be set up in Niels Henrik Abels vei so that the traffic from Sognsveien does not manage to get through.

2. *Reallocation of a police officer* – During a rescue operation it is necessary to prevent the public from entering the cordoned area. Most of the traffic has been blocked out, but a police officer is needed at Forskningsparken subway station to deflect alighting passengers. You know there is a police officer with low priority somewhere in the cordoned area who is not allocated, thus you want to allocate him to the subway station.

Each task-scenario consisted of nine steps. For a full timetable of the sessions, see Appendix E. Along with the task-scenarios, a scale was presented to measure the degree of seriousness. Each evaluator was asked to grade each user problem in accordance to the presented scale. The scale has been used in several evaluations in similar studies (Kjeldskov and Stage 2004, p. 607; Hornbæk and Frøkjær 2005, p. 395; Nilsson and Brændland 2009, p. 12)[33]:

1. *(L) Cosmetic* – The user of this prototype will only experience minor difficulties, unproblematic obstacles or few sources of irritations during task handling.

[33] The three letters in parenthesis refers to the first letter in the Norwegian translation of the element. *(L)lav/(L)ite, (A)lvorlig* and *(K)ritisk* would translate to the given scale.

2. *(A) Serious* – The user of this prototype will experience several difficulties, challenging obstacles or several sources of irritations during task handling.

3. *(K) Critical* – The user of this prototype will experience insoluble difficulties, impossible obstacles or too many sources of irritations during task handling.

After this introduction the sound recorder was started, and the walkthrough began. Each evaluator was given an evaluator form (Appendix E). For each step of each task, the form included a screenshot of the final state, along with space to fill out user problems and grade the degree of seriousness of the user problem with the scale presented above. The two task-scenarios were presented sequentially by the test leader (see next section), and each of the nine steps required to perform the task was presented one by one. After each step, the evaluators were given time to reflect and take individual notes.

All discussion was discouraged at this point. However, the evaluators were allowed to ask questions regarding uncertainties. After each of the two task-scenarios was completed, the evaluators presented their notes as each step was reviewed once again. This led to a plenary discussion where user problems were presented and graded. If there were disagreements on the degree of seriousness, it was rounded up to the highest degree of seriousness, or discussed further to deduce a grade to which everyone could agree. When the evaluators had presented their opinions the test leader and secretary was able to join in and partake in the discussion without affecting the opinions of the evaluators. After both walkthroughs and discussion rounds were complete, a final discussion was conducted. The intention was to sum up the user problems found, and try to evaluate the overall opinions in regards to layout, interaction mechanism and aesthetics.

11.2.3. Participants

The desired combination of *evaluators* was to have evaluators in the same patterns as described in (Følstad 2008, pp. 223-227; Nilsson and Brændland 2009, p. 3). This includes both usability experts and domain experts. However, due to practical reasons outside of my control, this was not possible within the time limits of this thesis. The police, who was responsible for providing domain experts, delayed the process to such a degree, that the evaluation had to be conducted without proper domain experts. This resulted in evaluations on usability experts with little insight to the problem domain. Three usability experts were used in each evaluation session.

In the first session, the usability experts were gathered from Department of Informatics, while they were all from SINTEF during the second session. They all had solid background in HCI, and it was a mixture of students completing their degree and senior researchers with many years of experience. Their age was spread over span of 30 years. A position of *test leader* was assumed by me, which meant I would be guiding the evaluators through the walkthrough. It also meant that I was responsible for staying on time and controlling the discussions. My thesis supervisor had seen and influenced the development of the prototype, thus he was not suited as an evaluator. He functioned as the *secretary*. He had experience as both test leader and secretary which made him valuable to the evaluation. His responsibility was to take notes and help with managing the discussions. While it is suggested by Følstad (2007b) that changing test leader between the two evaluations might reduce the bias from only having one test leader, it is only suggested when evaluating two different applications. For the same application Følstad also uses the same test leader.

11.2.4. Location and equipment

The first session was carried out in a seminar room at Ole Johan Dahl's house at Department of Informatics, University of Oslo. During the evaluation a wall-mounted television was used both for the introductory presentation and for the presentation of the UI. The three evaluators were seated around a table to easier allow discussions, while the test leader was standing the whole time. The secretary was also seated with the evaluators. During the experiment only the evaluators, secretary and test leader were present in the room.

The second session took place in a meeting room at SINTEF. The only difference was that a large PC-monitor was used instead of a television; otherwise the same procedure was used as during the first evaluation. The evaluators sat around a table with the secretary, while the test leader was standing.

11.3. Number of subjects

The number of participants during both evaluations has been relatively low, i.e. eight participants during the first evaluation, and then three in each session during the second evaluation. The number of subjects required to properly and representatively reveal all problems is a discussed topic in relevant literature (Bekker, Barendregt et al. 2005; Andreasen, Nielsen et al. 2007). While these results are mostly applicable to methods closer to heuristic evaluation, they are still relevant.

Heuristic evaluations are often conducted in groups, and during the expert-based walkthrough, the evaluators sit and reflect alone during most of the evaluation as the group discussion take place after individual note taking. To ensure cost and time effective evaluation it is essential to grasp what number of subjects that theoretically would yield the most justifiable evaluation. In (Bekker, Barendregt et al. 2005, pp. 333-335) the authors discuss the percentage of problems uncovered in relation to number of subjects. On the basis of theories on usability presented by Jakob Nielsen and Landauer (1993), they use the overall advise that *"5 subjects will uncover about 85% of the usability problems of a product for a given user group and a given set of tasks" (Nielsen and Landauer 1993)* to present the formula:

$$N(1-(1-p)^n)$$

This formula defines the number of usability problems found after *n* subjects. The *p* is the probability of finding the average usability problem, and *N* is the total number of problems found in the design. If a prototype was to be evaluated by 5 people, and the probability of finding the average usability problem was set to be 25%, the number of problems found can be predicted. 25 % would mean that on average each subject would find 25 % of the problem. If the total number of errors were 10, then with only 5 users you would discover 7.6 of these, meaning a discovery rate of 76%.

$$10(1-(1-0{,}25)^5) \approx 7{,}6$$

$$10(1-(1-0{,}30)^5) \approx 8{,}3$$

If the probability of finding the average usability problem increased with only 5 % to a total of 30%, then the discovery rate would rise to 83 %. This would imply that the number of usability problems found can be illustrated with diminishing return to scale as more and more testers are being included. This is illustrated in Figure 11.3-1 which is adapted from (Nielsen and Landauer 1993, p. 209) and (Bekker, Barendregt et al. 2005, p. 339).

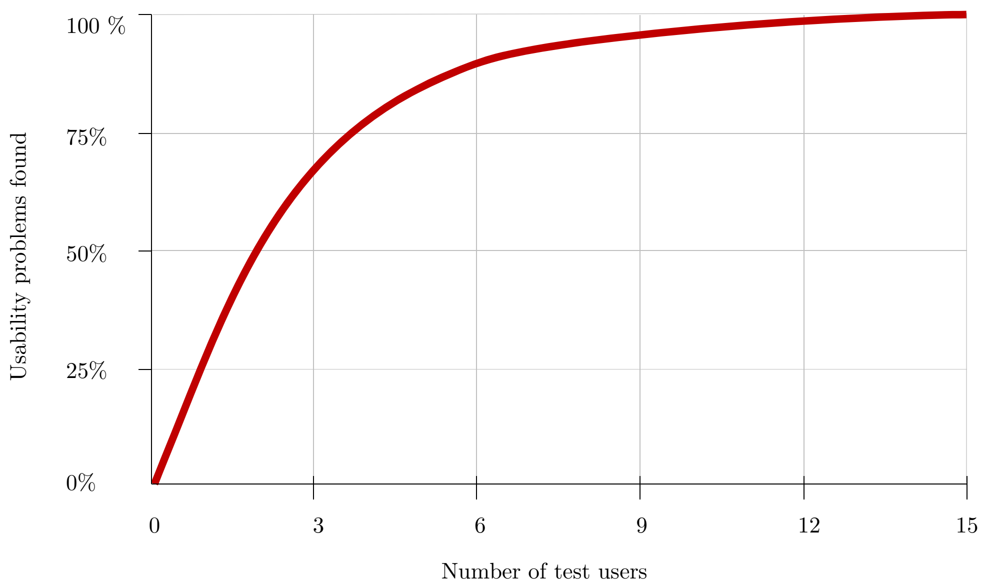


Figure 11.3-1: Relation between number of test users and usability problems

In (Bekker, Barendregt et al. 2005, p. 334) further topics that might affect this prediction are discussed, such as diversity of users, task complexity and application. The users in the intended user group for the prototype of this thesis is relatively homogenous therefore the diversity of users can be abstracted out as a relevant factor. The user characteristic presented in Chapter 6 defines the user as an expert. As seen from Figure 11.3-1, the important factor is the size of p, i.e. the probability of finding a problem. This also relies on the task familiarity and experience of the user. Since the evaluation covers standardized tasks the procedure is very similar each time.

The correlation between experience and problem findings has also been further investigated. By looking at initial use vs. extended use in regards to probability of problem findings, the topic further studied in (Bekker, Barendregt et al. 2005). However, the task complexity could be more relevant for such a prototype if the tasks presented were abnormal or unfamiliar. Since the tasks presented in the evaluation are standard and familiar, the complexity is not an issue.

11.4. Evaluation method discussion

> *"There is a clear need for evaluation methods that are specifically suited to mobile device evaluation, largely due to the vast differences between traditional desktop computing and mobile computing."*

(Barnard, Yi et al. 2005, p. 487)

Rogers, Sharp et al. (2007) claim some core heuristics are too general to properly evaluate newer products such as mobile devices. Recent literature exploring various evaluation methods within both general HCI and mobile UID have presented different results and conclusion in regards to the best suited method of evaluation (Kjeldskov and Stage 2004; Barnard, Yi et al. 2005; Kjeldskov, Graham et al. 2005).

While usability has been an established method of evaluation, it has been complemented with a growing number of attempts to "evaluate evaluation" the last two decades (Kjeldskov, Graham et al. 2005, p. 52). This includes empirical evaluations of the relative strengths and weaknesses found in different approaches and techniques of evaluation, often also under different circumstances. There are several factors that should be taken into account when selecting an evaluation method as the most suitable. Among several interesting questions related to this topic Kjeldskov, Graham et al. (2005) raise two important questions:

1. Should the evaluation be done in the lab or in the field?
2. Should the evaluation be based on usability experts and/or involve users?

11.4.1. In-situ or in-vitro?

As presented in Chapter 4, the use context, and thereby the physical and social environment, is an important factor. While data has been, and is still being, collected from field study activities (e.g. observations, shadowing) in the EMERGENCY-project, the evaluation of the prototype was not conducted in the field for this thesis. However, testing usability outside of a laboratorial setting in a field study is considered an important method of evaluation (Brewster 2002, p. 4) as it allows us to evaluate in more realistic environments. Thus, evaluation in "the real world", i.e. the proper user context, might seem the most appropriate.

As pointed out in (Rogers, Sharp et al. 2007, p. 667), several trade-offs exist with this method. Specific hypotheses about an interface or account cannot be tested with the same degree of certainty as in controlled environments. It is therefore relatively more demanding to determine the causes of user's behavior or problems with the usability. Other challenges with field studies include difficulties using data collection instrumentation (e.g. video camera, voice recorders), think-aloud protocols or shadowing, mostly due to little or no control over the physical environment in which the participants move around (Kjeldskov, Graham et al. 2005, p. 52). Besides these challenges, the following arguments can be raised to rather suggest controlled evaluation as the appropriate evaluation method:

1. *Difficulties with replication* – As presented in Chapter 4, an emergency situation is a highly complicated and unexpected process making it almost impossible to prepare for, and even more difficult to stage or replicate. Some field studies have been conducted in the EMERGENCY-project earlier, such as in the TYR-exercise, but in most cases the scenarios were known beforehand, thus making planning and coordination much easier.

2. *Situational uniqueness* – Each emergency situation creates an unpredictable and unique environment and the content and complexity of the user's task might vary with each situation. It is therefore more difficult to collect comparable data which may problematize triangulation or control-evaluations to correct for bias.

3. *High level of uncertainties* – There are still many factors that are not entirely unambiguous, e.g. domain knowledge. This makes the prototype more suited for laboratory-based evaluation. It is more difficult to consider one or few field studies representable due to unthought-of factors.

11.4.2. Experts or users?

In accordance to the design approach presented under research method, and following general UCD-principles, there has been a close cooperation with the domain and intended user group, both in this thesis and in the EMERGENCY-project. When evaluating prototypes end-users usually participate as evaluators to ensure testing with the indented audience. However, this is usually only applicable late in the development cycle as it requires a very high-fidelity prototype. The purpose of this evaluation was to identify user problems in an earlier phase. Thus, it allowed us to fix these issues, and then move on with the prototype.

The prototype presented in this thesis is the first of its kind in the EMERGENCY-project, hence it is more appropriate to use UIMs that include expert evaluation such as the expert-based walkthrough, since it may be used in any stage of the design process (Rogers, Sharp et al. 2007, p. 686). However, usability experts, software engineers and UI-designers do not have the same insight as work-domain experts when it comes to understanding the context of use of a domain-specific work-support system (Følstad 2007b, p. 218).

While it might be tempting to replace usability testing with methods such as heuristic evaluation, studies indicate that severe limitation might follow when skipping or replacing usability testing, and argue that a more balanced repertoire of usability assessment techniques should be used (Jeffries and Desurvire 1992, p. 39).

A combination as mentioned also helps balancing out the possibility of poor evaluators as it allows for both end-users and experts to partake in the evaluation. According to Jakob Nielsen, novice users make poor evaluators, with HCI experts 1.8 times as good, while domain and HCI experts are 2.7 times as good (Doubleday, Ryan et al. 1997, p. 107).

The expert-based group walkthrough is designed to allow both usability and non-usability experts such as domain experts to partake in the evaluation. Thus, the method itself is open to both experts and end-users. Følstad (2007b) defines *work-domain experts* as (1) potential end-users with direct experience from the work domain, or (2) persons with extensive secondary knowledge of the work domain[34]. The first session included three usability experts, while the second session included usability experts with some domain knowledge. Hence, the evaluation was carried out with a heavy weight on usability experts. Ideally, more domain experts should have been included in the evaluation, but domain experts were not available due to practical reasons. The thesis supervisor did however contribute with some domain knowledge.

The main motivations were similar to the typical advantages of expert evaluation, i.e. it's fast, it's cheap and it finds a lot of problems (Jeffries and Desurvire 1992, p. 41). The most common counter-argument is that it requires multiple evaluations, but multiple evaluations are both a part of the group-based expert walkthrough, and of methodological triangulation. Therefore this was not considered to be a disadvantage. There are three other arguments that suggest the usage of expert evaluation rather than tests with end-users.

1. *One user vs. user group* – Some problems might occur for several users, but not for the group of users being tested in the field. If one chooses to use analytic evaluation methods, experts who take the role as an intended user can evaluate the system representing the whole user group rather than just the one user, thus potentially discovering more user problems.

2. *Evaluating the entirety* – Since testing with users often excludes dialogs, errors or options, some parts of the design might be overlooked. When using an expert-based walkthrough (or similar methods), the evaluators have time to explore and question the entirety as they are not bound to only focus on completing the task similar to what a user in the field would do.

3. *Impossible to replicate* –Evaluating the prototype with users would also be more beneficial in field when context and task were also realistic. Replicating

[34] According to Følstad (2007b), extensive secondary knowledge may be held by a various number of people or roles, depending on the particular work domain.

the physical and social environment with realistic conditions (e.g. panic, stress) would require more effort and resources than available. Hence, the most realistic test environments are the annual TYR-exercises or other co-operative exercises. However, that was not possible given the time frame of this thesis.

Chapter 12

Results

This chapter presents the analyses of the data collected through the evaluations of the prototype. The results are divided into two parts, one for each of the two evaluations described in the previous chapter. Only the key results are presented in this chapter. Most of the presented results are complemented with supplementary data and graphs in Appendix D-F.

12.1. Evaluation 1: Completion time and error rate

The purpose of the first evaluation was to test out the basic functionalities of the map, i.e. panning, zooming and tapping. Three tasks were tested on a total of eight participants (as presented in Section 11.1.2). All tables and figures on individual time consumption and error rates are further presented in Appendix D, while this section only present the average results.

12.1.1. Data analysis

Table 12.1-1: Task-sorted average completion time and error rate

Task	Completion time	Deliberate errors	Accidental errors
Task 1	3 (± 1,5)	2 (± 1)	1 (± 1)
Task 2	2 (± 1)	1,5 (± 1,5)	1 (± 1)
Task 3	3 (± 1,5)	1 (± 1)	1 (± 0,5)

Table 12.1-1 gives an overview of the average completion time (in minutes for each task), and the error rate (error count for each task). Errors were divided into deliberate errors and accidental errors (previously presented in Section 11.1.2). The number in parenthesis is the standard deviation for each value. In six of the total 24 tests, the user's error was so critical that the application terminated unexpectedly. This has been adjusted for in Table 12.1-1 by including those who were very close to task completion, while excluding those who terminated the application early in the task. Because the variation was so high between the different users (see Appendix D), the standard deviation also became very high. As illustrated in Figure 12.1-1, the accidental errors had an average at 1 for all three tasks. On the other hand, the deliberate errors had a constant reduction rate of 0.5, dropping from an average of 2 during the first task to 1 during the last task.

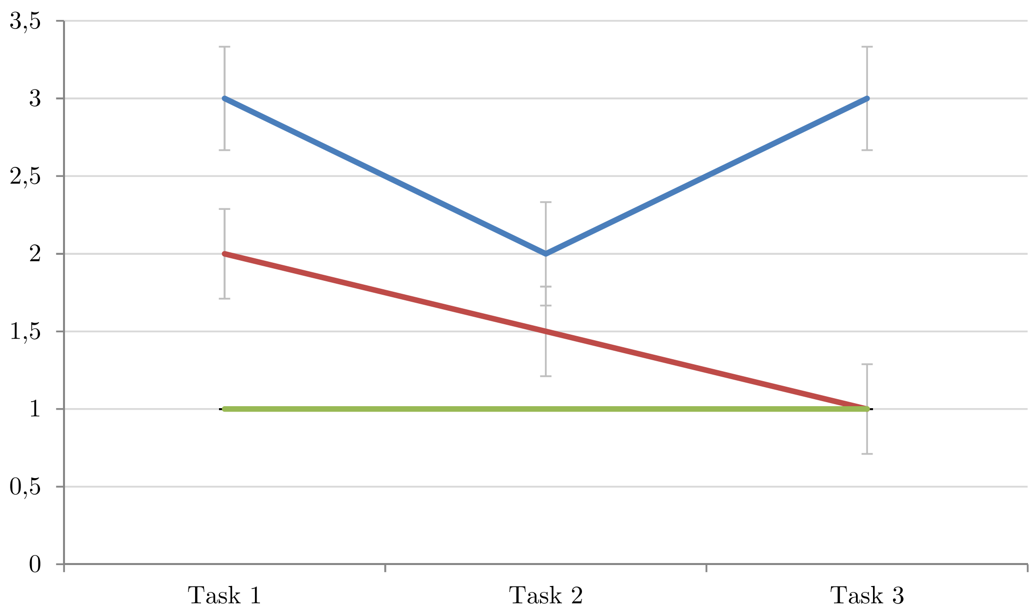


Figure 12.1-1: Average completion time and error rate

12.1.2. Summary

The purpose of the evaluation was not to find a trend between the tasks, although it might be interesting to use the development as an indication on the long-term values of average completion time and error count. Based on the data collected, the following results can be presented as a summary of the first evaluation:

1. *Task completion time* – The average completion time dropped 0.5 between the first two tasks, and increased with 0.5 between the last two tasks. Also, if comparing total completion time per task (Figure D-4 and Figure D-5 in Appendix D) to Table 12.1-1 and Figure 12.1-1, the trend is very similar. The different between the highest and lowest completion time, was reduced between each task, thus the average completion time can also be regarded as the completion time for an "expert users". Thirdly, if the completion time is compared to the expectancies from an expert user, the values are almost identical. Several evaluators solved some tasks faster than expected. The task completion time can therefore be said to be fairly accurate.

2. *Deliberate errors* – The deliberate errors dropped from an average of 2 during the first task, to an average of only 1 during the last task. The halving of the average deliberate error rate is a result of a reduction amongst the majority of the subjects rather than individual outliers (Figure D-6 and Figure D-7 in Appendix D). The deliberate error can be said to have decreased for each task, yet a similar trend would most likely not have continued (implying no errors from the fifth task).

3. *Accidental errors* – This value may seem to be the most consistent value if only looking at Figure 12.1-1, Figure D-6 and Figure D-7. It should be pointed out that these are only average values. In contrast to the deliberate errors, the pattern was not obvious from task to task; the extreme values were not equally congruent. The number of tests with no accidental errors was the same as numbers of tests without deliberate errors. Therefore, while the average deliberate errors dropped gradually, this value remained constant.

12.2. Evaluation 2: General features

The purpose of the second evaluation was to identify usability problems and suggest possible design improvements and successful design solution for the given UI. The data was collected from three sources: (1) own notes and secretary's notes, (2) notes in the evaluator's forms (Appendix E), and (3) sound recordings from the evaluation. The data was systematized and structured on a list form (Appendix F) from which the results in the next sections are presented. The results are presented independent of which group that brought up the issue. They are divided into general and functional features to separate the overall results from the more function-specific results. The evaluation revealed three suggestions on how the general features of the design could be improved.

12.2.1. Problems and suggested improvements

User problem #1 and *#3* in Table 12.2-1 concerns issues with how information was presented in the prototype. After reading the evaluators' form (Appendix E) during data analysis afterwards, it became clear that several more comments and suggested improvements regarding these topics were written down by the evaluators, than actually discussed in plenary. All relevant feedback has been included in Table 12.2-1.

Problem #1 was categorized as serious (A), and it was repeated several times in different and independent views. Some of the suggested improvements for the first problem overlapped with the suggestions for the third problem, which was *confusing or misleading information (#3)*. This was only graded as a cosmetic (L) problem. However, the overlap suggests that solving the first problem can reduce or completely eliminate the third problem as well. *User problem #2* concerned missing progress indication during task solving and was included in this general overview since it was mentioned during both task-scenarios. The problem was not related to the task solving itself (which is described in Section 12.3.3), but rather missing visualization of progress while in the middle of a task. The problem was graded serious (A) as several potential outcomes of confusion during task handling were discussed in plenary.

Table 12.2-1: Problems found with general features

#	Problem	Suggested improvements	Degree of seriousness
1	**Too much information:** The screen contains too much information, too many markers and covers too much of the map. This is both disturbing and reduces efficiency.	- Drop shadow - Filter amount of markers - Drop pointing tip - Scaled markers - Groups with text and symbol	A
2	**Missing progress indication:** The progress process should be visualized at all time to reduce progress understanding when jumping between screens or returning to phone from other activities.	- Progress bar on top of screen - Bigger text in headers - Inform user of desired action - Dialogue and/or confirmation windows	A

#	Problem	Suggested improvements	Degree of seriousness
3	**Confusing or misleading information:** More precise definitions and terms could be used to avoid confusion or misleading the user. Sometimes it takes too much time to comprehend the icon or description.	- Group with text and symbol - Use a more understandable language - More precise descriptions - Use more informative icons	L

12.2.2. Impressions of general features

The general impression of both evaluator groups was positive and everybody agreed that the map-based interface functioned well for solving tasks related to resource handling. The interface was perceived as easy to use. If adjustments according to the suggested improvements were made, both group genuinely felt the system could be used in emergency situations. It would allow the incident commander to easier keep overview via the map-based presentation, with symbols and metaphors instead of text only. Information would be easier comprehended, and it required less concentration from the incident commander.

However, during discussion several questions were brought up that were related to domain-specific uncertainties rather than problems with the design. For instance, during discussion of which filters to potentially put on top of the map layer, the first question asked was how much one filter would be used relatively compared to the other. Since no such system currently exists we had no prior observational data on this topic, and only end-users of the system would be able to estimate the use. The actual use is another matter, and would only be trustworthy measureable with user tests in realistic context. Even though one of the groups had some domain knowledge, there were incidents where there was an obvious uncertainty when deciding the degree of seriousness.

12.3. Evaluation 2: Functional features

From the total of 47 user problems discovered in the two sessions, 20 problems were removed when overlaps and similar problems were grouped. This left 27 problems. From these, three were categorized as problems concerning general features, and were presented in previous section. That left 24 problems that were related to functional features. They have been further divided into three categories:

1. Dialogue and navigation
2. Interaction and visualization
3. Task solving

The first category contains problems that mostly concern the user quality of the prototype, while the two last mainly include features tied to the use of the prototype for its intended purpose, i.e. handling resources.

12.3.1. Dialogue and navigation

This category includes problems and suggested improvements related to navigating through the system. It also includes problems concerning use of functionality, primarily in regards to layout, interaction mechanisms and logical construction of dialogues.

Table 12.3-1: Problems found with dialogue and navigation

#	Problem	Suggested improvements	Degree of seriousness
4	**Difficult list navigation:** Navigating through long lists of resources is difficult. There is no easy way of finding the desired item in the list.	- Color-coding based on type - Second level of expanding list - Bold font for sort key - Symbols to assist text	A
5	**List seems empty:** The list is first displayed in collapsed state, meaning no resources are shown for the two resource types. This can be confusing.	- Separate task and proceed to list for each task. Each list header then indicates subtype rather than type. - Utilize more of screen (auto-expanded)	L
6	**Too small text in list headers:** The text in the list headers is too small making it difficult to read, and harder to hit to expand list.	- Increased header block size - Increased font size	A

#	Problem	Suggested improvements	Degree of seriousness
7	**Missing progress symbol in list elements:** The list should indicate that pressing a list element takes you further (or to another screen).	- Use an arrow-symbol	L
8	**Weak colors in dialogues:** The dialogues include text that has a font color too similar to the background, thus making it hard to read.	- More contrasting colors - Increased text size - Drop long text, only "ok?"	A
9	**Unclear buttons:** The buttons in the information box for resources are unclear as their icons describe the action poorly.	- Add text description - More representative icons (pin as reallocation, crosshair to find similar)	L
10	**Exit-button not present:** The application does not have an explicit exit-button. If the user closes the application in the middle of a task, it should reset the next time the application is launched.	- Either explicit exit-button or terminate process when normal exit.	L
11	**Menus disappear on press:** When pressing a menu item, the menu disappears.	- Permanent menu	L
12	**Reallocation disappears:** After reallocating a resource, sometimes the confirmation box appears on top of the new position. This doesn't allow the user to see what they are confirming.	- Box placed on top or bottom. - Move map behind box.	A

There were many comments on the list interface used to find and select resource to allocate. It was a combination of cosmetic (L) and serious (A) problems. The evaluators agreed that list was the best format, but it lacked good structure and readability. There were some disagreements on how the problem would best be solved if the list over resources became too long. However, several improvement suggestions were given. A suggestion put forward proposed that the list only covered one resource type, i.e. either people or equipment. This way, the list could be grouped not by type, but rather by subtype. This would give better readability, fewer list elements, and thereby increased efficiency. On the other hand, I would require a restructuring of the menu in the main screen. Other comments and found problems were related to color and visibility, mostly too weak colors and too weak contrasts which would only require minor color adjustments to fix.

12.3.2. Interaction and visualization

This category includes user problems and suggested improvements related to the use of the map to keep an overview of different resources. Allocation and reallocation of different types of resources are also included. The user problems can be seen in regards to navigation, interaction or visualization.

Table 12.3-2: Problems found with interaction and visualization

#	Problem	Suggested improvements	Degree of seriousness
13	**Difficult to distinguish symbols:** The symbols on markers are too hard to distinguish. They may get too rich on detail level.	- Filter amount of markers - Increase size	L
14	**Difficult selections:** When assigning details to an allocation, the selection on count and priority is too difficult.	- Replace drop-down with spinner/wheel - Utilize screen size better - Narrower shape on drop-down - Add padding	A
15	**Missing color codes for priority button:** The radio buttons that allows the user to assign priority are not color marked, hence the color coding on priority used elsewhere is not available here.	- Add color	L

#	Problem	Suggested improvements	Degree of seriousness
16	**Pressing markers is difficult:** It is challenging to hit the indented marker due to icon cluttering. It may result in irritation or delay due to pressing wrong markers.	- Reduce number of markers - Increase size	A
17	**Confusing icons:** The icons used to indicate the different types of markers are confusing and not easily understood.	- Use more clear icons - Use text	L
18	**Color adjustments:** The two circles defining the operational area are too transparent, thus making them hard to spot.	- Adjustments of color tones - Reduce transparency	A
19	**Inconsistent layout on menu:** The menus change appearance between the different levels in the menu. This creates an undesired inconsistence.	(none)	L
20	**Filter status missing:** No text or symbol indicates whether filters are enabled or not, which may be confusing when resources of a certain type are allocated, yet not visible due to filters.	- Little icon on top of screen - Add text	A

Most of the user problems found relates to difficulties with interaction, i.e. it requires too much of an effort to complete a desired action. There were two serious (A) problems related to interaction. In general, they were mostly related to distinguishing and selecting markers, which is a central part of the interaction. As specified under general feature problems, the screen became too crowded, thus the information became too overwhelming. Following the logic of the evaluators, decreasing the total number of markers would considerably reduce this problem.

However, issues such as detail of richness or confusing icons should be separated as individual problems that are unsolvable by only decreasing the marker count. Some problems were similar to comments from the previous category, such as the problem with too transparent colors, which clearly also requires color adjustment. It should be mentioned that while similar problems have been listed under the previous sections, it was still categorized as a serious (A) problem in this list.

12.3.3. Task solving

User problems and suggested improvements concerning the tasks solved in the scenarios are presented in this category: allocating a resource and reallocation a resource. This includes navigation, interaction and visualization of information which may restrain, or even prevent, the task completion.

Table 12.3-3: Problems found with task solving

#	Problem	Suggested improvements	Degree of seriousness
21	**Tasks too far away:** To get to the indented task, the user has to click through two menus, which is too far for important tasks. They should be easier accessible.	- Context-menu that pops up on long press - Move to first level at menu - Separate filters to own menu - Move filters to top of map	A
22	**Unavailability uncertain:** If resources are unavailable as new resources, yet still available for reallocation they should be included to avoid confusion.	- Include unavailable resources in list - Automatic include allocated resources if no new resources are available	L
23	**Difficult positioning:** When positioning the marker during an allocation with a long-press, the chances of missing intended target is high, thus this might conflict with interest of accuracy.	- Use a crosshair - Use a button instead of automation	L

#	Problem	Suggested improvements	Degree of seriousness
24	**Missing state information:** When reallocating a resource, the current state of that resource should be displayed before completing the reallocation.	- Bar at top indicating current state - Grey out/hide other resources	A
25	**Markers not auto-snapping:** When placing a marker on a map it does not auto-snap to the road which makes it more dependent on the accuracy of the user	- Auto-snap based on layer information	L
26	**Reversed colors:** The marker indicating current position is grey while the destination is colored. It should be opposite.	- Automatically reallocate based on nearest geographical - Use arrowhead to indicate direction - Switch the colors	L
27	**No automated reallocation:** The user cannot select to automatically reallocate the nearest available resource rather than doing it manually.	- Automatically reallocate based on nearest geographical	L

The two main problems with task solving were related to tasks being too far away, and state information missing during reallocation. These were both categorized as serious (A) problems. The first problem was discussed, and once again the lack of end-user experience made it difficult for the evaluators to predict the actual frequency of allocation and reallocation. The problem was rounded up to serious since it potentially could be problematic.

However, these two problems share some similarities with the improvement suggestions for the problems found under general features. Thus, solving those problems would likely reduce or even solve these problems as well. Other problems such as uncertainty about unavailability also overlaps with list problems found under Section 12.3.1. Once again, some comments were made in regards to the coloring; however there were some disagreements on this topic. This time, the color issues were not related to the usage of color, or even which color to use, but rather what each color indicated. This was discussed intensively, yet only regarded as a cosmetic (L) problem.

12.4. Result summary

As presented in Appendix F, the first session in evaluation 2 gathered a total of 22 user problems. These were distributed over only two degrees of seriousness, respectively 12 cosmetic problems and 10 serious problems. The second session resulted in 25 user problems, from which 17 were graded as cosmetic, 6 were serious and 2 were critical. Table 12.4-1 has been used to generate illustrations over problems identified in each session (Figure D-4). The distribution of these problems can be found in Figure D-5.

Table 12.4-1: Problems found in each session

Session	**# of total problems**	**# of cosmetic problems *(L)***	**# of serious problems *(A)***	**# of critical problems *(K)***
1	22	12	10	0
2	25	17	6	2
Total	47	29	16	2

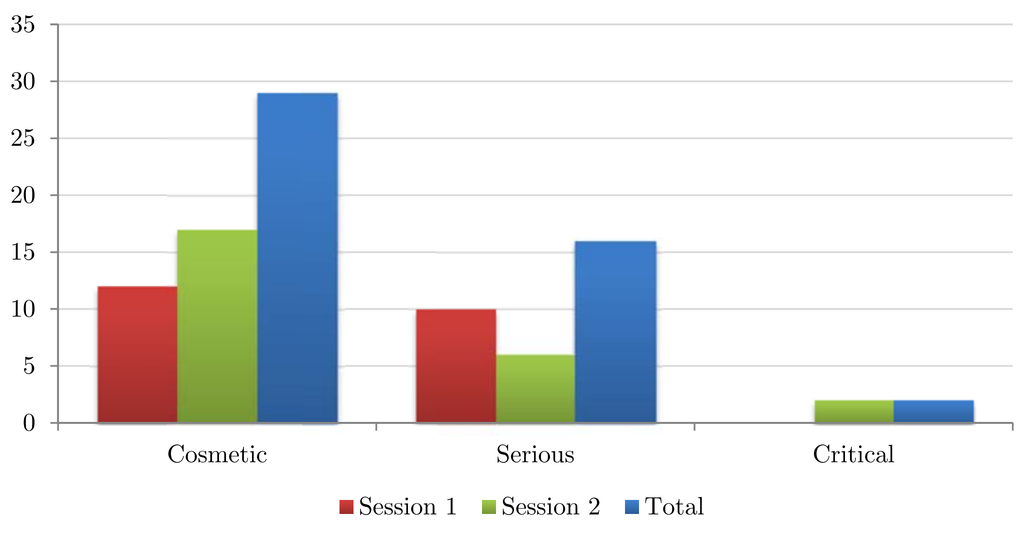


Figure 12.4-1: Number of problems found

As Figure 2.4-1 indicate, the majority of problems were categorized as either cosmetic (64%) or serious (34%). Only 2 critical user problems were found (4 %). During removal of overlaps and grouping of these user problems, both critical user problems were included in the 27 presented problems in Section 12.2 and 12.3. However, the count of cosmetic user problem was dominating, therefore none of the 27 user problems could be considered critical when grouped. All similar problems with two different degrees of seriousness were rounded up to avoid this problem. This resulted in a distribution of 15 cosmetic and 12 critical problems, which gave relative percentage of 44% and 56%. This made the distribution more uniform, which is fair since the serious problems should weigh more than cosmetic problems.

As mentioned earlier, modifying the prototype according to some user problems may fix other problems since the suggested improvements overlap. In such cases it would be more plausible that serious problems corrected cosmetic problems rather than the other way around. Thus, upgrading the degree of seriousness may be practical in this matter as well. It is also justifiable when considering the general feedback. Several problems were enlisted by the evaluators due to insecurity about the relevance. Some questions were raised that neither I, nor my thesis supervisor, were able to answer on the spot. This was mostly due to lack of end-user experience. In general, the evaluators tended to be more lenient than strict during the grading of seriousness.

Chapter 13

Discussion

> *"All the design research in the world is useless unless designers lay out the implications of the research. It's astounding how often this crucial step is overlooked."*
>
> *(Saffer 2006, p. 94)*

The main objective of this thesis was three-parted. (1) Conduct a study of related literature and data collection of domain knowledge about user, context and task. This would to help identify the design requirements for supporting resource allocation tasks on mobile devices amongst incident commanders in the police. (2) Transfer this knowledge about design challenges and design requirements into a prototype. This would allow us to carry out an evaluation with usability and domain experts to validate the design requirements. (3) Analyze the findings from the evaluation, and thereby put forward design implications for future work.

Before the design implication can be presented, the findings from the evaluation should be compared against principles, guidelines and requirements from literature and collected information. Based on the most important findings, this chapter defines four problem areas. These problem areas are then discussed, and design implications are then laid out. The design implications are used to present modification of the prototype. The final section discusses the validity of the work carried out in this thesis.

13.1. Problem areas

12 problems were categorized as serious (A) in the results from the second evaluation (Section 12.4). These were the basis for defining the problem areas. The problems that were selected to be addresses were 8 out of these 12 problems. The

selection was made based on three factors: (1) whether the problem was brought up by both groups or not, (2) the discussions it generated during the plenary part of the evaluation, and (3) the potential for automatically solving or reducing other problems.

The selection of user problems is presented in Table 13.1-1, along with the problem areas they form. Each defined problem area is introduced throughout the next subsections.

Table 13.1-1: Presentation of problem areas

Problem area	#	User problem(s)
Overcrowded presentation of information	1	Too much information
	16	Pressing markers is difficult
Difficult list navigation and selection	4	Difficult list navigation
	14	Difficult selections
	24	Missing state information
Filters not visualized	20	Filter status missing
Progression through task not visualized	2	Missing progress indication

13.1.1. Overcrowded presentation of information

This problem area originates from the two user problems: *too much screen information (#1)* and *pressing markers is difficult (#16).* The common problem was overcrowdings caused by a high number count of markers that were often overlapping. By following guidelines for creating easily understood interfaces that do not irritate the user; the markers were made large and easily clickable considering the small screen size. Relevant theory points out that each marker should give a distinct meaning as a resource type in general, but also in relation to other adjacent markers. To achieve this, a considerable size was also required to properly present the icon symbolizing the resource type. Text description was purposely avoided, as it overlaps poorly and requires large horizontal areas.

It was similarly avoided to keep a consistent size and shape on markers even if the text size yielded different markers. Also, it may overlap with textual information from the map layer such as road names, and it should be redundantly presented to avoid confusion. This is difficult with text only. Therefore, the markers were purposely made relatively large.

During the evaluation, the marker size became a problem rather than a benefit. This confirmed that theory does not always agree with user's preferences. This problem was mentioned by all evaluators at some point during the evaluation. The evaluators felt the map was too cluttered with markers, and that this amount needed reduction. The evaluators mentioned smaller markers as the best way to decrease the overwhelming effect of all the markers being displayed simultaneously. This required the clickable areas to become even smaller, and the symbol illustrating the resource type shrunk as well. Looking back at Fitts' law (presented in Section 8.1.2), reducing the marker size should theoretically cause reduced efficiency. The evaluators argued that smaller icons would still increase the chances of hitting the indented marker as the space between the markers increased. This would result in increased effectiveness and increased satisfaction, due to fewer errors and less irritation. Thus, while not necessarily theoretically justifiable, their argument was still valid.

Several other suggestions for improvement were presented by the evaluators. One suggestion was to filter away redundant information, i.e. only displaying the necessary markers. While this is line with theories about dynamic interfaces who recommend only visualizing necessary information, the evaluators had no preferences in regards to which markers to prioritize if some were to be filtered away; nor did any of us in the EMERGENCY-project. This problem may be solved in different ways depending of what information that was redundant. However, it became obvious that this require more domain knowledge and experience from end-users.

Another suggestion proposed to drop the pointing tip of the marker. The pointing tip was primarily included to create a pin-effect, where a large marker could point at a very specific geographic location on the map. Otherwise, it would have been almost impossible to see exactly where the marker was pointing. If a marker was laid right on top of a position of the allocation, the area around that position would be covered by the marker. And if the marker was presented next to a position, it would still have required a line, arrow or needle to pin it to the position. Therefore, removing the pointing tip of the marker was not an option considered. However, reducing the size of the pointing tip was interesting as it did not disturb the accuracy, yet required less space.

Another good suggestion was to remove the shadow effect. All markers are given shadows by default. Since it created a nice contrast, it was not removed. Yet, as pointed out by the evaluators, the marker took up almost 50% more width because of this shadow, thereby making the clickable area for each marker larger than the actual size of the marker. Beside too many markers, this was the main reason behind the user problem *pressing markers is too difficult (#16).* The chances of accidentally pressing another marker were higher due to the shadow. Because the markers had no borders to indicate the clickable area, it was more difficult to recognize where the edges of the marker began. Especially when two icons were close or partly overlapping, the chances of accidentally pressing wrong marker was high. Thus, the suggestion was well received as it could clear up much excessive space around the marker without disturbing any other part of the interface.

By solving or reducing this problem area, some of the less important user problems related to this topic, e.g. *difficult positioning (#23)* should have been reduced as well, or may even have been eliminated.

13.1.2. Difficult list navigation and selection

The lists were not a part of the map interface, but rather a part of the list-based interface used during allocation and reallocation. This problem area consists of three user problems, primarily *difficult list navigation (#4)*. As a part of the task-scenarios presented during the evaluation, the incident commander had to find the desired resource from a list of resources. Based on relevant literature, the list-based interface was regarded as the most appropriate for selecting resources. This was also seen as a measure to limit errors; instead of letting the user tell the system directly which resource that was desired (e.g. by entering the name of the resource), the user should select from a list that only includes available resources. The user context, being characterized by stress and low attention, and external conditions (e.g. snowstorm), also suggest averting manual text entries. While multimodal gestures such as speech recognition could be considered as an interesting alternative, that introduces some challenges as well, e.g. how to deal with background noise.

Nevertheless, lists were unanimously considered the best option. While the evaluators agreed to the format, they did not agree on the way the resource types were presented. As the list included one expandable list for each resource type, the list became too long according to the evaluators. Some argued it should be presented as a search box with autocompleting, while others suggested using two levels of expandable lists. There were obvious disagreements on how to properly solve this problem.

General design principles were brought up to point out other weaknesses with the presentation. Each list was sorted according to resource subtype, yet all list items were similar regardless of subtype. This meant that a command truck was presented confusingly alike cordons, even though the former was categorized as a vehicle, and the latter as miscellaneous equipment. The list needed redundancy to provide an easier categorization. Suggestions included icons of subtype to visualize subtype and coloring of headers according to subtype for easier filtering. After considering these suggestions, the conclusion was to not use colors, as introducing a new color scheme could further confuse the user. While mostly being based on intuition, this point is also well argued in Section 9.3.3.

However, using colors to solve other user problems was still possible. By including all unavailable resources, i.e. resources that were already used in another allocation, in red text, it could solve the problem of *unavailability uncertain (#22)*. Using icons was considered a good suggestion, as it is an easy way of visualizing context without breaking the format. It also applied well to the design principles of consistency. Thus it was the most preferred feedback with regards to both our own opinions and relevant design theory.

Another feature that would allow the lists to become even easier in navigation, is to separate allocation of equipment from allocation of personnel. This was suggested by the evaluators as a more comprehensive modification; however it would solve several problems, amongst them *list seem empty (#6)*, and reduce other, such as *difficult list navigation (#4)*. If the list did not contain both resource types, the expandable headers could each expand one of the three subtypes instead. This would occupy more of the screen, and simultaneously reduce the numbers of elements in each list. This would also only expand each list to one type of subtype, which would mean the sorting of subtype is already done when resources are displayed. This was considered a good suggestion as it gives several benefits without disturbing rest of the prototype. While it requires major modifications, it would not change the structure, only the content of the current structure.

The two other problems, *difficult selections (#14)* and *missing state information (#24)* were only partly related to the problem with *difficult list navigation (#4)*. However, modifying the first has consequences for the two others. The difficulties with selection concerned entering resource count when allocating a new resource. To properly solve problems with selection, domain knowledge and experience should be used to indicate a realistic number for allocations before deciding upon the appropriate interaction mechanism. For vehicles and persons, this was not an issue, as these normally tend to be allocated individually. For smaller equipment such as roadblocks or cordons, the count would be the most essential factor when deciding to go with drop-down, spinner-wheel or plus-minus button. However, the feedback suggesting more padding and smaller width on the drop-down was taken into account. For selection of priority, the difficulties lied in presentation of the option rather than the interaction. The vertical list of radio buttons indicated a degree of priority, but the suggestion of introducing color codes as well was interesting to ensure redundancy. It also requires minimal effort to incorporate this feature.

The *missing state information (#24)* was mentioned during reallocations, as the current state of priority was not visualized when updating an allocation. The first suggestion was to use the bar at the top to indicate the current priority. While it was not considered by the evaluators to be an optimal solution to the problem, it would solve most of the problem without making major modifications to an interface that otherwise worked well. However, this would require the top bar to be available, i.e. not be used in other context and thereby infringing the consistency principle. As seen in next section, using the top bar was also suggested for other problems.

Another suggestion mentioned was to have the radio button that corresponded to the current priority state, automatically checked. While this was a good idea for the first time the view was open, it would have disappeared as soon as the incident commander checked another radio button. The state information would only be temporary, which is not ideal. Besides, it can be assumed that if the user remembers the current state, then it would not be necessary to repeat it at all.

13.1.3. Filters not visualized

This problem area was only based on *filter status missing (#20)*, yet it was considered important as it overlaps with the first problem area where one suggestion was to filter away redundant information. In such a case, filter status should be visualized. The application contains several options for filtering as presented in Section 10.4.4. The most relevant is still the filter that allows only certain allocations to be visible, thus reducing the overcrowding of markers. Such filters may confuse the incident commander to believe that no resources are allocated when they are in fact only hidden. According to the evaluators, the incident commander should be notified when allocations were hidden to avoid such situations. The evaluators suggested either text or symbol to visualize the filters.

Traditionally, filters are visualized with overlaying symbols indicating active filters. In map applications, it would be natural to place this on top of the map. Since the screen size already limits the view of the map, placing more static layers of information on top of map should be avoided. The prototype does not have any icons for resource type, i.e. equipment or people, but only for subtypes of resources (presented in Section 10.4.2). This implies that visualizing resource filters with graphics require two new symbols that are otherwise not necessary. Introducing more symbols would require the user to memorize more to properly use the prototype, and thereby require a higher cognitive load (i.e. more pressure on the working memory). It would also break with the principle of consistency as the symbols are not used elsewhere. Based on these theoretical and practical arguments to avoid visualization of filters with symbols, the best option was to use text. A textual presentation of filters would allow less required memorization, and it could also be placed in the top bar over the map. Thus, it would not occupy any screen space at the map's expense. There is little chance of misunderstanding as the two words necessary, e.g. *"equipment hidden"*, would be self-explanatory. This was the suggestion brought up by the evaluators that seemed most reasonable.

An argument against this suggestion would be that it does not apply well for multiple filters used simultaneously. Since the purpose of filter status is to avoid misunderstanding of whether allocations are made or not, it only requires three states. The other filters are mostly to distinguish certain markers rather than hiding or showing markers. Those problems are less dependent of filter status, and should therefore not interfere with the current suggestion. If there were more than three states, or the filters allowed several combinations, then the textual filter indication might be problematic.

13.1.4. Progression through task not visualized

This problem area is related to task solving with the prototype rather than the interface or interaction of the prototype. Since *missing progress indication (#2)* was common for both task-scenarios, it was included as a general feature problem in Section 11.2. This was also related to one of the only two critical problems found; *progress may be lost* (Appendix F). If progression is visualized, this critical problem would not be an issue. Thus, solving this problem would take care of other problematic aspects of the prototype as well.

The first suggestion proposed modifications on the existing elements, such as larger fonts in the header text. While this might visualize the current step better, it would not give an indication of the step in relation to the task progress. Thus, it would not give an overview of the progress, just reminding the user of the current step. This suggestion was therefore refused early. Only a few feasible suggestions were made by the evaluators. The most interesting proposal included a progress indication on top of the screen. Either visualized, or written in text. As mentioned previously, using the top bar for textual information was suggested in several problem areas. In this case it would imply informing the user of progression by stepwise incremental, e.g. *"2/4: Select resource:"* where the former digit refers to the current step, and the latter refers to the total steps in the task. The progress could also be visualized with a progress bar on top of the screen. This would cover some of the map. However, it would be justifiable if the user actually benefits from this, since losing overview in the middle of a task would be significantly more critical than the reduces effectiveness due smaller map area displayed. Besides, the incident commander normally interacts with the map before initiating the allocation, which then brings up the menu; hence it would not cover the map while the map was interesting.

Some other proposals were put forward. These included informing the user of desired action in a pop-up box, dialogue or confirmation windows in a conversing interaction format. This would require the user to always give feedback. This might seem like a good idea for a novice, but for an experienced incident commander this would likely reduce both the effectiveness and satisfaction due to longer completion time and increased irritation. These were all rejected as the potential negative aspects were too dominating, and the dialogue windows present in the prototype were already considered somewhat superfluous.

13.2. Design implications

Through the previous sections in this chapter, four problem areas have been defined and discussed based on the results from the evaluations. Through these four problem areas we can derive four high-level design implications. Each of these design implication is presented and explained below, including suggestions for implementation. In addition, references from related work, usability theory, domain knowledge or evaluation criteria presented earlier in the thesis, are mentioned to support the implications. The four design implications are:

1. Limit the information
2. Ensure redundancy
3. Indicate filter status
4. Visualize process

13.2.1. Limit the information

The user should only have to see the information that is necessary to perform the desired task. As presented in Section 7.3, (Streefkerk, van Esch-Bussemakers et al. 2008) suggests that most information is only necessary at certain times. This statement heavily encourages filtering away superfluous information. By using filters, it is also easier to swap content while the structure and interface remain intact which is suggested by Luyten, Winters et al. (2006) as an important feature. This also ensures consistency. Using filter is also in line with the principle about visibility, i.e. only showing interesting options and hiding the rest. From relevant literature, (Burstein, Holsapple et al. 2008) points out that information directed towards the user should be filtered. The problem with too many markers gives an example of how information overload may result in reduced satisfaction and efficiency. However, it is important that information filtered out is easy to bring back again. Otherwise, the filtering will only work against its purpose.

13.2.2. Ensure redundancy

The user should always have several indicators on the meaning of information. Due to the low attention span that may be expected from the user, redundancy increases the chances of correctly understanding the meaning of information. This is important to ensure visibility as it distinguishes different pieces of information. It also reduces the chance of errors, thus contributes to the principle of constraints. One theoretical suggestion for implementation includes color coding of text (e.g. green for low priority) which is presented in Section 9.3.3. When using color coding, it is vital to not to have contradicting meanings for one color, thus each color should only be used for one type of information. This is to ensure consistency, and to avoid confusion. A successful implementation of redundancy should increase the satisfaction due to added user-friendliness, while fewer errors should increase the efficiency.

13.2.3. Indicate filter status

The user should know what filters that are enabled or disabled at all times. There are two main motivations behind this implication: (1) it reduces the cognitive load required, and (2) it minimizes the chances of misunderstanding. This implication mainly relates to the design principle about constraints by preventing the user from making mistakes, and feedback by informing the user of the current state. The context of use also suggests that filter status should be indicated to minimize the pressure on the attention span of the user. Less required cognitive load should increase the satisfaction, while the efficiency and effectiveness should increase due to fewer errors. (Burstein, Holsapple et al. 2008) suggests that the filter status should be indicated. The top bar could be used to state the filter status textually. Alternatively, a graphical icon may be layered on top of the map to indicate filters. The discussion in Section 13.1.3 suggests avoiding this if possible.

13.2.4. Visualize progress

The user should always know how far he has come in a task through a progress indicator. In time-critical applications such as this, the user cannot afford to make errors; hence the system should facilitate for easy understanding of the progress, thereby maximizing the efficiency. Efficiency will also increase if the progress is visualized and the user does not have to stop and wonder about how far he has come. This is relevant when users are away from the phone in periods, something which is very likely within this problem area, and the users is unsure about where he left off. To implement such a feature, the most apparent suggestion is a progress bar indicating the progress. As discussed in Section 13.1.4, another option would be to use textual indications.

13.3. Prototype modifications

In evaluations where feedback has been based on relatively graded degrees of seriousness, some user problems will likely require more time and effort to correct. Certain problems tend to have a low degree of seriousness and require small changes to the prototype, while other problems have a high degree of seriousness, although they require considerable modifications of the prototype. In this section we present a how the four problem areas discussed in Section 13.1 can be solved or at least reduced by using the design implications laid out in previous section. The results from the evaluation showed that the system works. The purpose is to present modifications that would solve user problems without major modifications.

13.3.1. Marker size and shadow

This modification concerns the first problem area, and these changes were made according to the two user problems *too much screen information (#1)* and *pressing markers is difficult (#16)*. Three modifications were made to reduce the overwhelming amount of information: (1) the shadow was dropped for all markers, (2) the marker size was reduced, and (3) the size of the pointing tip was reduced.

Figure 13.3-1: Reduction of marker size

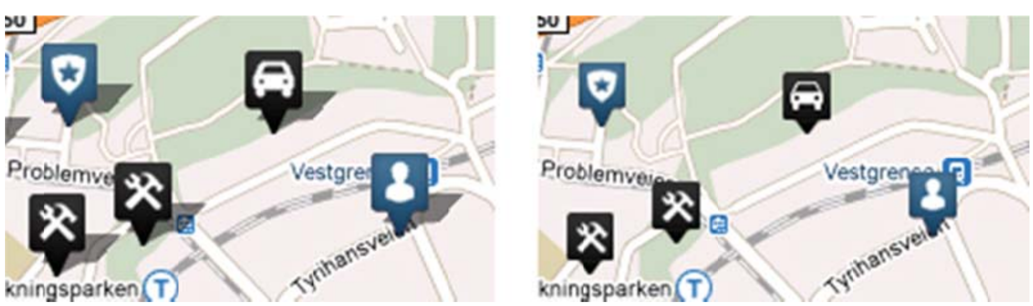


Figure 13.3-2: Before and after marker modification

Dropping the shadow did not require much effort and had no apparent negative consequences. Reducing the size of the pointing tip of markers was more challenging. As seen in Figure 13.3-1 the marker size is considerably reduced. The width of the marker was halved, and combined with the height reduction the total surface reduction is 61%, i.e. the new marker only covered 39 % of the size the original marker did. While this reduce the marker size and thereby the surface of the screen where this marker can be pressed, it simultaneously generates more space between markers, and only the marker becomes clickable rather than marker and shadow. It should therefore reduce the problems with markers not being easily pressed as well.

13.3.2. List appearance

As presented in the second problem area, there were problems related the lists interface. First of all, the problem with *difficult list navigation (#4)* pointed towards easier overview in the lists. To facilitate for more intuitive and orderly lists, a modification had to be made in the map-interface first. As presented in Section 13.1.2, separating resources into either "new equipment allocation" or "new personnel allocation" would allow the list view to be much better exploited. For example, if the lists only have to display equipment resources, the list headers can be used to expand and collapse lists with subtypes of equipment resources (Figure 13.3-3). This also utilizes more of the screen space, thus reduces the problem *lists seem empty (#6)*. Through such a modification, the incident commander does not have to worry about personnel, and the problem with *too much information (#1)* is also reduced. While the total number of list elements is halved, expanding each list also reveals fewer items, and only of one subtype. This way the incident commander has less chance of pressing wrong item.

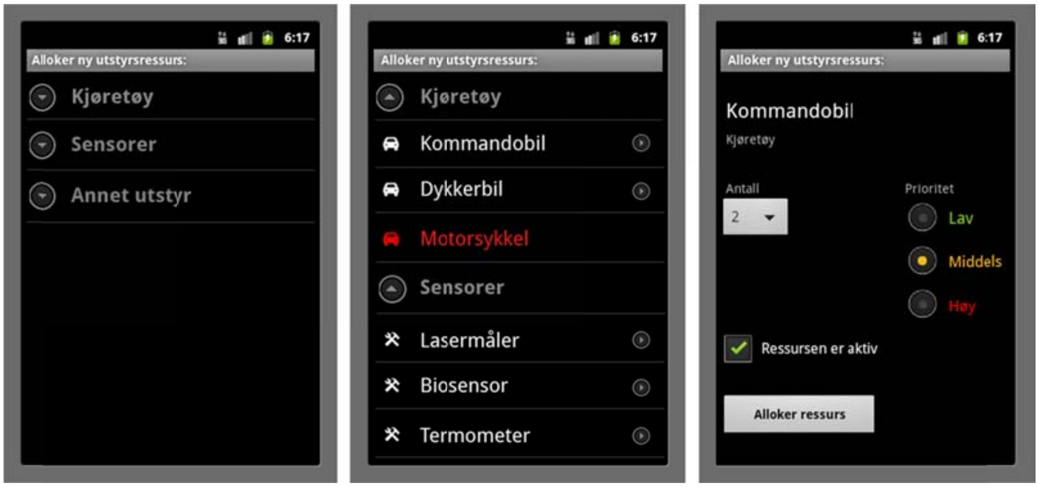


Figure 13.3-3: Modifications to the list interface

Two more modifications have been added to solve two other user problems with lists. Each list element now includes an arrow indicating progress when pressing an item. This was an easy measure to solve the problem *missing progress symbol in list elements (#7)* without disturbing anything else. The other modification adds resources that are already allocated to the list. This is a way of indicating that even though there are no new resources of a certain type, the resources are already allocated and may be reallocated. Therefore, they are colored red for unavailability. Since they cannot be allocated, they do not include an arrow. Although color theory presented in Section 9.3.3 suggests not using red color again for another meaning, it is just used here to illustrate the point. This is one alternative to handle the problem *unavailability uncertain (#22)*.

Finally, the last screenshot in Figure 13.3-3 indicates modification to deal with the problem *difficult selections (#14)*. Colors have been added to the priority selection to easier distinguish and to add redundancy. The drop-down to input count has only been reduced in size since the uncertainty about a realistic value for the count will heavily influence how this is shaped. Therefore, this is not modified at this point.

13.3.3. Filter indicators

Filter status missing (#20) is a problem related to the third problem area. Filtering markers may help reduce the visible amount, without confusing the user. If one resource type were to be used more than another, that filter could be activated by default. The evaluators suggested either textual or graphical visualization of the filters. To resolve this problem, right-aligned text filters were added to the top bar, indicating that resources were hidden from the view (Figure 13.3-4).

Figure 13.3-4: Three filter indicators

The original header was kept for use in other situations. In regards to the design principle of consistency, the left part of the header should be reserved for titles. Simultaneously, the user will know to look to the right for headers. As discussed earlier, since this prototype only had three states, the textual indicator was used, even though there are still uncertainties on how effective this would be.

13.3.4. Progress visualization

To solve the problem with *missing progress indication (#2)*, the most obvious suggestion was to include a progress bar on the top of the screen. Instead of using a horizontal progress bar that gradually fills up (similar to loading bars), the preferred method of indicating progress was using numbers. This allows the user to easily see the current step. Since the tasks have a fixed number of steps required to complete the task, this does not interfere with consistency, and it will always look the same. Additionally, it allows using the same font, colors and backgrounds to create the least intrusive progress indicator. Figure 13.3-5 illustrates how the progress bar can be implemented without taking up too much space and blend into the existing interface.

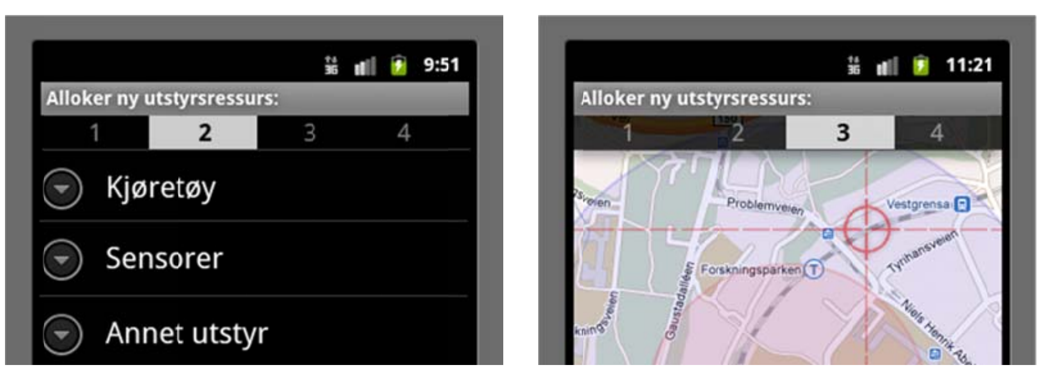


Figure 13.3-5: Number-based progress bar

13.3.5. Other modifications

Besides the problem areas presented in section 13.1, there were two additional suggestions from the evaluations that were implemented. While the evaluators graded the problems as only cosmetic, the suggestions for improvement were considered as modifications that might solve several other problems, including some graded as serious. No problem with marker positioning alone was graded serious, although there were several cosmetic user problems that combined could be regarded as a serious problem. Marker positioning is an essential part of tasks related to resource allocation, thus this is an important topic that should be fixed.

Instead of using the main menu to initiate new resource allocations, the user brings up a context menu by long-pressing on a desired position. The first screenshot in Figure 13.3-6 illustrates the context menu that allows the user to begin either an allocation or reallocation with position already selected. Thus the position is selected before specifying the details rather than afterwards.

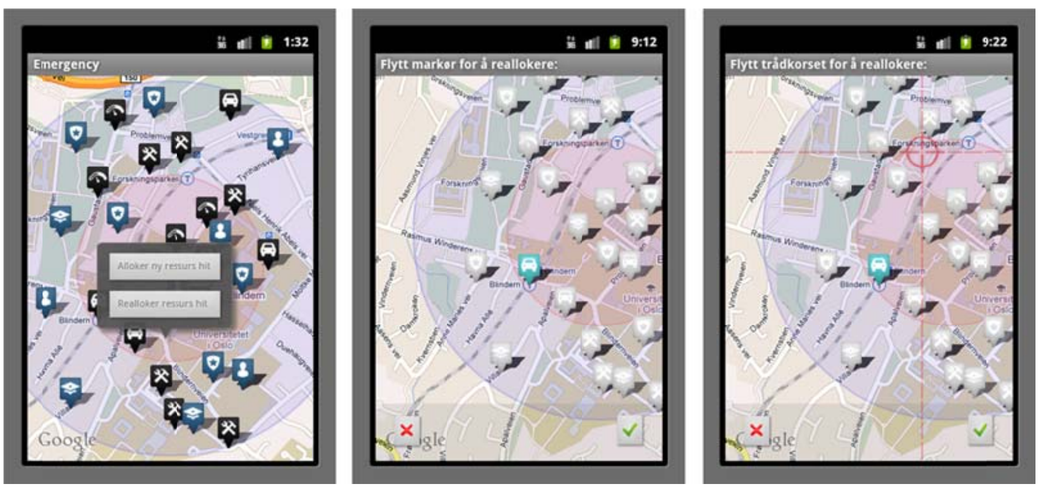


Figure 13.3-6: Context menu for task initiation

The two other screenshots in Figure 13.3-6 are related to reallocation. During reallocating, the user has to position the marker at the desired location. The drag-and-drop interface presented to the evaluators was popular, although the evaluators pointed out that ideally it should allow the user to double-check the position before automatically continuing. Thus, dropping the marker should not trigger next step, but only move the marker, and then wait for a confirmation from the user. This is presented in the second screen in Figure 13.3-6, where a button triggers the next step. This way the user can keep reallocating until satisfied with the position. This is an easy way of implementing error prevention and increase user satisfaction, without changing anything with the interaction mechanism.

Since this is an important topic, an alternative suggestion from the evaluators was also implemented. This is illustrated in the third screenshots in Figure 13.3-6. These two alternatives for the same functionality can be subject to future evaluation. The idea is to let the user select desired location and wait for button press before continuing. The difference is that the alternative includes a crosshair instead of a drag-and-drop interaction. This would allow a more precise positioning. The challenge is to decide whether the map moves or the crosshair moves when the user wants to move the crosshair. In the third screenshot, the crosshair moves, however this is not confirmed as the best alternative. Regardless of which of these two alternatives that are considered the best, they both hold an advantage to the current solution.

While the context menu in the first screenshot might solve some of the problems that occur by automatically using the location of the position where the long press is detected, there should be an option to adjust this position after resource details have been entered or updated. This is important to effectiveness as it would otherwise require the user to restart the task, and efficiency as it prevents the user from making more errors.

13.4. Validity and criticism

As presented in Section 2.4, there was no relevant work that covered exactly the same problem domains as this thesis. As a consequence, most of the domain knowledge collected from related work derives from combinations of several partly overlapping works. Ideally, this should have been avoided. As mentioned by participants of the advisory board, a lot of work is brought into the problem domain of this thesis may not necessarily be transferrable. Thus, it is possible that some information is not relevant or representative, even though presented as related work. Not all knowledge is transferrable to this domain due to its uniqueness in character.

While domain knowledge was brought into this thesis via previous work in the EMERGENCY-project, interviews and frequent meetings with the thesis supervisor, the domain knowledge was lacking during evaluations of the prototype. The intended test in user context and expert evaluation with domain experts were not conducted due to postponement of planned exercises and difficulties obtaining timely access to domain experts. This created an unbalanced composition between usability experts and domain experts, thus the results of the evaluations may suffer as experience with usability testing tends to find more user problems than field studies (Duh, Tan et al. 2006, p. 186).

The results from the evaluations with usability experts are mostly based on the evaluators' analytical prediction of how individuals will interact with the system during emergency situations. Accurate prediction of individuals' reactions in such situations is very difficult (Doheny and Fraser 1996, p. 3). Additionally, the external factors that might affect the situations are often very complex and hard to imagine for usability experts. While the derived implications from the results correspond with the requirements from the collected domain knowledge, the results should be compared to results from domain expert evaluations to get a more representative set of results.

As presented in Section 12.4, the usability experts tended to be more lenient than one can assume the domain experts would have been, as they were very aware of their own lack of domain understanding. Thus, their insecurity may have influenced them to not grade a user problem as serious or critical, even though usability principle suggested so. The results presented in Chapter 12 should therefore have taken *halo effect*[35] into account when problems were grouped. However, the evaluation was conducted in two sessions, so the triangulation should have minimized the chances of cognitive bias.

Another problem related to evaluation is the methodological complexity of me conducting the evaluations as test leader. My presence as the developer might have put pressure on the evaluators. It is suggested that designers, when present at such evaluations, tend to nudge the evaluators in the desired direction (Saffer 2006, p. 183). Me being the test leader, and my thesis supervisor acting as secretary, was still considered the best option due to practical and educational reasons even though we were aware of this problem beforehand. If it would have been considered too problematic, then the thesis supervisor could have led the evaluation.

[35] *Halo effect* is a term used to describe situation were an evaluator's perception of a feature affects the perception of other features.

Chapter 14

Conclusions and future work

This final chapter summarizes the work and contribution of this thesis. A brief overview is given of the whole process, and a summary of the most important findings in this thesis are then presented. Finally, the possible directions for future work with results and implications from this study are considered.

14.1. Summary

This thesis has presented the most important implications for designing ICT-support on mobile devices in emergency work. The implications results from extensive research about the specific problem-domain and evaluations of a prototype. Related work and collected domain knowledge was used to investigate and discuss the task, the user and the user context, i.e. resource management tasks amongst incident commanders in the police during emergency situations. The domain investigation revealed a set of guidelines on how to make supportive and non-intrusive solutions, which were then combined with theories on interface design and usability to deduce general design requirements for the particular problem-domain. Design challenges related to mobile devices such as small-screen impact were combined with the gathered requirements to scope out the most relevant requirements and theoretically appropriate interface for the intended purpose. This allowed us to develop a prototype that could help validate and update the understanding of the problem area. The prototype was developed for state of the art mobile devices and focused on how a map-based interface functioned for decision support, and which design alternatives that provided the best support when handling resources. After several rounds of prototyping, a proper prototype was developed and considered mature enough for evaluation using task-based scenarios. The main evaluation of the prototype was conducted in two sessions with usability experts. The evaluation revealed several user problems that were discussed against related work and collected domain knowledge, which finally led to four problem areas. Based on these four problem areas, adjustments were made to the prototype, and finally the implications of design were presented.

14.2. Contribution

This purpose of this thesis has been to present the main design implications for map-based interfaces for mobile devices in emergency response. This was derived through a study of resource handling amongst incident commanders in the police. The main achievement is the contribution to domain-specific decision support in emergency response. The work in this thesis has been based on three main objectives: (1) identifying design requirements and design challenges, (2) developing a prototype and conducting evaluations, and (3) defining problem areas and presenting design implications for future work. Much domain information was gathered about tasks within emergency response, and these particular tasks were well-suited for prototyping. They were also selected because of the central role and important function in all emergency situations. This makes data collection, knowledge and experience all very much transferable to other tasks within the police, but also to other agencies. The particular tasks serve an important function in e.g. medial response or fire agency as well where a local leader has overlapping areas of responsibility. This is also applicable to Red Cross and other voluntary organizations. Thus, considering general impact and contribution, this thesis might hopefully present contributions that may benefit other agencies as well. While the problem area was scoped to domestic terms, the results and implications are not only applicable to domestic studies. Design theory and knowledge from relevant work was mostly collected from foreign sources exploring the same domain. With any luck, the work in this thesis might contribute to other work within the same field on an international level as well.

14.3. Findings and design implications

The prototype and evaluation resulted in several interesting findings that eventually led to the presentation of design implications. To explore these challenges, a lot of features of a final version were abstracted away (e.g. network problematic and centralization of information). However, the prototype was intentionally made to support future implementations like multimodal gestures and GPS-support.

Furthermore, it became obvious that domain knowledge or usability theory were not good enough as design guidelines individually. Knowledge from other fields and relevant literature are not always applicable to this particular domain, as it has very unique and characteristic qualities that needs to be taken into account when designing. As mentioned in the first chapter of the thesis, a lack of understanding of user and context might result in only partly successfully solutions; hence it is fundamental to gather knowledge about the task at hand, the user, and user context, and not only rely on design theories alone. The good access to usability experts contributed to a solid theoretically foundation. On the other hand there was a lack of domain-experts and potential end-users at times, which then became very obvious. For example, the group-based expert walkthrough sessions raised several interesting and crucial questions from the evaluators that we were unable to answer. There were fewer domain-experts at disposal than desired. While it did not restrain the work of this thesis very much, it would have been an apparent advantage to conduct more evaluations with end-users that are domain-experts. An optimal combination would have been an equal share of domain and usability expert as combined knowledge is required to properly design solutions for such demanding applications.

Nevertheless, the prototype was well received during the evaluations, and positive feedbacks were given. It was a common opinion that the format and interface was well-suited for solving tasks related to resource handling, especially after the discovered user problems were corrected. However, as presented throughout this thesis, the uniqueness and variance in situational context and task property does not allow us to regard the prototype as a complete or optimal solution for all variations and problems within the problem domain. It can still give a good understanding of the fundamental properties of a prototype, as well as guidance on how the development and evaluation procedure should be conducted in similar studies.

The prototype and evaluations allowed us to discover user problems which were grouped into four problem areas. This eventually led to the presentation of the design implications:

1. Limit the information
2. Ensure redundancy
3. Indicate filter status
4. Visualize process

14.4. Future work

Results and implications from this thesis open up several prospects and possibilities for future work. In this section, different ideas for further implementations of the prototype are presented and explained, before remaining challenges and possibilities are mentioned and future work is proposed.

14.4.1. Further implementations

There were several remaining features that would have been interesting to include in the current prototype. Mainly, the prototype modifications presented in Section 13.3 should be fully implemented. Some of these modifications are already implemented, yet the major restructuring of the interface still remains. Other features that should be implemented without breaking the scope mostly concern *multimodal interaction* with the user and *tracking of resources*. While the prototype was not mature enough from the beginning, it has now reached a level where it is natural to include such features.

Multimodal gestures have become fairly easy to implement, especially on top of already working solutions. Both usability theory and domain knowledge suggest giving multimodality a chance at least as it may enhance the increase in value considerably. The most natural gestures include implementation of accelerometers and gyroscope for motion and gesture detection such as reacting to shaking phones. This could be used to facilitate for both direct interaction (e.g. shaking phone to refresh the screen) and indirect interaction (e.g. detecting when incident commander is moving). Another feature that could provide added value to the prototype is speech recognition. Issuing commands via speech would allow the incident commander to communicate with sound only, and this could potentially lead to a system where the task handling could be performed more independent of the screen. Both of these features would significantly improve the interaction possibilities in situations where normal use is impossible, e.g. performing tasks via speech when outside in the cold wearing gloves. An alternative to speech recognition and gestures could be designated hardware buttons. For example, smoke divers use designated hardware buttons outside their suits or uniforms to interact with the system. This could also be implemented in a prototype such as this.

Tracking of resources mostly concerns creating a dynamic interface where resources that are moving, e.g. vehicles or people, also move on the map. Most equipment used by the police is tracked and can be included in a similar manner. Furthermore, the GPS-functionality of the mobile device should be used to position the incident commander on the map as well. This allows for a better overview in regards to current position, and it automatically generates tracking data which can be made available to other resources. It would also require less reporting between resources as positions would update automatically.

The last, and probably most significant, suggestion for improvement is implementing an *automation of task handling*. This idea was proposed by one of the evaluators of the prototype. During reallocation, the incident commander has to manually select which resource to reallocate. Sometimes, it may be desirable to just allocate the geographically nearest resource available. With all data available in the current prototype, it is possible to determine the physical distance between resources, and thereby calculating which resource of a desired state and priority is the nearest, and then allocate this to the desired location. This would relieve the incident commander of much valuable time and make task handling more efficient and effective.

This thesis has presented a prototype that examines tasks related to resource allocations. Handling resources is only one of several areas of responsibilities for the incident commander. If we look back at Section 6.1.2, several other task categories could be solved on mobile devices. The current prototype allows incident commanders to call person resources directly via the interface, but there are many other communication features that can be implemented. *Communication* in particular should therefore be further explored. *Handling location* and *handling information about the incident* may also be of interest when expanding the prototype to cover other suitable tasks.

14.4.2. Evaluations with domain experts

As mentioned, the prototype was not considered properly evaluated by domain-experts. While it is always desirable to test a prototype in a proper user context, the circumstances for realistic settings in this context require very much preparation and resources. In general, emergency situations, especially representative ones, are very difficult to recreate, and the factors such as stress and anxiety are almost impossible to manipulate. The prototype should therefore be properly evaluated by experts analytically before moving on to more realistic environments. After implementing the suggested modifications in Section 13.3, the prototype should be evaluated. The group-based expert walkthrough was used with success in this study, and it is recommended to begin with a similar evaluation with two groups of domain-experts. This will probably reveal more problems with the prototype, yet they are more likely to be problems related to task solving rather than usability. The prototype should then be modified to correct the revealed problems, and should then be tested in context.

14.4.3. Tablet

Appropriate tablets were not available at the startup of the EMERGENCY-project. They were therefore not considered as an option. Since that time, the tablets have established themselves as a proper and familiar device with obvious benefits compared to mobile phones. While the mobile phone provides certain benefits, some tasks are better solved on tablets. In relevant literature prior to the introduction of tablets, people often talk about something between a small mobile device and a laptop as the optimal device. As suggested in Section 10.1, the main challenge with mobile phones is the limited screen size, thus well-functioning interfaces for mobile phones would most likely function similarly on tablets as well. The portability between mobile applications and tablet applications is good in general, and often allows mobile application to run directly on tablets without any modifications to the code. Thus, the prototype can be transferred to tablets for comparison. Even if the code needs modification, it will not require much effort to make the code compatible with tablets as well. However, transferring this prototype to a tablet would put some new restraints on the application. GPS-positioning is currently not available on all tablets, and there is no integrated phone. The physical size is also considerably larger than the standard mobile phones, thus tablets introduces new technological and physical circumstances that needs to be studied further.

References

Ambler, Scott W. (2000). The Unified Process Construction Phase: Best Practices in Implementing the UP, CMP, ISBN: 978-1929629015.

Andreasen, Morten Sieker, Nielsen, Henrik Villemann, Schrøder, Simon Ormholt and Stage, Jan (2007). What happened to remote usability testing?: an empirical study of three methods. Proceedings of the SIGCHI conference on Human factors in computing systems. San Jose, California, USA, ACM**:** 1405-1414 ISBN: 978-1-59593-593-9.

Android (2010a). Android 2.3 Compatibility Definition. 7. Hardware Compatibility, Google Inc.

Android, Google's (2010b). "Adding SDK Components | Android Developers." Android Developers. Retrieved 10-12, 2010, from http://developer.android.com/sdk/adding-components.html.

Apple (2010). "Discrete Gestures and Continuous Gestures." Event Handling Guide for iOS. Retrieved 16-03-2011, 2011, from http://developer.apple.com/library/ios/#documentation/EventHandling/Conceptual/EventHandlingiPhoneOS/GestureRecognizers/GestureRecognizers.html#//apple_ref/doc/uid/TP40009541-CH6-SW12.

Bachrach, Arthur J (1962). Psychological research : an introduction. New York, Random House,

Baker, Nick (2010). "Why do we all use Qwerty keyboards?". Retrieved 16-02, 2011, from http://www.bbc.co.uk/news/technology-10925456.

Barnard, L., Yi, J.S., Jacko, J.A. and Sears, A. (2005). "An empirical comparison of use-in-motion evaluation scenarios for mobile computing devices." International Journal of Human-Computer Studies **62**(4): 487-520.

Bekker, Mathilde, Barendregt, Wolmet, Crombeen, Silvia and Biesheuvel, Mariëlle (2005). Evaluating Usability and Challenge during Initial and Extended Use of Children's Computer Games. People and Computers XVIII — Design for Life. Fincher, Sally, Markopoulos, Panos, Moore, David and Ruddle, Roy, Springer London**:** 331-345, ISBN: 978-1-84628-062-7.

Bennett, Simon, McRobb, Steve and Farmer, Ray (2005). Object-Oriented Systems Analysis and Design using UML 3/e, McGraw-Hill Education, ISBN: 0077110005;978-0077098643.

Berre, Jørgen (2009). Slik snur Obama Oslo på hodet. Nettavisen. Oslo, Mediehuset Nettavisen AS

Bevan, N. (1995). "Usability is quality of use." Advances in Human Factors/Ergonomics **20**: 349-354.

Boehm, B. and Hansen, W. (2001). "The spiral model as a tool for evolutionary acquisition." CrossTalk **14**(5): 4–11.

Boehm, Barry W. (1988). "A Spiral Model of Software Development and Enhancement." Computer **21**(5): 61-72.

Borysowich, Craig (2007). "Prototyping: Types of Prototypes." Observations from a Tech Architect: Enterprise Implementation Issues & Solutions. Retrieved 17-02, 2011, from http://it.toolbox.com/blogs/enterprise-solutions/prototyping-types-of-prototypes-14927.

Bradley, Jay, Mival, Oli and Benyon, David (2009). Wizard of Oz Experiments for Companions. HCI 2009 - People and Computers XXIII – Celebrating people and technology, British Computer Society.

Brenner, David J. and Cadoff, Marilyn A. (1985). Guide to computer-aided dispatch systems. Springfield, Virginia,

Brewster, Stephen (2002). "Overcoming the Lack of Screen Space on Mobile Computers." Personal Ubiquitous Comput. **6**(3): 188-205.

Brown, C.M. (1999). Human-computer interface design guidelines, Intellect Books, ISBN: 1871516544.

Burigat, Stefano and Chittaro, Luca (2008). Decluttering of Icons Based on Aggregation in Mobile Maps. Map-based Mobile Services. Meng, Liqiu, Zipf, Alexander and Winter, Stephan, Springer Berlin Heidelberg**:** 13-32, ISBN: 978-3-540-37110-6.

Burstein, Frada, Holsapple, Clyde, Walle, Bartel and Turoff, Murray (2008). Decision Support for Emergency Situations. Handbook on Decision Support Systems 2, Springer Berlin Heidelberg**:** 39-63, ISBN: 978-3-540-48716-6.

Carver, Liz and Turoff, Murray (2007). "Human-computer interaction: the human and computer as a team in emergency management information systems." Commun. ACM **50**(3): 33-38.

Chittaro, L. (2006). "Visualizing information on mobile devices." Computer **39**(3): 40-45.

Chittaro, Luca (2003). Human-Computer Interaction with Mobile Devices and Services. Udine, Italy, Springer, ISBN: 9783540408215.

Cohen, Philip R. and McGee, David R. (2004). Tangible multimodal interfaces for safety-critical applications. Communications of the ACM, ACM.

Constantine, Larry L. and Lockwood, Lucy A. D. (2002). "Instructive interaction: Making innovative interfaces self-teaching." User Experience, Constantine & Lockwood, Ltd. **3**(1).

Danielsson, Karin, Naghsh, Amir M. and Dearden, Andy (2006). Distributed Participatory Design. Workshop at the 4th Nordic Conference on Human-Computer Interaction. Oslo, Norway, NordiCHI

Danielsson, Karin, Naghsh, Amir M., Gumm, Dorina and Warr, Andrew (2008). Distributed participatory design. CHI '08 extended abstracts on Human factors in computing systems. Florence, Italy, ACM**:** 3953-3956

Davis, Fred D., Bagozzi, Richard P. and Warshaw, Paul R. (1989). "User Acceptance of Computer Technology: A Comparison of Two Theoretical Models." Management Science **35**(8): 982-1003.

Davis, Ziff (2011). Smartphone Definition from PC Magazine Encyclopedia. PC Magazine Encyclopedia. Magazine, PC, Ziff Davis, Inc

Denzin, Norman K. (1970). The research act in sociology: A theoretical introduction to sociological methods. London, Butterworths, ISBN: 0408701242.

Denzin, Norman K. (2006). Sociological Methods: A Sourcebook (Methodological Perspectives), Transaction Publishers, ISBN: 978-0-202-30840-1.

di Tada, Nicolas and Large, Timothy (2010). Emergency Information System. 7th International ISCRAM Conference, ISCRAM.

Dilmaghani, Raheleh B. and Rao, Ramesh R. (2009). A Systematic Approach to Improve Communication for Emergency Response. 42nd Hawaii International Conference on System Sciences, IEEE.

Doheny, J. G. and Fraser, J. L. (1996). "MOBEDIC -- A decision modelling tool for emergency situations." Expert Systems with Applications **10**(1): 17-27.

Doubleday, Ann, Ryan, Michele, Springett, Mark and Sutcliffe, Alistair (1997). A comparison of usability techniques for evaluating design. Proceedings of the 2nd conference on Designing interactive systems: processes, practices, methods, and techniques. Amsterdam, The Netherlands, ACM**:** 101-110

DSB, (Direktoratet for samfunnssikkerhet og beredskap), Kystverket and forurensningsdirektoratet, Klima- og (2010). Veiledning om Enhetlig ledelsessystem (ELS) ved brann, redning og akutt forurensning. Tønsberg. **0511**

Duh, Henry Been-Lirn, Tan, Gerald C. B. and Chen, Vivian Hsueh-hua (2006). Usability evaluation for mobile device: a comparison of laboratory and field tests. Proceedings of the 8th conference on Human-computer interaction with mobile devices and services. Helsinki, Finland, ACM**:** 181-186

Eckstein, Robert (2007). "Java SE Application Design With MVC." Java Feature Stories. from http://www.oracle.com/technetwork/articles/javase/index-142890.html#1.

Ferré, X., Juristo, N., Windl, H. and Constantine, L. (2001). "Usability basics for software developers." Software, IEEE **18**(1): 22-29.

Fiedrich, F., Gehbauer, F. and Rickers, U. (2000). "Optimized resource allocation for emergency response after earthquake disasters." Safety Science **35**(1-3): 41-57.

Fitts, P.M. (1954). "The information capacity of the human motor system in controlling the amplitude of movement." Journal of experimental psychology **47**(6): 381.

Floyd, Christiane (1984). "A systematic look at prototyping." Approaches to Prototyping: 1-18.

Frøkjær, E., Hertzum, M. and Hornbæk, K. (2000). Measuring usability: are effectiveness, efficiency, and satisfaction really correlated?, ACM.

Følstad, Asbjørn (2007a). Group-based Expert Walkthrough. R3UEMs: Review, Report and Refine Usability Evaluation Methods. Law, Dominique Scapin & Effie

Følstad, Asbjørn (2007b). "Work-Domain Experts as Evaluators: Usability Inspection of Domain-Specific Work-Support Systems." International Journal of Human-Computer Interaction **22**(3): 217 - 245.

Følstad, Asbjørn (2008). The effect of group discussions in usability inspection: a pilot study. Proceedings of the 5th Nordic conference on Human-computer interaction: building bridges. Lund, Sweden, ACM**:** 467-470

Gale (2010). Prototype. Encyclopedia of Small Business, Gale Cengage Learning. **2:** 1100 ISBN: 9781414420288; 978-0-78-769112-7;978-1-41-441040-1.

Gillham, Bill (2000). Developing a Questionnaire (Real world research) Continuum International Publishing Group Ltd, ISBN: 978-0826447951.

Goodhue, Dale L. and Thompson, Ronald L. (1995). "Task-Technology Fit and Individual Performance." MIS Quarterly **19**(2): 213-236.

Goodman, Robert (1997). "The Strengths and Difficulties Questionnaire: A Research Note." Journal of Child Psychology and Psychiatry **38**(5): 581-586.

Gram, C. and Cockton, G. (1996). Design principles for interactive software, Kluwer Academic Publishers, ISBN: 0412724707.

Hagen, Penny, Robertson, Toni, Kan, Melanie and Sadler, Kirsten (2005). Emerging research methods for understanding mobile technology use. Proceedings of the 17th Australia conference on Computer-Human Interaction: Citizens Online: Considerations for Today and the Future. Canberra, Australia, Computer-Human Interaction Special Interest Group (CHISIG) of Australia**:** 1-10

Hang, Alina, Rukzio, Enrico and Greaves, Andrew (2008). Projector phone: a study of using mobile phones with integrated projector for interaction with maps. Proceedings of the 10th international conference on Human computer interaction with mobile devices and services. Amsterdam, The Netherlands, ACM**:** 207-216

Harrower, Mark and Sheesley, Benjamin (2005). Designing Better Map Interfaces: A Framework for Panning and Zooming Transactions in GIS. **9:** 77-89,

Hartson, H.R. and Hix, D. (1989). "Toward empirically derived methodologies and tools for human-computer interface development." International Journal of Man-Machine Studies **31**(4): 477-494.

Heaton, Nigel (1992). What's wrong with the user interface. How rapid protoyping can help. Software Prototyping and Evolutionary Development, IEE Colloquium on. Human Applications, Loughborough London , UK, IEEE Xplore**:** 7/1-7/5

Hollingsed, Tasha and Novick, David G. (2007). Usability inspection methods after 15 years of research and practice. Proceedings of the 25th annual ACM international conference on Design of communication. El Paso, Texas, USA, ACM**:** 249-255

Hornbæk, K. and Frøkjær, E. (2005). Comparing usability problems and redesign proposals as input to practical systems development, ACM.

HTC (2010). "HTC Desire HD - Overview." HTC - Products. Retrieved 16/03, 2011, from http://www.htc.com/www/product/desirehd/overview.html.

Höysniemi, Johanna, Hämäläinen, Perttu and Turkki, Laura (2004). Wizard of Oz Prototyping of Computer Vision Based Action Games for Children. IDC '04: Proceedings of the 2004 conference on Interaction design and children: building a community, ACM.

InvestorWords (2011). Proof of concept. InvestorWords.com - Investing Glossary

Işıklar, Gülfem and Büyüközkan, Gülçin (2007). "Using a multi-criteria decision making approach to evaluate mobile phone alternatives." Comput. Stand. Interfaces **29**(2): 265-274.

ISO, International Organization for Standardization (1998). ISO 9241-11: Ergonomic requirements for office work with visual display terminals (VDTs) - Part 11 : Guidance on usability. Exigences ergonomiques pour travail de bureau avec terminaux a ecrans de visualisation (TEV), Technical Committee ISO/TC 159, Ergonomics, Subcommittee SC 4, Ergonomics of human-system interaction.

ISO, International Organization for Standardization (1999). ISO 13407: Human-centred design processes for interactive systems. Processus de conception centrée sur l'opérateur humain pour les systèmes interactifs, Technical Committee ISO/TC 159, Ergonomics, Subcommittee SC 4, Ergonomics of human-system interaction.

Jacko, Julie A. (2007). Human-Computer Interaction. Interaction Design and Usability. Beijing, Springer, ISBN: 978-3-540-73104-7.

Jeffries, Robin and Desurvire, Heather (1992). "Usability testing vs. heuristic evaluation: was there a contest?" SIGCHI Bull. **24**(4): 39-41.

Jhangiani, I. and Smith-Jackson, T. (2007). Comparison of mobile phone user interface design preferences: perspectives from nationality and disability culture, ACM.

Jokela, Timo, Iivari, Netta, Matero, Juha and Karukka, Minna (2003). The standard of user-centered design and the standard definition of usability: analyzing ISO 13407 against ISO 9241-11. Proceedings of the Latin American conference on Human-computer interaction. Rio de Janeiro, Brazil, ACM**:** 53-60

Jokinen, Kristiina (2008). User Interaction in Mobile Navigation Applications. Map-based Mobile Services. Meng, Liqiu, Zipf, Alexander and Winter, Stephan, Springer Berlin Heidelberg**:** 168-197, ISBN: 978-3-540-37110-6.

Jones, Matt and Marsden, Gary (2006). Mobile Interaction Design, John Wiley & Sons, ISBN: 0470090898.

Joshi, Suhas and Torp, Thomas (2010). Report - Handling emergency incidents with mobile devices. Oslo

Kato, Tsuneaki, Fukumoto, Jun'ichi, Masui, Fumito and Kando, Noriko (2006). WoZ Simulation of Interactive Question Answering. Proceedings of the Interactive Question Answering Workshop at HLT-NAACL 2006,, New York City, NY, Association for Computational Linguistics.

Khalilbeigi, Mohammadreza, Schweizer, Immanuel, Bradler, Dirk, Probst, Florian and Steimle, Jürgen (2010). Towards Computer Support of Paper Workflows in Emergency Management. 7th International ISCRAM Conference, ISCRAM.

Kjeldskov, J. and Graham, C. (2003). "A review of mobile HCI research methods." Human-computer interaction with mobile devices and services: 317-335.

Kjeldskov, J., Graham, C., Pedell, S., Vetere, F., Howard, S., Balbo, S. and Davies, J. (2005). "Evaluating the usability of a mobile guide: The influence of location, participants and resources." Behaviour & Information Technology **24**(1): 51-65.

Kjeldskov, J. and Stage, J. (2004). "New techniques for usability evaluation of mobile systems." International Journal of Human-Computer Studies **60**(5-6): 599-620.

Kondaveti, R. and Ganz, A. (2009). Decision support system for resource allocation in disaster management. Engineering in Medicine and Biology Society, 2009. EMBC 2009. Annual International Conference of the IEEE.

Kotek, Brian (2002). "MVC design pattern brings about better organization and code reuse." TechRepublic. from http://www.techrepublic.com/article/mvc-design-pattern-brings-about-better-organization-and-code-reuse/1049862.

Krahnstoever, N., Schapira, E., Kettebekov1, S. and Sharma, R. (2002). Multimodal Human-Computer Interaction for Crisis Management Systems. Sixth IEEE Workshop on Applications of Computer Vision (WACV'02), IEEE.

Ladstein, Njål (2009). "Funksjonsrettet ledelse for operasjonsledere." from http://www.phs.no/no/Studietilbud/Etter--og-videreutdanning/Videreutdanninger-med-studiepoeng/Ledelse-og-organisasjon/Funksjonsrettet-ledelse-for-operasjonsledere/.

Lahlou, Saadi (2009). Augmented Environments and Design. Designing User Friendly Augmented Work Environments
From Meeting Rooms to Digital Collaborative Spaces. Limited, Springer-Verlag London,

Lanfranchi, Vita and Ireson, Neil (2009). User Requirements for a Collective Intelligence, British Computer Society.

Lee, Minkyung and Billinghurst, Mark (2008). A Wizard of Oz Study for an AR Multimodal Interface. ICMI '08: Proceedings of the 10th international conference on Multimodal interfaces, ACM.

Lethbridge, Timothy C., Sim, Susan Elliott and Singer, Janice (2005). "Studying Software Engineers: Data Collection Techniques for Software Field Studies." Empirical Software Engineering **10**(3): 311-341.

Lim, Youn-Kyung, Stolterman, Erik and Tenenberg, Josh (2008). "The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas." ACM Trans. Comput.-Hum. Interact. **15**(2): 1-27.

Luyten, Kris, Winters, Frederik and Coninx, Karin (2006). A Situation-Aware Mobile System to Support. OTM Workshops 2006, LNCS 4278, Springer-Verlag Berlin Heidelberg.

Marcus, Aaron (1984). "Graphic design for computer graphics." Comput. Ind. **5**(1): 51-63.

McInnes, F. R., Jack, M. A., Carraro, F. and Foster, J. C. (1997). User response to prompt wording styles in an automated banking service with a Wizard of Oz simulation of word-spotting. Advances in Interactive Voice Technologies for Telecommunication Services (Digest No: 1997/147), IEE Colloquium on.

Meng, L., Zipf, A. and Winter, S. (2008). Map-based mobile services: design, interaction, and usability, Springer Verlag, ISBN: 3540371095.

Miller, G. A. (1956). "The magical number seven, plus or minus two: Some limits on our capacity for processing information." Psychological Review **63**: 81-97.

Montgomery, Geoffrey (2008). "Color Blindness: More Prevalent Among Males." Breaking the Code of Color. Retrieved 18-03, 2010, from http://www.hhmi.org/senses/b130.html.

Morse, Scot F. and Anderson, Charles L. (2004). "Introducing application design and software engineering principles in introductory CS courses: model-view-controller Java application framework." J. Comput. Small Coll. **20**(2): 190-201.

Muller, Michael J., Matheson, Lisa, Page, Colleen and Gallup, Robert (1998). "Methods & tools: participatory heuristic evaluation." interactions **5**(5): 13-18.

Nadal-Serrano, Jose M. (2010). Towards very simple, yet effective on-the-go incident response preplanning: using publicly-available GIS to improve firefighters. 7th International ISCRAM Conference, ISCRAM.

Naghsh, Amir M., Danielsson, Karin, Fischer, Gerhard, Bratteteig, Tone, Blomberg, Jeanette and Nocera, José Abdelnour (2008). Distributed-PD: challenges and opportunities. Proceedings of the Tenth Anniversary Conference on Participatory Design 2008. Bloomington, Indiana, Indiana University**:** 290-291

Nakatani, Mie and Nishida, Shogo (2007). Prospective Interfaces for Emergency Management in Large Scale. IEEE International Conference on Systems, Man and Cybernetics, 2007. ISIC. , IEEE.

Newlon, Christine M., Pfaff, Mark, Patel, Himalaya, de Vreede, Gert-Jan and MacDorman, Karl (2009). Mega-Collaboration: The Inspiration and Development of an Interface for Large-Scale Disaster Response. 6th International ISCRAM Conference, Gothenburg, Sweden, ISCRAM.

Nielsen, J. (1994). Usability inspection methods, ACM.

Nielsen, Jakob (2003) Usability 101: Introduction to Usability. Alertbox: Current Issues in Web Usability

Nielsen, Jakob (2005). "Ten Usability Heuristics." UseIt. Retrieved 21-02, 2011, from http://www.useit.com/papers/heuristic/heuristic_list.html.

Nielsen, Jakob and Landauer, Thomas K. (1993). A mathematical model of the finding of usability problems. Proceedings of the INTERACT '93 and CHI '93 conference on Human factors in computing systems %@ 0-89791-575-5. Amsterdam, The Netherlands, ACM**:** 206-213

Nilsson, Erik G. (2010a). Challenges for Mobile Solutions for Emergency Response. Oslo, SINTEF**:** 3 ISBN: 978-82-14-04958-9.

Nilsson, Erik G. (2010b). Tasks and information models for local leaders at the TYR training exercise. Oslo**:** 31 ISBN: 978-82-14-04479-9.

Nilsson, Erik G. and Brændland, Gyrd (2009). EMERGENCY: Evaluering av DISKO, SINTEF IKT ISBN: 978-82-14-04445-4.

Nilsson, Erik G. and Stølen, Ketil (2010). Ad Hoc Networks and Mobile Devices in Emergency Response – a Perfect Match?, SINTEF ICT.

Norman, D.A. (2002). "The psychopathology of everyday things." Foundations of cognitive psychology: core readings.

Norros, Leena, Hutton, Robert, Grommes, Patrick, Colford, Nick, Liinasuo, Marja and Savioja, Paula (2009). Analysis of work demands of multi-agency emergency. ECCE '09: European Conference on Cognitive Ergonomics: Designing beyond the Product --- Understanding Activity and User Experience in Ubiquitous Environments VTT Technical Research Centre of Finland.

NSD (2011). Melde- og konsesjonsplikt. Forskning og personvern. Bergen, NSD Personvernombudet for forskning

O'Dell, Mike (2011). "Timebox Development." CSE 4317 - Senior Design II. Retrieved 14, from http://ranger.uta.edu/~odell/CSE_4317_Senior_Design_II/CSE4317%20TIMEBOX%20DEVELOPMENT.PPT.

Paelke, V., Reimann, C. and Rosenbach, W. (2003). A visualization design repository for mobile devices, ACM.

Pérez, Ignacio Javier, Cabrerizo, Francisco Javier and Herrera-Viedma, Enrique (2010). "A Mobile Decision Support System for Dynamic." IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS—PART A: SYSTEMS AND HUMANS: 1-13.

Petrie, Jennifer N. and Schneider, Kevin A. (2007). Mixed-fidelity prototyping of user interfaces. Proceedings of the 13th international conference on Interactive systems: Design, specification, and verification. Dublin, Ireland, Springer-Verlag: 199-212

Pilone, Dan and Pitman, Neil (2005). UML 2.0 in a Nutshell, O'Reilly Media, Inc., ISBN: 978-0-596-00795-9.

Plotnick, Linda, Ocker, Rosalie, Hiltz, Starr and Rosson, Mary Beth (2008). Leadership Roles and Communication Issues in Partially Distributed Emergency Response Software Development Teams: A Pilot Study. Proceedings of the Proceedings of the 41st Annual Hawaii International Conference on System Sciences, IEEE Computer Society: 29

Politidirektoratet (2007). Politiets beredskapssystem del 1 (PBS1) - Håndbok i krisehåndtering. Oslo, ISBN: 978-82-92524-49-7.

Politidirektoratet (2009). Om øvelse Tyr. Politiet

Politihøgskolen (2007). Studieplan - Funksjonsrettet ledelse for innsatsledere. FRL innsatsledere. Stavern

Qureshi, Samia Asloob and Durrani, Qaiser S. (2010). "Practice of Usability Engineering in SDLC." Proceedings of Graduate Colloquium on Computer Sciences (GCCS) **Volume 2**(Department of Computer Science, FAST-NU).

Raento, M., Oulasvirta, A., Petit, R. and Toivonen, H. (2005). "ContextPhone: A prototyping platform for context-aware mobile applications." IEEE Pervasive Computing: 51-59.

Rogers, Yvonne, Sharp, Helen and Preece, Jenny (2007). Interaction Design - Beyond Human-Computer Interaction, Wiley, ISBN: 978-0-470-01866-8.

Rudd, Jim, Stern, Ken and Isensee, Scott (1996). Low vs. high-fidelity prototyping debate. interactions. New York, ACM. **3**

Saffer, Dan (2006). Designing for interaction: creating smart applications and clever devices. Berkeley, CA, USA, Peachpit Press, ISBN: 0321447123.

Sauro, Jeff and Kindlund, Erika (2005). A method to standardize usability metrics into a single score. Proceedings of the SIGCHI conference on Human factors in computing systems. Portland, Oregon, USA, ACM**:** 401-409

Schön, Donald Alan (1984). The Reflective Practitioner: How Professionals Think In Action, Basic Books, ISBN: 978-0465068784.

Sinha, Anoop K. and Landay, James A. (2002). "Embarking on Multimodal Interface Design." Fourth IEEE International Conference on Multimodal Interface (ICMI'02) **0-7695-1834-6/02**: 2-5.

Siqueira, Isabela G., Ruiz, Linnyer Beatrys, Loureiro, Antonio A. F. and Nogueira, José Marcos (2007). "Coverage area management for wireless sensor networks." International Journal of Network Management **17**(1): 17-31.

Sommer, R. and Sommer, B.B. (1992). A practical guide to behavioral research, Oxford University Press, ISBN: 0195026918.

Sourcing, Levi9 Global (2010). "Testing Glossary." Testing Technologies Retrieved 22-02, 2011, from http://www.software-testing-outsourcing.com/glossary.html#R.

Streefkerk, Jan Willem, van Esch-Bussemakers, Myra P. and Neerincx, Mark A. (2008). Field Evaluation of a Mobile Location-Based Notification. MobileHCI '08: Proceedings of the 10th international conference on Human computer interaction with mobile devices and services ACM.

Stølen, Ketil (2010a). "EMERGENCY - SINTEF." from http://www.sintef.no/Home/Information-and-Communication-Technology-ICT/Cooperative-and-Trusted-Systems--/Projects/EMERGENCY/.

Stølen, Ketil (2010b). "The EMERGENCY Team." Retrieved 15/12, 2010, from http://folk.uio.no/ketils/emergency/the-emergency-team.htm.

Thomas, Peter J. (1995). The Social and Interactional Dimensions of Human-Computer Interfaces. London, Press Syndicate of Cambridge University Press, ISBN: 0-521-45302-X.

Uluca, Doguhan, Streefkerk, Jan Willem, Sciacchitano, Brian D. and McCrickard, Scott (2008). Designing Automated Handheld Navigation Support. MobileHCI '08: Proceedings of the 10th international conference on Human computer interaction with mobile devices and services Amsterdam, ACM.

Vieweg, Sarah, Palen, Leysia, Liu, Sophia B., Hughes, Amanda L. and Sutton, Jeannette (2008). Collective Intelligence in Disaster: Examination of the Phenomenon in the Aftermath of the 2007 Virginia Tech Shooting. 5th International ISCRAM Conference, ISCRAM.

Vigerust, Trond, Andersen, Jan Einar and Vollebæk, Lars-Erik (2009). "Optimalisert Pasient Evakuering Norge (OPEN)." Ambulanseforum **Vol. 4**(4-2009): 22-29.

Waltz, Carolyn, Strickland, Ora Lea and Lenz, Elizabeth (2010). Measurement in Nursing and Health Research, Springer Publishing Co Inc, ISBN: 9780826105073.

Wang, Hsiu Feng (2007). Are icons used in existing computer interfaces obstacles to Taiwanese computer users? Proceedings of the 14th European conference on Cognitive ergonomics: invent! explore! London, United Kingdom, ACM**:** 199-202

Way, Steven C. (2009). Criteria for Evaluating Mobile Technologies for Crisis Response. 2009 World Congress on Privacy, Security and Trust and the Management of e-Business, McMaster University, IEEE.

White, Connie, Plotnick, Linda, Kushma, Jane, Hiltz, Starr Roxanne and Turoff, Murray (2009). An Online Social Network for Emergency Management. 6th International ISCRAM Conference, Gothenburg, Sweden, ISCRAM.

Wu, Philip Fei (2009). User Acceptance of Emergency Alert Technology: A Case Study. 6th International ISCRAM Conference, ISCRAM.

Appendix A

Timeboxing

Timeboxing is an application development technique that primarily focuses on a strict time schedule and fixed time limits. The purpose of Timeboxing is to provide a technique that adjust the scope of the development after the time limits, i.e. products are redefined to fit the time schedule (O'Dell 2011). Since this approach usually last 60-120 days, it is well-suited as a technique for prototyping in this thesis. As illustrated in Appendix Figure A.1, the approach requires definitions of essential features first, and then stays in a development cycle with continuous review and feedback until the time is up.

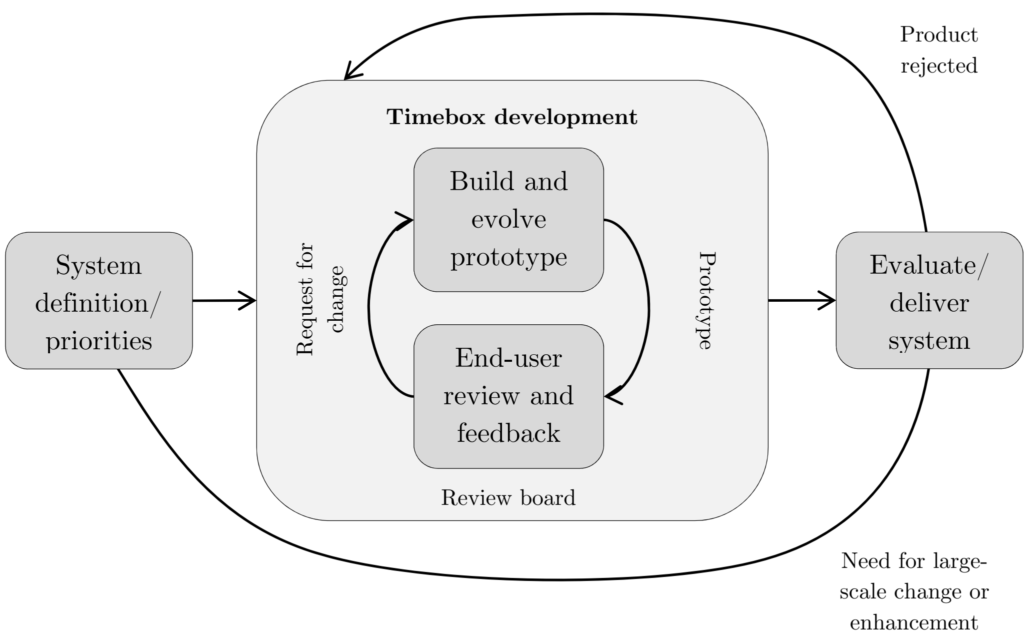


Figure A-1: Concept of timeboxing

Appendix B

Interview summary

This is a summary of the first interview with an incident commander and his supervisor, an operational commander. The incident commander is working at tactical level with experience from events of all sizes and complexities, therefore also well familiar for ICT in their division, while the operational commander is his working as his boss one level higher. Before the meeting the interviewees were informed with the purpose of the interview and the more long-termed objects of the EMERGENCY-projects. An interview agreement was signed upfront in accordance to the Norwegian Social Science Data Services[36].

The operational commander began by explaining what level of leadership he and his division works at. He points out early that their work is very event driven and exemplifies with current events such as the ongoing World Ski Championship[37] in Holmenkollen. A recent example of ICT decision-support in the Police is presented: the Swedish Police have developed a computational formula for decision support in search after missing persons. By estimating factors such as possible direction, probable distance, preferred path based on physical attributes, weather conditions, nearby points of interest last seen locations etc., thereby support their decision making. As operational leader in the largest city and capital of Norway, a lot of central issues (such as mass demonstration, high-security foreign visits etc.) automatically becomes a part of his responsibility. This is reflected in their associational annual courses and seminars where the different emergency agencies get together to discuss and explore typical scenarios for Oslo as a capital. This is also said to better the communication between agencies. Major events such as the Obama-visit[38] often require the capital police to regard similar events that outside of Oslo would be considered as important, at a lower priority. Based on higher

[36] NSD: Personvernombudet for forskning (Norwegian Social Science Data Services)
[37] FIS Nordic World Ski Championships 2011
[38] The Obama-visit refers to U.S President Barrack Obama's 26 hour stay in Oslo due to him receiving the Nobel Peace Prize in December 2009. This visit required one of the most comprehensive security measure seen in Oslo in modern times (Berre 2009).

frequency of involvement in different cases he tries to explain the suggested difference in competence between the capital police and the police in minor and more rural areas. Higher frequency leads to improved learning which again increases the knowledge and expertise. An outline of the district division of Oslo is given where five zones covers their own geographic region of the city. The operational level does not interfere with the tactical level, but are involved when requested. While each agency of tactical level has responsibility within their designated zone, they do borrow and lend each other resources in bigger-scale operations. This however requires authorization from operational level.

The incident commander then gives an in-detailed explanation of how incident commanders work with ICT. They use positioning provided from operational level. If needed, they have a printer in the car to print maps. The connection to criminal registers and other centralized databases is encrypted through VPN. This also includes PO[39], the internal communication system. He refers to other software being utilized such as MapSource[40]. The computer used is placed next to the driver seat in the car and uses the mentioned systems. The PO is mostly used in a later phase, while MapSource is used to draw in situational information from operational level. Besides the VPN often being unstable, the general impression of the ICT-equipment present to incident commanders is that it takes too long to start up the communication. If the computer is not turned on during the drive to the scene of incident, it is usually too late. It takes approximately 5-6 minutes from you turn on the computer until you can retrieve useful information. The ideal solution is described by the incident commander as a solution that works immediately and assists the incident commander by being both non-intrusive and intuitive in use. Otherwise it would require too much time and attention and thereby preventing the incident commanders from doing their actual work, which is being leaders at a tactical level. Otherwise he would not consider it to be good enough. It must also be "police-proof". He uses the word police-proof (as a word-play on the word foolproof) to describe a system that doesn't allow a policeman to make any errors when using the system. They cannot differentiate the user's technical knowledge, so it must not allow the users to make errors. In a map-based solution different layers of information should be selectable based on either zoom levels or desired views. More issues such as security topics or network problems, i.e. subjects that are regarded as unproblematic in this thesis, are also mentioned by the incident commander. He elaborates on how features that are useful often require an incident commander to switch application, context and interaction. An example could be live-feed of either images or video from an aerial perspective provided by helicopters. In situations such as mass demonstration an aerial view gives a better understanding of how the

[39] PO is an abbreviation for "*Politiets Operative System"* which translates to the operative system of the police.
[40] MapSource is a map application manufactured by Garmin Ltd.

masses move. This practice has been used with success in Sweden. This continues with an unprepared and on-the-fly description of a future solution for incident commanders. Inspired by recent technology he mentions a tab-based interface where each tab allows for a different activity thus allowing easy switching between context and tasks. This would also eliminate the issue of having to kill one application to use another. One tab could include a map of allocated resources with car number and another tab could provide a textual view. This would be organized and displayed in accordance to what information that is available and not based on source of the information. Another future feature could be to snapshot actions performed to automatically log all actions. This way, other actors entering the operation could easily trace and walk through all the incident commander's actions.

Another mentioned topic was real-time information. Since they use pencil, printed maps and notepads today, updates are reported through radio. He mentioned that incident commanders often delegated work to "second-in-commands" or designated loggers, but he prefers to do this through radio. This often leads to delays and miscommunication. The delay eventually leads to a mismatch between the situation overview at operational level (the staff) and tactical level (incident commander). Work at operational level could overlap with the work at tactical level if the operational level was not one step ahead and did their work which is organizing for the tactical level. For an incident commander it is important to know that the operational level is one step ahead looking at what resources we will need in the next phase, or making sure food is sent up during longer missions, so that the incident commander only have to worry about tactical issues in the field. The miscommunication can be illustrated with the game Chinese whispers where something being said changes meaning as it goes through a chain of people, ending up at the recipient with another meaning than intended. Since situations are explained over radio there can be a mismatch between what the incident commander said and what they heard at operational level, and also between how the incident commander meant for something to be interpreted and how they in fact interpreted it at operational level.

An illustration was drawn to explain the areas of interest for the incident commander. This included three levels. The first level was an inner barrier within which the incident commander had full overview of the situation and resources. This was regarded as the critical zone. Then a second circle was drawn outside the first to include the area in which the remaining emergency response operated. This was important for the incident commander in regards to available resources. Then outside this the third circle police officers were allocated to support (e.g. prevent public access to the area) the operation. While these police officers do not report directly to the incident commander, they use and request resources that might be valuable to the incident commander, so they are not irrelevant. The incident commander must be able to request these resources. Equipment and personnel, are also given a status, typically either active or passive. Since there is a high level of involved personnel, the incident commander hardly knows the details of all resources that have been allocated. Most tasks are so general that they can be performed by "anyone", meaning it does not matter whether which police officer it is as long as it is a police officer. Such personnel were referred to as anonym personnel. In situations that require exact competence and knowledge, the incident commander needs specific personnel like bomb experts or entry team. It is also vital for the incident commander to have an overview of local resources outside the responding agencies. This could be experts (e.g. industrial leaders in case of gas leakage) or just available resources such as landowners. These were referred to as *fagleder*[41]. A description is given for the three common steps to get a situation overview: localize, observe, identify. The first point is localizing both the critical and affected area. The second refers to observing activity, development and reactions within the area. The last point is identifying involved and affected persons, structures etc. This is used as a general rule of thumb. They also have a list of checkpoints to describe out the action pattern that should be followed. Referred to as *tiltakskort*[42] this is a familiar concept in all agencies, amongst them Red Cross. This is often used at the end of operations to control the steps taken throughout the operation.

[41] Fagleder is used a term to describe a leader with knowledge, access or expertize within a certain field that is required to respond properly to a situation.
[42] Tiltakskort refers to a methodical description on how to handle a situation.

Appendix C

Domain models

In (Nilsson 2010b) several domain models are presented as UML class diagrams (Pilone and Pitman 2005) to outline individual concept and the structures in which they are connected. While Nilsson include four models with different variations and extracts, but only two are related to this thesis. The first is information connected to resources while the other is information connected to allocations.

Information connected to resources

The focus in this model is on information connected to (1) resource available and (2) resource needed to handle the incident. This includes location, owner etc. Resources are divided into personnel and equipment.

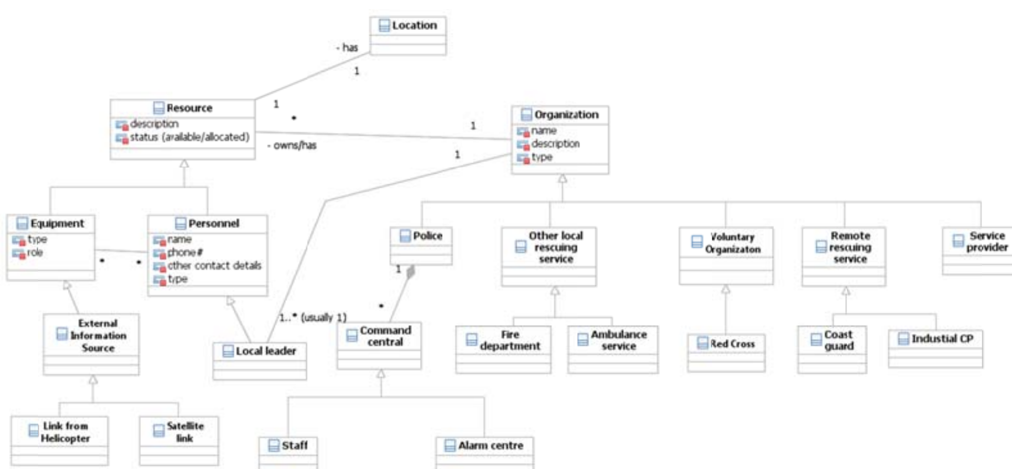


Figure C-1: Information connected to resources

Information connected to allocation

The focus in this model is the information connected to where available or needed resources mentioned in the previous section are actually allocated. This model connects the resource model with another model that focuses on plans and actions.

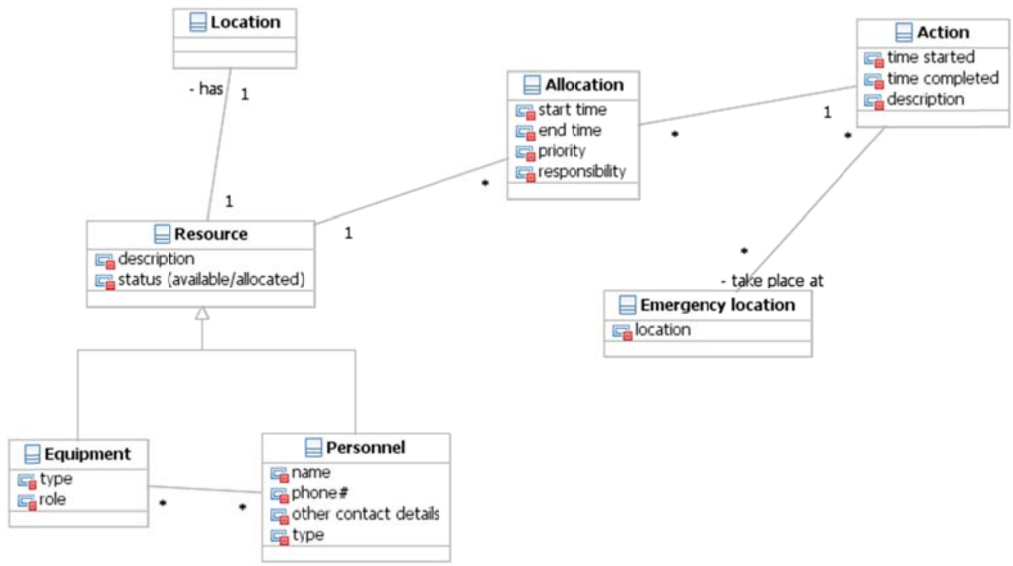


Figure C-2: Information connected to allocations

Appendix D

Evaluation 1: Data

The tables are inspired by the data analysis in (Rogers, Sharp et al. 2007, pp. 658-659). Each of the three tables represents each task carried out by the users.

Table D-1: Task 1: Use panning to find a specific resource

Participant	Time	Reason for task termination	Deliberate errors	Accidental errors
A	3	Successful completion	2	1
B	4	Successful completion	2	0
C	1	Unexpected termination of application	4	2
D	3	Successful completion	3	1
E	5	Successful completion	2	3
F	2	Participant requested termination	2	1
G	1	Unexpected termination of application	1	1
H	2	Successful completion	1	0
M	3		2	1
SD	1,5		1	1

Table D-2: Task 2: Use zooming to get an overview of all resources.

Participant	Time	Reason for task termination	Deliberate errors	Accidental errors
A	2	Unexpected termination of application	3	0
B	2	Successful completion	2	2
C	3	Successful completion	1	1
D	3	Successful completion	3	2
E	3	Successful completion	0	2
F	3	Successful completion	3	0
G	2	Successful completion	0	1
H	1	Unexpected termination of application	0	2
M	2		1,5	1
SD	1		1,5	1

Table D-3: Task 3: Use tapping to display resource details.

Participant	Time	Reason for task termination	Deliberate errors	Accidental errors
A	2	Successful completion	1	0
B	3	Successful completion	0	1
C	3	Unexpected termination of application	1	1
D	1	Unexpected termination of application	2	1
E	3	Successful completion	1	1

F	3	Successful completion	1	2
G	2	Successful completion	2	2
H	2	Successful completion	0	2
M	2		1	1
SD	1		1	0,5

Table D-4: Summary of all tasks

Participant	Total time	Total deliberate errors	Total accidental errors	Total errors
A	7	6	1	7
B	9	4	3	7
C	7	6	4	10
D	7	8	4	12
E	11	3	6	9
F	8	6	3	9
G	5	3	4	7
H	5	1	4	5
M	7	5	4	8
SD	2	2	1,5	2

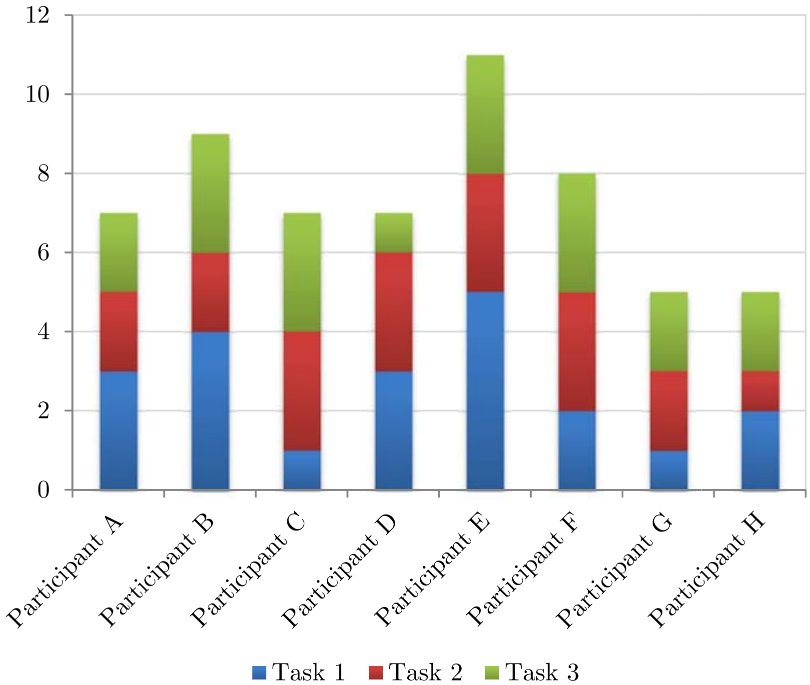


Figure D-1: Total completion time per participant

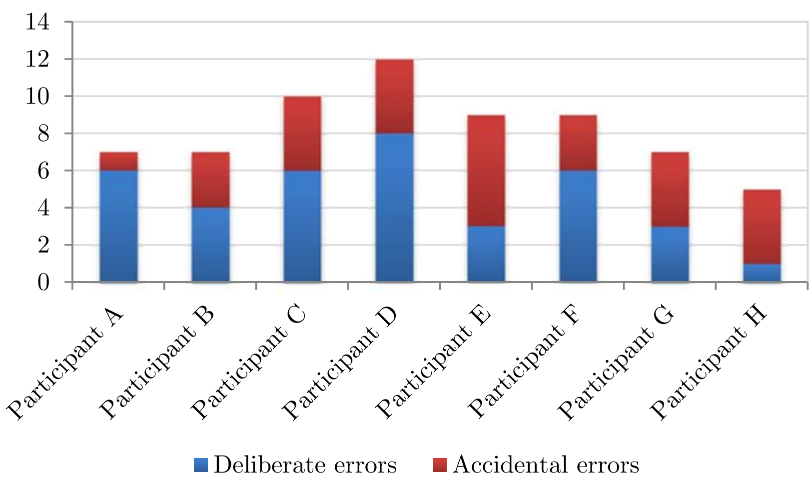


Figure D-2: Total deliberate and accidental error rate per user

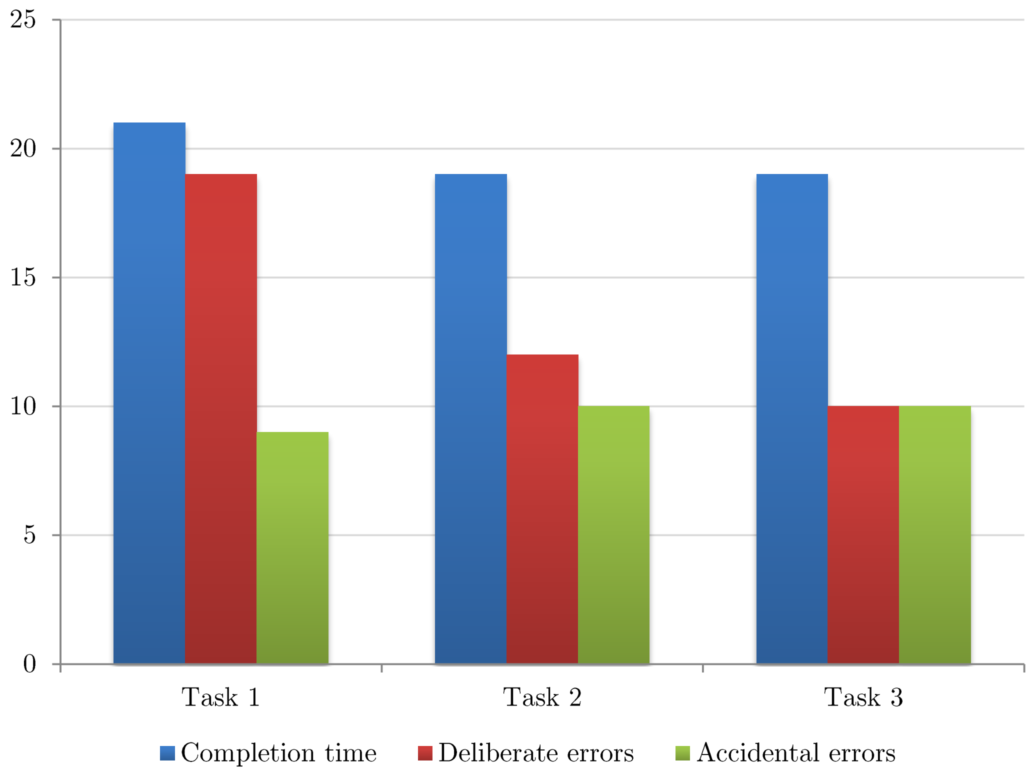


Figure D-3: Total values for completion time (min) and error rate (count)

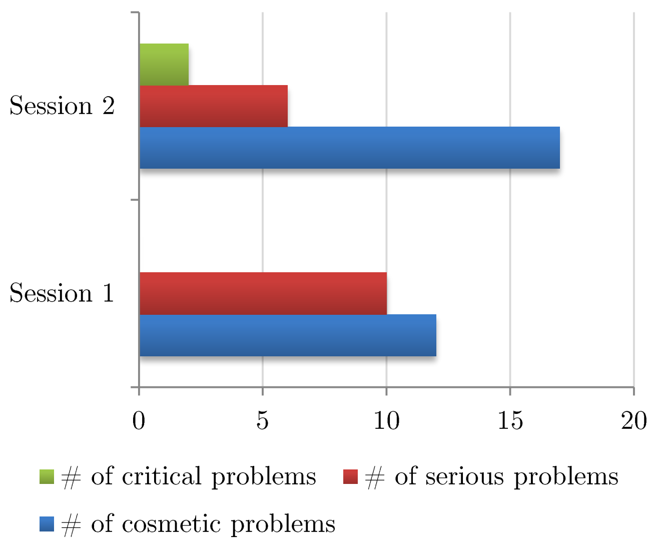


Figure D-4: Number of problems found in each session

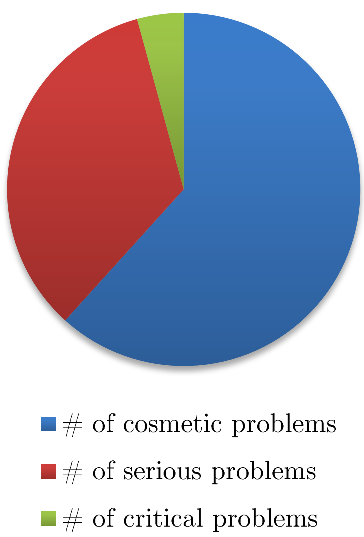


Figure D-5: Distribution of problems

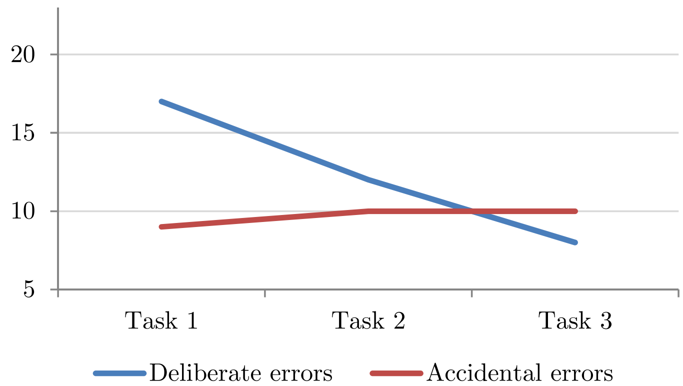


Figure D-6: Total count of deliberate errors and accidental errors

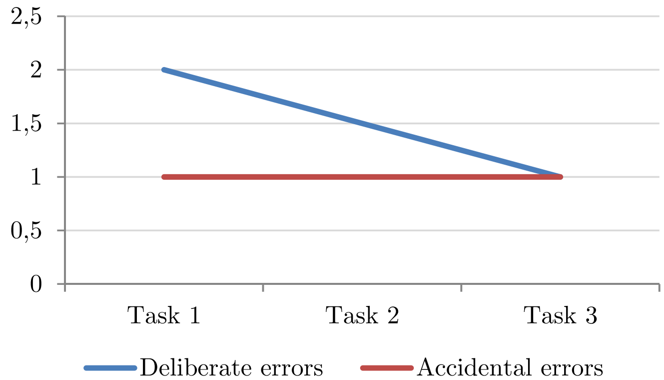


Figure D-7: Average count of deliberate errors and accidental errors

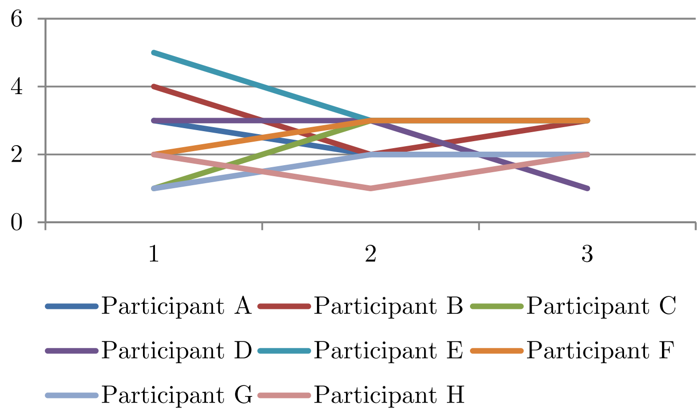


Figure D-8: Completion time per task for each participant

Appendix E

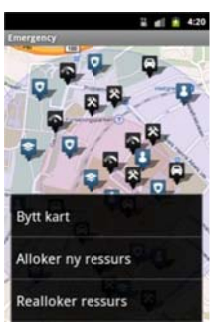
Evaluation 2: Forms

Dokumentasjon for evaluatorer

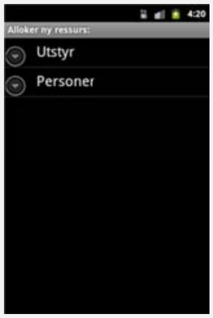
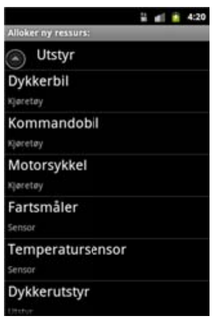
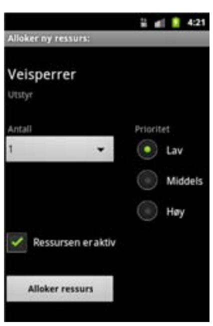
Alvorlighetsgrader:
L (Lite): Små hindre eller irritasjonsmomenter
A (Alvorlig): Store hindre eller irritasjonsmomenter
K (Kritisk): Uoverkommelige hindre eller irritasjonsmoment 1

1. Allokering av veisperrer

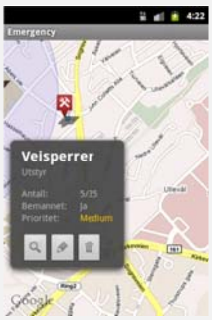
Det trengs fem veisperrer for å hindre trafikken i å kjøre av ringveien og inn i det avsperrede området. Veisperrene må settes opp i Niels Henrik Abels vei slik at trafikken fra Sognsveien ikke slipper til.

#	Skjermbilde	Brukerproblemer eller endringsforslag	Alvorlighetsgrad
1a			
1b			
1c			

Alvorlighetsgrader:
L (Lite): Små hindre eller irritasjonsmomenter
A (Alvorlig): Store hindre eller irritasjonsmomenter
K (Kritisk): Uoverkommelige hindre eller irritasjonsmoment

#	Skjermbilde	Brukerproblemer eller endringsforslag	Alvorlighetsgrad
1d			
1e			
1f			
1g			

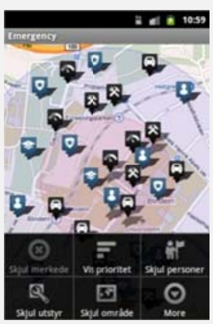
Alvorlighetsgrader:
L (Lite): Små hindre eller irritasjonsmomenter
A (Alvorlig): Store hindre eller irritasjonsmomenter
K (Kritisk): Uoverkommelige hindre eller irritasjonsmoment 3

#	Skjermbilde	Brukerproblemer eller endringsforslag	Alvorlighetsgrad
1h			
1i			
1j			

Alvorlighetsgrader:
L (Lite): Små hindre eller irritasjonsmomenter
A (Alvorlig): Store hindre eller irritasjonsmomenter
K (Kritisk): Uoverkommelige hindre eller irritasjonsmoment 4

2. Reallokering av politimann

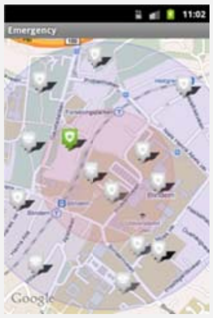
Under en redningsaksjon blir det nødvendig å hindre gjennomstrømning av trafikk innenfor et visst område. Det meste av trafikk er sperret ute, men det trengs en politibetjent til Forskningsparken T-banestasjon for å hindre avstigende passasjer fra å entre det avsperrede området. Du vet det finnes en politimann med lav prioritet som ikke er allokert og du ønsker derfor å allokere han til T-banestasjonen.

#	Skjermbilde	Brukerproblemer eller endringsforslag	Alvorlighetsgrad
2a			
2b			
2c			

Alvorlighetsgrader:
L (Lite): Små hindre eller irritasjonsmomenter
A (Alvorlig): Store hindre eller irritasjonsmomenter
K (Kritisk): Uoverkommelige hindre eller irritasjonsmoment

#	Skjermbilde	Brukerproblemer eller endringsforslag	Alvorlighetsgrad
2d			
2e			
2f			
2g			

Alvorlighetsgrader:
L (Lite): Små hindre eller irritasjonsmomenter
A (Alvorlig): Store hindre eller irritasjonsmomenter
K (Kritisk): Uoverkommelige hindre eller irritasjonsmoment 6

#	Skjermbilde	Brukerproblemer eller endringsforslag	Alvorlighetsgrad
2h			
2i			
2j			

Alvorlighetsgrader:
L (Lite): Små hindre eller irritasjonsmomenter
A (Alvorlig): Store hindre eller irritasjonsmomenter
K (Kritisk): Uoverkommelige hindre eller irritasjonsmoment 7

Table E-1: Scheduled timetable for group-based expert evaluation

Tidsplan

Aktivitet	**Tid**
Introduksjon	15
Oppgave 1	
Steg 1a	6
Steg 1b	4
Steg 1c	3
Steg 1d	3
Steg 1e	3
Steg 1f	3
Steg 1g	3
Steg 1h	4
Steg 1i	3
Diskusjon av oppgave 1	10
Oppgave 2	
Steg 2a	4
Steg 2b	4
Steg 2c	3
Steg 2d	4
Steg 2e	4
Steg 2f	4
Steg 2g	2
Steg 2h	4
Steg 2i	2
Diskusjon av oppgave 2	10
Oppsummering til slutt	10
Ledig tid (buffer)	12

Appendix F

Evaluation 2: Data

In this appendix the user problems found in the two evaluation session during the group-based expert walkthrough presented in Section 12.2. The two sessions revealed a total number of 47 user problems, however some problems overlap. For each problem the evaluators were asked to come up with improvement suggestions and then grade the degree of seriousness. The letters L, A and K refers to the Norwegian translation of the three grades: *(L)lav/(L)lite* – Cosmetic, *(A)lvorlig* – Serious, and *(K)ritisk* – Critical. The degree is further explained in Section 12.2. The step indicates which step in the evaluation form the problem was found (Appendix E).

Session 1

Table F-1: Data from session 1

#	Step	Problem	Description	Suggested improvements	Discussion topics	Degree of seriousness
1	1a	Disturbing shadow on markers	Each marker is presented with a shadow that is disturbing for the overview of the situation.	Drop the shadow.	(none)	L
2	1a	Too many markers	It is confusing and overwhelming when a high amount of markers are displayed simultaneously.	Filter amount of markers displayed based.	How realistic is this number of allocations? Which ones are most important?	A
3	1a	Too large markers	The markers are currently too large and occupies too much of the total screen size.	Drop the pointing tip and use a circle instead or include scaling of icons. Use a pin point.	What type of marker should be used and how big? What is a proper size?	A

#	Step	Problem	Description	Suggested improvements	Discussion topics	Degree of seriousness
4	1a	No grouping of markers	The markers do not group and this can be problematic if too many resources are adjacent.	Use text or symbol to indicate multiple resources with one marker, e.g. a plus-symbol.	How to group? By type or position?	L
5	1a	Confusing icons on markers	The icons used to indicate the different types of markers can be confusing.	Use other icons that more clearly indicates the resource type.	(none)	L
6	1b	Difficult to get to task	It is too difficult to get to the desired task via two levels in the menu.	Context menu that pop-ups when long-pressing or moving up to first level of the menu.	Which alternative is the best?	A
7	1b	Inconsistent layout on menus	The menu changes appearance between the two levels. This is an Android-limitation.	(none)	(none)	L
8	1d	Difficult list navigation	When expanding a resource type for availability the list should be easier to cycle through.	Color-coded based on type. Second level of expanding list. Use bold for sort key. Use a symbol to assist icons. Search field with autocomplete.	What is best suited for an uncertain list length? What sorting key is best?	A
9	1e	Missing symbol	Each list element should have a symbol to indicate that pressing it takes you further.	Arrow-based icon to suggest advancement.	Is it necessary?	L
10	1g	Difficult to select count	The drop-down from which the count is set, is both oddly shaped and includes very small items.	Narrower shape. More padding. Use scroller wheel instead.	Right amount of color. Problematic if amount is 100. Better with scroller.	A
11	1g	Missing color codes for priority	The priority radio buttons are not color coded. Both the text color and click color is default.	Color code text or selections with red, yellow and green to indicate priority level.	Color the eye of the buttons or the ring? Color code text as well?	L
12	1i	Missing state information	The current state in which the user allocate the defined resource before continuing, should be displayed.	Use a dialog window to inform the user of the current state. Use a bar at the top. Grey out/hide	Where to place without blocking potential allocation point on map?	A

#	Step	Problem	Description	Suggested improvements	Discussion topics	Degree of seriousness
				other resources.		
13	1i	Markers not auto-snapping	When placing a marker it does not auto-snap to road, building or other point of interest.	Auto-snapping based on map layer information.	(none)	L
14	1i	Exit-button not present	Some smartphones switch between application and save the state. The user should have an option of restarting the application.	Either an explicit exit-button that exits or a kill-process button where the process is killed.	Could be handled by the operating system?	L
15	2a	Filter not indicated	There is no symbol or text that specifies what filters that are currently activated.	A little icon at the top for indication. Text on screen.	(none)	A
16	2b	Disappearing menus	After clicking on desired menu item the menu disappears.	Permanent menu always present on the bottom.	Can it justify the map space that it occupies?	L
17	2d	Color code not switching	When hiding all resources of a certain type, the remaining does not automatically switch to priority color coding.	Color code remaining resources for all remaining resources.	Too much automation? Should this be handled by the application? *[Some disagreement on this point]*	L
18	2f	Confusing icons	The icons on the "find similar"-button and "edit"-button are confusing.	Use pin as button icon to indicate reallocation and crosshair for similar resources.	Can this be clear without text?	A
19	2h	Undesired automation	When dropping the marker in drag-and-drop mode the reallocation is done.	Instead of automatic advancement, the user should decide when the placement is ready via e.g. a button.	How severe is this for an advanced user? *[Some disagreement on this point]*	A
20	2i	Reallocation disappears	The reallocation may disappear behind the confirmation box that is centered.	The dialog window can be placed either top or bottom. The map behind the box	What to do if distance covers the entire map? Which position should be visible?	A

#	Step	Problem	Description	Suggested improvements	Discussion topics	Degree of seriousness
				could be moved.		
21	2i	Reversed colors	The marker indicating the current position is grey, while the destination is colored.	This should be reversed. An arrow can be used to indicate destination and direction.	Is color reversing right? How well-suited are arrows when several resources are moving? *[Some disagreement on this point]*	L
22	2i	No automated reallocation	The user cannot automatically reallocate the nearest available resource to a given point.	Automatic reallocation based on geographical position and priority.	How does this affect the degree of control? Is the situation overview lost?	L

Session 2

Table F-2: Data from session 2

#	Step	Problem	Description	Suggested improvements	Discussion topics	Degree of seriousness
1	1a	Too weak blue and red sectors	The two circles indicating the area of incident are too weak and hard to spot.	Carry out a user test with different light conditions.	Should circle colors be strengthened or the background map weaker?	A
2	1a	Difficult to distinguish symbols	It is difficult to separate different icons. May get too rich on detail level.	Remove some markers and increase size or filter away.	(none) *[Some disagreement on this point]*	L
3	1a	Too much information	Too many markers on screen make it difficult to get an overview.	Filter away unnecessary markers. Drop shadow effect on markers.	(none)	L
4	1b	Menu option on wrong level	The task is too difficult to reach. It should be presented earlier.	Move it to the first menu. Separate filters to own menu. Move filters on top of map.	What is most important between filters and tasks?	L
5	1b	Replace text with toggle	Menu items should avoid text to utilize the	Use high and low contrast or	Will it be sufficient without text?	L

#	Step	Problem	Description	Suggested improvements	Discussion topics	Degree of seriousness
		function	limited space better.	symbols to indicate toggled or not.		
6	1b	Understandable language	Confusions might arise if tasks are presented with unfamiliar terms. Current terms seems complicated.	If they are familiar terms then no change is necessary.	How familiar are these terms?	L
7	1c	Confusing menu item descriptions	Some tasks, such as switching maps, have confusing names.	Group with other filters, and create a more precise term. Switch description with map type.	(none)	L
8	1c	Too small and too many markers	There should be larger and fewer markers that allows for less confusion and less errors.	Create a full-screen menu or group tasks.	Will it make it easier? Grouping creates additional steps.	L
9	1d	Too small text	The list headers that expand the sub-lists are too small.	Increase font size and add an icon to indicate resource type.	How many items will be in the list? Are icons alone, text alone, or icon + text best suited?	A
10	1d	List seems empty	The list only includes two list headers. It should have a header not for each type, but for each subtype. More of the screen should be utilized.	Split tasks in menu to two subtasks, one for each resource type. Then each list header can be subtype instead of type.	Will the alternative, two-level list, be too complicated?	L
11	1d	Unavailability uncertain	If resources are not available they should be included to inform of unavailability. Otherwise it can be confusing.	Have unavailable resources in lists (as red or greyed out) to clarify the unavailability.	Can it be too distracting if the list is too long?	L
12	1d	Progress indication missing	It is unknown to the user how many steps he has completed and how many is left of the task. The process progress should be visualized.	Use a progress bar or include step information in header to indicate progress. Bigger text on the header.	Is text or graphics best suited to visualize the progress?	L
13	1e	Unstructured list	The list is sorted on subtype which is the small text. The list should be sorted on the larger text.	Either add color sorting or make sort key clearer. Could be combined with suggested solution for 1d.	What is the best sort order?	A
14	1g	Drop-down is unfit	The count selection should be easier.	Can be done with a wheel. Search	How long are the lists?	L

#	Step	Problem	Description	Suggested improvements	Discussion topics	Degree of seriousness
			Difficult to select item with drop-down.	function is an alternative if larger lists. For much longer lists, another step could be included.		
15	1h	Selections are too difficult	It should be easier to define the parameters for an allocation.	Wheel instead of drop-down (1g), and bigger elements. Utilize the screen size better. It should be clearer on what priority really means.	(none)	L
16	1i	Confirmation missing	Where is the user in relation to the progress now? You have to learn that you are not finished as the system does not indicate this.	The system should present a message to clarify this. Header text or message box can be used.	(none)	K
17	1i	Zooming is difficult	When positioning the resource it is difficult to zoom. The zoom handlers are to unavailable.	A crosshair can be used to indicate position.	When panning should the map or the crosshair move?	A
18	1i	Positioning is difficult	When positioning a marker with a long-press it is easy to miss.	Use crosshair-idea (1i) and press a button when satisfied with the position.	(none)	L
19	2e	Priority should be default	The priority color should be default.	Color coded markers based on priority rather than type.	What is most relevant to the user? *[Some disagreement on this point]*	L
20	2e	Colors might be too similar	Not all colors might necessarily be distinguished from each other, especially red-green color blind people.	Some adjustment of color tone or saturation might solve this. The colors themselves are ok.	(none)	A
21	2e	Box is anonym	When a box is shown a priority view, it does not color the selected resource with a separate color.	The selected resource should have a selection color that is not green, yellow or red.	How misleading or confusing is this?	A
22	2f	Weak color on text	Information in the information box is both	Utilize the screen size better by	How much of the map can the	L

#	Step	Problem	Description	Suggested improvements	Discussion topics	Degree of seriousness
			too small and too weak. This makes the text hard to read.	using more of the screen. Use a more contrasting color and increase text size.	information box take up?	
23	2f	Unclear buttons	What is the action associated with each of the buttons? It is unclear.	Either text should be added or more representing icons should be used to indicate the actions of the buttons.	What symbols are better for "show similar" or "reallocate"?	L
24	2g	Progress may be lost	It may be confusing to the user that he is still in the same window. He should enter a menu where details can be specified.	The confirmation window should not take us back to the map, but to the “allocate resource”-screen (1h)	Is this step and further unnecessary?	K
25	2i	Too small text	The text in the confirmation dialog is too small.	The confirmation dialog should drop the header and only ask “ok?” as this will allow larger text.	(none)	L

Appendix G

Informed consent form

INFORMASJON OG SAMTYKKESKJEMA

EMERGENCY-prosjektet *(Mobile decision support in emergency situations)* gjennomføres av bl.a. SINTEF i perioden 2009-2012. EMERGENCY-prosjektets formål er å utvikle teknologier for mobil beslutningsstøtte som kan effektivisere beslutningsprosessen i krisesituasjoner og redusere feilmarginen ved beslutningene som tas. EMERGENCY fokuserer spesielt på design av brukergrensesnitt for mobile enheter til utrykningspersonell, utvikling av rutiner for å systematisere erfaringer og metoder for å forutsi informasjonsbehov og risikoer i krisesituasjoner. Som en del av prosjektet utfører Erik G. Nilsson et PhD-studium ved Institutt for Informatikk ved Universitetet i Oslo, og det skrives flere mastergradsoppgaver ved samme institutt, bl.a. av Suhas G. Joshi.

Som en del av aktivitetene for evaluering og validering vil det bli avholdt gruppeevalueringer av prototyper utviklet i forbindelse med prosjektet. Som en del av disse evalueringsmøtene vil vi gjøre datainnsamling ved at deltagerne blir intervjuet gjennom deltagelse i evaluering av prototyper. Vi ønsker å gjøre opptak av intervjuene/evalueringsaktivitetene for at vi skal kunne analysere dataene i etterkant. Slike opptak vil bli slettet så snart dataene er ferdig analysert, og senest innen prosjektet avsluttes. Deltakelse i møtene vil på ingen måte påvirke deltagernes arbeidsforhold, og deltagerne kan når som helst velge å trekke tilbake sitt samtykke uten å oppgi noen grunn.

I analysene og publisering av funn vil de innsamlede dataene vil bli avidentifiserte. Overordnet informasjon om kjennetegn ved enkeltpersonen (kjønn, alder, utdannelse, yrke etc.) vil oppbevares i separate dokumenter. Dataene ikke vil kunne spores tilbake til enkeltpersoner. Deltagerne fra EMERGENCY-prosjektet er underlagt taushetsplikt, også etter at EMERGENCY-prosjektet er ferdigstilt. Datainnsamlingsaktiviteten vil bli rapportert til Personvernombudet for forskning ved Norsk samfunnsvitenskapelig datatjeneste og oppfyller deres krav til konfidensialitet og oppbevaring av data.

I tråd med Personvernombudets anbefaling om behandling av personopplysninger, ønsker vi skriftlig samtykke på at du vil delta i intervjuer/evalueringer. Vi minner om at du når som helst kan trekke dette tilbake uten å oppgi noen grunn ved å kontakte Erik G. Nilsson på telefon 930 89 47 eller per e-post egn@sintef.no, eller Suhas Joshi på telefon 957 59 061 eller per e-post joshi@ifi.uio.no. Fyll ut svarslippen nederst på siden og lever til Erik G. Nilsson eller Suhas G. Joshi før intervjuet/evalueringen.

Ved å signere nedenfor bekrefter jeg at jeg har mottatt skriftlig informasjon om studien i tilknytning til EMERGENCY-prosjektet og at jeg ønsker å delta i studien.

Dato: ______________________ Sted: ______________________

Underskrift: ____

Appendix H

Translations

Action phase	Aksjonsfase
Advisory board	Rådgivningskomite
Agency	Etat
Alarming phase	Alarmeringsfase
Announcement phase	Meldingsfase
Arrival phase	Ankomstfase
Card with plan of action	Tiltakskort
Chief of staff	Stabssjef
Critical	Kritisk
Data Protection Directive	Personverndirektivet
Effort phase	Innsatsfase
Execution phase	Gjennomføringsfasen
Incident commander	Innsatsleder
Low	Lav
Metro	T-bane
National Police Directorate	Politidirektoratet
Norwegian Police University College	Politihøgskolen
Norwegian Research Council	Norges forskningsråd
Norwegian Social Science Data Services	NSD Personvernombudet for forskning
Operational leader	Operasjonsleder
Operative system of the police	PO
Personal data regulations	Personopplysningsforskriften
Police commissioner	Politimester
Preparatory phase	Forberedelsesfasen
Professional leader	Fagleder
Regulations on the processing of personal data	Personopplysningsloven
Rescue management	Redningsledelse
Ring road	Ringvei

Serious	Alvorlig
Staff	Stab
Stepping-down phase	Nedtrappingfasen
Supplementary phase	Etterarbeidsfasen
Test leader	Testleder
Travel phase	Reisefase
Unit leader	Delleder

Appendix I

Prototype: CD and URL

A walkthrough of the functionalities of the prototype presented throughout this thesis is given in Chapter 10. The source code for the prototype is available on the attached CD. It contains all necessary files, along with a short explanation of how to test the prototype. The content is also available at:

http://folk.uio.no/suhasgj/master