An exploratory study of how augmented reality can be utilized in emergency control rooms

TANJA MALBASA & KENNETH S. RØNNING

SUPERVISOR
Tim A. Majchrzak

University in Agder, 2019
Faculty of Social Science
Department of Information Systems

Preface

This thesis is conducted through the last part of the master program in Information Systems at the University in Agder. To conduct the thesis, we discussed the theme and opportunities with both professors and fellow students in our department. We got a supervisor, which introduced us to the AUREAS project and researches from the University of Duisburg - Essen in Germany. We also got the chance to travel to Germany for a kick off seminar where we discussed different techniques to shape the project and research question. The result of the cooperation with the German researches has formed our master thesis which has been developed throughout the spring semester of 2019.

The purpose of the thesis is to understand how augmented reality can support work done in emergency control rooms. The aim is to contribute with new perspectives within the field of crisis management.

We want to thank all the people who have contributed and assisted us through this period. We want to thank our supervisor at the University of Agder, Associate Professor Tim a Majchrzak for all his support and valuable feedback through the duration of our thesis. We also want to thank our supervisor at the University of Duisburg - Essen, Graduate Student Researcher Jennifer Fromm, for all her support and guidance through our stay in Duisburg, Germany. We also appreciate her for her help in arranging interviews and support through our data collection.

Our thanks to our informants representing an emergency control room in Norway. Furthermore, we want to thank our institute, the Department of Information Systems at the University in Agder, and the Centre for Integrated Emergency Management (CIEM) for their financial support of our field trip to Duisburg, Germany.

Date: 04.06.2019

Kristiansand, Norway

Tanja Malbasa

Kenneth S. Rønning

Summary

The possibility to research on augmented reality in emergency control rooms gained our interest as it gave us the possibility to focus on both technological and social aspects. This exploratory study is conducted as phase one in the AUREAS-project, under the dispenses of Centre for Integrated Emergency Management at the University in Agder. Throughout the study we explored how augmented reality can support work done by operators in emergency control rooms.

Our literature review evaluates related literature and relevant theories for this concept. The terms of crisis types, crisis management and augmented reality are explained.
Results from the systematic literature review show that little prior research is done on augmented reality in emergency control rooms. Hence, this gap was closed with expert interviews where our informants provided insights missing in the literature review.

Augmented reality can be used to provide better situational awareness for the operators in emergency control rooms, first and foremost by providing pictures from the crisis scene rather than relying on own imagination and perception of reality based on vocal information gathering. By using augmented reality in emergency control rooms, the operators can also get more accurate GPS localization of the caller, and a more detailed map system with topographical details, as their already existing map is in need for improvement. Prior literature unveils that augmented reality is benefital to take advantage of in cooperative work done between operators and first responders. However, this was contradicted by our informants where they state that their job is finished when first responders arrive at the crisis scene. Hence, we cannot constantate that augmented reality is a technology that *will* provide better efficiency or easen their working tasks in the emergency control rooms. To prove this, one needs another type of approach like testing and prototyping, which we did not have.
Our discussion elaborates how the findings from the interview are presented in relation to prior literature.

For our study we used an exploratory qualitative approach. The systematic literature review is described in detail, with categories found in the literature. The process of data collection is divided into nine semi-structured interviews, all conducted in an emergency control room in Norway. We used an inductive approach to categorize the results from the interviews.

We conclude with four guidelines for an AR application that can support work done by operators in emergency control rooms.
Suggestions for further research are given to ensure further importance of our findings.
The limitations of our study are presented to be influenced by lack of prior research and time constraints.

Content

Table Index:

Figure Index:

1.0 Introduction

Emergencies, crises and disasters happen frequently with significant impact on the lives of countless people (Chan, Anslow, Seyed & Maurer, 2016 p. 349). To respond to these events many organizations work in collaborative effort to mitigate the effects of those events. For all these groups of people working together, an emergency control room works as a hub for centralized communication and planning (Chan et al., 2016, p. 349). A major challenge in existing centres is that many of those rely on aging technologies, leaving many potential improvements available out, yet even a minor improvement can lead to significant benefits and cost-savings (Chan et al., 2016, p. 349).

There is a significant opportunity to utilize new technologies to address concerns regarding both individual crises related work in a control centre, but also to encourage collaboration between teams while providing a more effective response to emergencies (Chan et al., 2016, p. 350). Existing teams provide few supporting tools to encourage collaboration, and with a lack of connectivity between members of the emergency control centres as well as responders in the field, it becomes apparent how an information transfer can be slow, inaccurate, and often very repetitive (Chan et al., 2016, p. 352). This applies both to information transferred from one crisis respondent in the field to one sitting in the control centre. With so many apparent benefits to greater use of new technological tools within those centres, it seems logical that these tools should be integrated (Chan et al., 2016, p. 352). However, this is not currently the case. Despite difficulties in integrating and maintaining new technological tools, the benefits are non-trivial, and it is worthwhile to examine future possibilities of tools (Chan et al., 2016, p. 352).

In the aftermath of major disasters, first responders are rapidly dispatched to save lives and infrastructure (Ramchurn, Wu, Jiang, Fischer, Reece, Roberts, Rodden, Greenhalgh & Jennings, 2016, p. 83). One example that highlights the trivial potential of augmented reality in crisis management, is that the technology can help field workers to quickly move within the critical areas during an extreme event, in order to communicate the state of structures and infrastructures to the emergency control room in real time and identify the mitigation measure. Several organizations and industries have however become aware of the technology, as the augmented reality market is expected to reach a size of 209 billion U.S dollars in 2022 (ICD Worldwide Semiannual Augmented and Virtual Reality Spending Guide, 2018).

In the research context, our topic is young and vibrant with unanswered questions to be explored and examined. However, our topic is also important not only for improving crisis related work for practitioners such as operators in emergency control rooms, but also for researchers because we close an important research gap found in our systematic literature review.

Based on our proposal our research question is as follow:

RQ: How can the use of augmented reality (AR) technology support operators working task in emergency control rooms?

In areas where there is little prior research, qualitative research methods are appropriate (Creswell, 2014, p. 20). For our thesis, we chose an exploratory research design combining 9 interviews with operators in emergency control rooms with a systematic literature review. The interviews are intended to elucidate the individuals' relevant experience and their interpretations of these, while the systematic literature review is used as an analysis of existing literature in the field. The exploratory design is usually relevant for most qualitative research projects, as well as in ours (Creswell, 2014, p. 20). Many of our road choices have been made during the project as new insights are gained. Issues and selection strategy have been adjusted as the project progressed and as we have become aware of which nuances of the original problem that can particularly give relevant knowledge.

This chapters' further outline is as follow: in section 1.1 we will present limitations, section 1.2 is reserved for explaining conceptual clarifications, and in section 1.3 we will present our motivation for conducting this thesis.

1.1 Limitations

The master thesis is in its entirety performed as part of the project Augmented Reality Support for Decision-Making in Crisis Management (AUREAS), which is conducted under the auspices of the University of Agder's Centre for Integrated Emergency Management department and is carried out in collaboration with the representants from University of Duisburg - Essen. We have chosen to refine the task of dealing only with the responsive action moments that arise in emergency control rooms when a crisis occurs. Similarly, we have chosen to limit the task of embracing only crises that arise in Norway. The study is also time-limited for a semester, which reflects the scope of the study.

1.2 Conceptual clarifications

In this section, key concepts for this master's thesis have been clarified and defined. The terms will be used comprehensive. If other terms are used as substitutes, this is clarified in current text.

Table 1: Conceptual clarifications

Concept	Definition
Operator	A person working in a emergency control room, particular with picking up emergency calls.
Emergency Control Room	Is a building or a room where operators receive telephone calls from members of the public in need of assistance.
Augmented Reality	*An enhanced version of reality created by the use of technology to overlay digital information on an image of something being viewed through a device* (Merritam-Webster, 1992).

1.3 Motivation

A major motivation for this task is our great interest in augmented reality and crisis management. Compared to most other countries, Norway is very safe. Our resources, our geographical location and our stable democratic society give us a very good starting point (Direktoratet for samfunnssikkerhet og beredskap, 2019). Nevertheless, we can also be affected by small and large crises. Thus, the motivation is strengthened by the expectation that Norway's resistance and limitations in crisis management will be strengthened in the future (Direktoratet for samfunnssikkerhet og beredskap, 2019). The choice of topic was therefore a clear path for us. On the other hand, we had challenges to concretise and narrow the thesis.

The reports' further outline is as follows: Chapter two is reserved for previous research and definitions, while chapter three is reserved for the method, which will include descriptions of how we conducted the systematic literature review, and the interviews. In chapter four, we will describe the research context, while the results will be presented in chapter five (systematic literature review) and chapter six (interviews). In chapter six, a thorough discussion of our results found in the previous chapters will be presented. The conclusion, together with implications are left for chapter eight. Last, but not least: references are reserved for chapter nine, and the appendixes are reserved for chapter ten.

2.0 Previous research and definitions

In this chapter we will introduce important definitions and categorizations for our academical research. The previous research presented in this chapter also forms the basis for theory and knowledge development, as well as our conceptual matrix in our systematic literature review (Webster & Watson, 2002). The chapter is divided into two sections: Crisis Management, and Augmented Reality.

2.1 Crisis Management

2.1.1 Definition of Crisis

Throughout the decade, various definitions of crises have been presented, and mostly combine previous definitions to some extent. No definition of disaster is universally accepted (Shaluf, 2007). Moreover, the definitions have common elements which is their severity (Shaluf, 2007). Typical characteristic of a crisis situation can be that it is emotionally stressful; you may suffer from confusion, friction, pressure and stress, quickly changing situations; limited time to make decisions about what to do, ambiguous situations; may be lack of clear information about what is happening, and information uncertainty; again - lack of clear information, and news may travel fast, shaping the public perception of the crisis and how it is being handled (Queensland Government, 2017).

2.1.2 Types of Crisis Situations

Disasters can be classified into three types: natural; man-made; and hybrid (Shaluf, 2007). Natural disasters are catastrophic events resulting from natural causes such as volcanic eruptions, tornadoes, earthquakes, etc., over which man has no control. Natural disasters are often termed “Acts of God”.

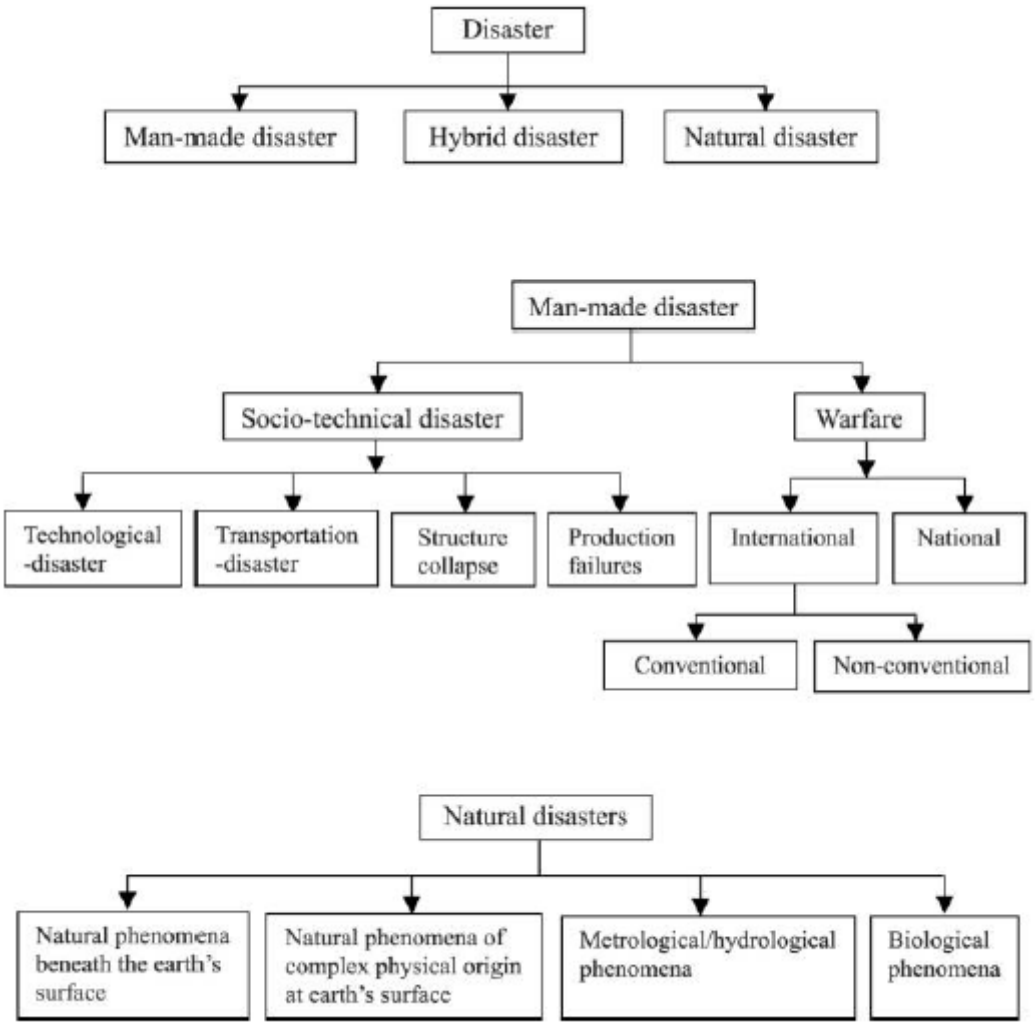


Figure 1: Types of disasters (Shaluf, 2007)

Man-made disasters, on the other hand, are those catastrophic events that result from human decisions. The International Federation of Red Cross and Red Crescent Societies (2003) highlighted that a man-made disaster refers to non-natural disastrous occurrences that can be sudden or more long-term. Sudden man-made disasters include structural, building and mine collapses when this occurs independently without any outside force. In addition, air, land, and sea disasters are all man-made disasters. Long-term man-made disasters tend to refer to national and international conflicts. There are disasters that result from both human error and natural forces. These are hybrid disasters. An example of a hybrid disaster is the extensive clearing of jungles causing soil erosion, and subsequently heavy rain causing landslides (Shaluf, 2007). Natural, man-made and hybrid disasters, and disastrous events are summarized in Figure 1.

2.1.3 Crisis Management Approaches

As the concept of crisis management has seen a stable development over the last twenty years, three well-known approaches; Fink's (1986) four-stage model; Mitroff's (1994) five-stage model; a basic three-stage model; and Myers (1993) four stage approach, emerge from a study of various crisis management approaches. These approaches have initiated several people used is as a reference in the development of their crisis model (Yazdanifard & Siang, 2013). However, we will only present Fink's four stage model, because it is the one most applicable to our study.

Fink's four stage model

Fink (1986) was one of the first to develop a crisis model and divided the anatomy of a crisis into four stages: the prodromal crisis stage, when warning signals of a potential crisis emerge; the acute crisis stage, when trigger event and ensuing damage of the crisis occur; the cornice crisis stage, when lasting effects of the crisis continue and clean up begins; and the crisis resolution stage, when the crisis is no longer a concern to stakeholders (Yazdanifard & Siang, 2013). Fink separates the crisis event into three stages. Fink stated it begins with a trigger event (acute phase), moves to extended efforts to deal with the crisis (chronic phase), and concludes with a clear ending (resolution) (Yazdanifard & Siang, 2013). The different stages of the life cycle require different actions from the crisis manager. As a result, crisis management is performed in stages and is not one simple action (Yazdanifard & Siang, 2013).

2.1.4 Roles in Crisis Management

According to the book written by LESLP (2007, p. 21-25) Gold, Silver and Bronze are title of functions adopted by each of the emergency services and are not rank related, but rather role related. These functions are equivalent to 'strategic', 'tactical' and 'operational'. The different commanders wear uniquely identifiable marks, so they understand each other's functions and authority.

Bronze commanders

Bronze commanders are operational and will according to the book written by LESLP (2007, p. 21-25) control and deploy resources of their respective service within a geographical sector or specific role and implement the tactics defined by the silver commander.

Silver Commanders

Silver commanders are tactical and according to the book written by LESLP (2007, p. 21-25) they will attend the crisis scene, take charge and be responsible for formulating the tactics to be adopted by their service to achieve the strategy set by Gold Commanders. Silver will not be personally involved with activities close to the incident, but remain detached.

Gold Commanders

Gold commanders are strategic and according to the book written by LESLP (2007, p. 21-25) they oversee each service, responsible for formulating the strategy for the incident. These Gold commanders is in overall charge of their own respective organization, and delegates tactical decisions to their Silver commanders. The Gold commander will determine the strategy and record a strategy statement. They will also monitor and review the strategy consecutively during any incident.

Operators

Operators also called dispatchers, is responsible for reception and management of requests for emergency assistance and all the information is obtained through telephone communication with a caller who is often distressed and out of control. The functions of emergency dispatching must include the use of predetermined questions, pre-arrival telephone instructions, and pre-assigned response levels and modes (Clawson, 1989).

2.1.5 Emergency Control Rooms

In Norway, an emergency management control centre is a physical (conference room, building, room) or virtual (telephone conference call) location designed to support emergency response and crisis communication activities, and where emergency control room operators receive incoming telephone calls from members of the public in need of assistance (Department of Homeland Security). An emergency management control centre is used to support on-scene activities through the prioritization of activities and the allocation of available resources (Department of Homeland Security). A major function within the emergency management control centre is communication between the emergency response teams and other management. Control centres usually work in teams or variable shift patterns, and are open twenty-four hours a day, all year around (Department of Homeland Security). Callers can make contact through the fire department (110), police (112) or medical assistance (113).

Physical locations are used as emergency control rooms. It must be outfitted with furniture, telephone and internet access and be near enough office equipment (Department of Homeland Security). It is also worth to mention that an emergency control centre is a place where highly trained experts monitor information and prepare for known and unknown events, and gather in the event of an emergency to exchange information and make decisions quickly (Department of Homeland Security). The conference room or other space to be used as the emergency control centre should be equipped with the following equipment and supplies: Communication equipment to handle incoming and outgoing calls; computers and printers to network resources, electronic mail and the internet; information gathering and display tools including access to radio and television (preferably with recording capability) or internet news resources like white boards, TV monitors, projection units or flipcharts with easel and markers to compile and display information; hard copies of emergency response, business continuity and crisis communication plans, contact lists, resource inventory and diagrams of facilities and system; stationery, business and incident management forms, pens, pencils,

markers and supplies; food, water and dining supplies for the staff (Department of Homeland Security).

2.2 Augmented Reality

2.2.1 Definition of Augmented Reality

Augmented Reality is a variation of virtual environments, or virtual reality as it is more commonly known (Azuma, 1997). Virtual environment technologies completely immerse the user inside a synthetic environment. While immersed, the user cannot see the real world around them. In contrast, augmented reality allows the user to see the real world, with virtual objects superimposed upon or composited with the real world (Azuma, 1997).
The concept of a "virtuality continuum" related to the mixture of classes of objects presented in any display situation, as illustrated in Figure 2, where real environments, are shown at one end of the continuum, and virtual environments, at the opposite extremum (Milgram & Kishino, 1994).

The case at the left consist solely of real objects, and can for example include observation via a conventional video display of real-wolds scene (Miligram & Kishino, 1994). On the virtuality continuum, one can see that augmented reality is located left of real environments since that which is being augmented is not some direct representation of a real scene, but rather a virtual world, one that is generated primarily by computer (Milgram & Kishino, 1994). The latter case, at the right, defines environments consisting solely of virtual objects, an example of which would be a conventional computer graphic simulation. As indicated in the figure, the most straightforward way to view a mixed reality environment, therefore, is one in which real world and virtual world objects are presented together within a single display, that is, anywhere between the extrema of the virtuality continuum (Milgram & Kishino, 1994).

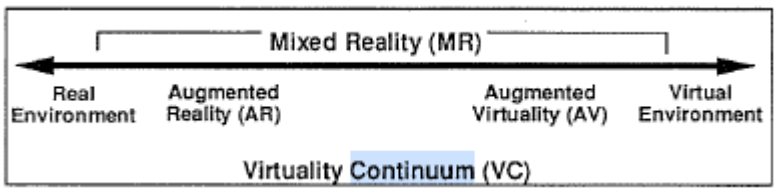


Figure 2: Representation of a "virtuality continuum" (Milgram & Kishino, 1994).

2.2.2 Augmented Reality Devices

According to Lee (2009) wireless augmented reality may be used with different devices, and wearable computing and handheld devices representing two of the most popular solutions today. Both wearable computing and handheld computing share similar attributes: highly mobile with limited power and processing capacities. Nivedha & Hemalatha (2015) highlight

that most researchers have been focusing on developing technology which improves the user's visual experience, and says that only in recent years some researches have started to shift their research interests to improve the user's interaction experience. Thus, the fact that wearable computing and handheld devices share similar attributes, they also have some unique attributes. Wearable augmented reality has some limitations to its weight, limited battery life restricts working time and problems regarding connectivity, where it is limited to the network infrastructure where it's based. Hence, this technology comes at a high price and has limited functionality. However, Lee (2009) highlights its benefits where head mounted display can be extended to track head orientations, which provides immersive experience for users, and is difficult to be implemented using handheld devices.
Nivedha & Hemalatha (2015) also highlights that hardware developed over the years, where computing and graphics power of handheld devices became significant enough for AR applications. This led to more interest from researchers using handheld devices for Augmented Reality due to their portability and popularity. The current smart phones provide several advantages such as high-quality colour display, a fast processor, high-resolution digital camera, large memory space, small size, affordable price and its lightweight. It's also possible to use GPS and compass sensors to find their location, and they can exchange data with other devices over broadband data connections. According to Nivedha & Hemalatha (2015) all these capabilities of smart phones support mobile AR in a more natural way than other wearable and handheld AR systems.

2.2.3 Information Visualization Techniques

Augmented Reality allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. According to Nunes, Lucas, Simões-Marques and Correia (2018) augmented reality systems can be classified according to the type of display used, involving optical or video. According to Nunes et al. (2018) it is possible to classify augmented reality into four types of systems:

Direct optical vision system
The system uses glasses or helmets with lenses that allow the direct reception of the real image, while allowing the projection of virtual images properly adjusted to the real scene.

Direct video vision system
Uses helmets with coupled video cameras. The real environment is captured by the micro-cameras and is mixed with virtual elements generated by a computer. It is directly displayed in the user's eyes through small monitors mounted on the helmet.

Monitor based video vision system
This is the most commonly used system and it uses a webcam to capture the real environment. Once captured, the actual environment is mixed with the computer-generated virtual elements and the result is displayed on the monitor. The view of the user usually depends on the positioning of the webcam.

Projection optical vision system
This type projects images of virtual objects onto surfaces of the real environment. The result is presented to the user without the need to use any type of device.

According to Nunes et al. (2018) information visualization and interaction is key to enhance user experience for mobile augmented reality applications. This is due to the small screen, the limited angle and the short distance seen through the camera, many points of interest are off-screen, making it difficult to quickly find the information you need. It is then necessary to find ways to represent and search for off screen objects. The following three techniques are the most commonly used to represent off-screen objects in augmented reality applications on mobile devices:

Mini map
This technique consists of placing a representation of the user's location and points of interest around them, so it is possible to see where objects are not appearing on the screen of the mobile device. This technique, although accurate, is difficult to interpret since it is necessary for the user to align with the reference systems.

3D Arrows
This technique consists of using 3D arrows to direct to points of interest. The size of the arrow is proportional to the distance the point of interest is. The main disadvantage of using this technique happens when there are many points of interest nearby as it can get too confusing.

Sidebars
This technique consists of having two sidebars to represent off-screen objects. It is also possible to integrate information about the distance, direction and type of the point of interest that is off the screen, allowing users to quickly identify relevant information.

3.0 Research Design

This chapter will clarify which choices regarding research method, strategies and design that has been made throughout the leap of the thesis. As we already mentioned in the introduction, our study was conducted by the qualitative research method, which is designed to help researchers understand people and the social and cultural context within they live (Myers, 2008, p. 5). We have chosen to combine a systematic literature review to identify a research gap and then tried to close it with our interviews. The systematic literature review and interviews combined with relevant theory will be the foundation for our analysis and discussion. According to Creswell (2014), an inductive approach will help our findings to be more comparable to other research. By using the inductive approach - which generally are associated with qualitative research, and starts with data, and end up with theory or model development, we want to observe the issue regarding use of augmented reality in emergency control rooms in order to come with a theory of the phenomenon we are studying. The open and explorative research design has led to many choices been taken during the project as new insights are gained.

The choice of method is based on own assumptions of what is suitable for this task. According to Kaplan & Maxwell (2005), much data about the subjects'' own assumptions goes away when one encodes data, which we clearly do not want (Kaplan and Maxwell, 2005) Moreover, qualitative studies also fit well in studies where the problem is something unclear or loose (Jacobsen, 2005, s. 131). The advantages and disadvantages of qualitative research approaches are summarized in table 2.

Table 2: Qualitative research approach (Jacobsen, 2005, s.135).

Advantages	Disadvantages
→ Depth and detailed understanding → Comprehensive understanding of a phenomenon → Flexibility in data collection	→ Cluttered and detailed information → High degree of costs, especially during the analysis phase → Proximity to the respondents can destroy the ability of analytic distance → Too much flexibility can lead to the survey never being completed

The term “empirical” data is used in research on knowledge obtained by means of systematic observations and surveys (Sigurd Tønnesen, 2019). This contrasts with the assumptions and knowledge derived from theoretical considerations, personal impressions (so-called: anecdotal evidence) or non-systematically obtained observations or experiences (Sigurd Tønnesen, 2019). In empirical research one can therefore not only jump to a conclusion, but set strict requirements on the burden of proof before any conclusions are drawn (Johannessen, Tufte & Kristoffersen, 2010). In order to fulfil the requirements of the burden of proof, we have provided a systematic approach to our method.

This chapter is divided into following sections: 3.1 Systematic Literature Review, 3.2 Expert Interviews, 3.3 Validation of Findings, 3.4 Research Ethical Guidelines and 3.5 Methodological Limitations.

3.1 Systematic literature review

Investigating concepts requires an indefinite amount of reading (Kitchenham, Brereton, Budgen, Turner, Bailey, & Linkman, 2008). Hence, good literature reviews are a needed part of providing scientists with a broad spectrum of knowledge and is a good way to take advantage of an overview of existing literature in an area, making it easy to identify gaps or deficiencies in current research, and suggest areas for further research (Kitchenham et al., 2008). Fink (2005, p. 3) defines a systematic literature review as:

"a systematic, explicit, comprehensive, and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners."

By adopting a systematic methodology for literature reviews, we can take assessments that allow us to investigate conflicting or coincident findings, and identify issues that require further investigation. Furthermore, they include the ability to assess the consistency and generalization of the evidence regarding specific scientific questions and are particularly useful for integrating the information from a group of studies examining the same phenomena (Kitchenham et al., 2008). A rigorous literature review, according to Fink's (2005) definition, must be *systematic* in following a methodological approach, *explicit* in explaining the procedures by which it was conducted, *comprehensive* in its scope of including all relevant material, and hence *reproducible* by others who would follow the same approach in reviewing the topic (Okoli & Shabram, 2010).

We are inspired by Kitchenshams' guidelines for performing a systematic literature review. This guideline is based on a collection of three existing guidelines used by medical students, two books produced by researchers based on social science, and discussions with researchers from other disciplines that are involved in evidence-based practice. The guidelines cover three phases of a systematic literature review: planning the review, conducting the review and reporting the review. They provide a relatively high level of description. They do not consider the impact of the research questions on the review procedures, nor do they specify in detail the mechanisms needed to perform meta-analysis (Kitchenham & Charters, 2007). The methodological approach for structured literature reviews that we have followed is presented in figure 3: *Methodological approach for literature reviews (Kitchenham & Charters, 2007)*

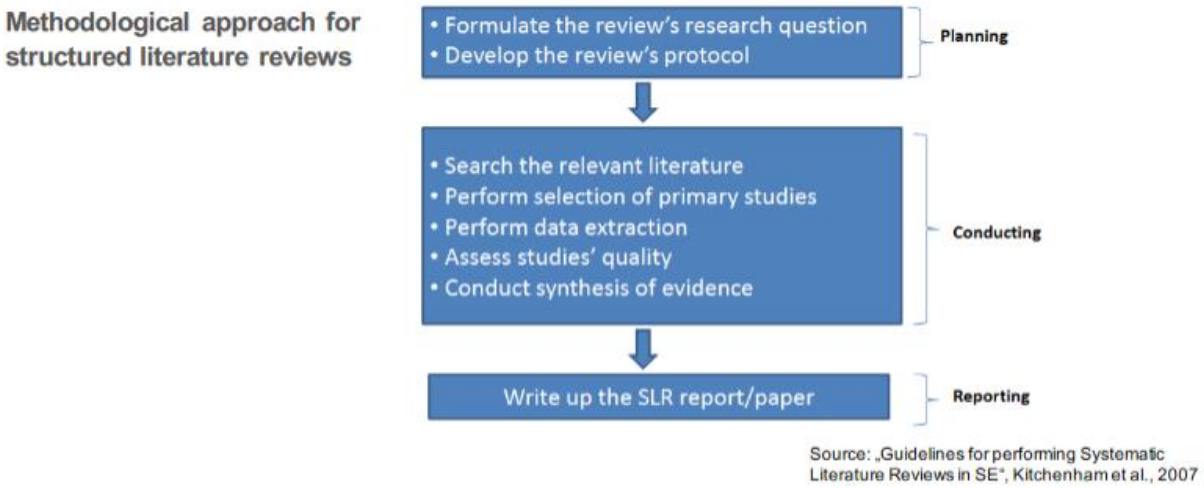


Figure 3: Methodological approach for literature reviews (Kitchenham & Charters, 2007)

The advantages of systematic literature reviews are (Kitchenham & Carters, 2007):

- The well-defined methodology makes it less likely that the results of our literature is biased, although it does not protect against publication bias in the primary studies.
- They can provide information about the effects of some phenomenon across a wide range of settings and empirical methods. If studies give consistent results, systematic reviews provide evidence that the phenomenon is robust and transferable.
- The studies give inconsistent results, sources of variation can be studied. In the case of quantitative studies, it is possible to combine data using meta analytic techniques. This increases the likelihood of detecting real effects that individual smaller studies are unable to detect.

The major disadvantage of systematic literature reviews is that they require considerably more effort than traditional literature reviews. In addition, increased power for meta-analysis can also be a disadvantage, since it is possible to detect small biases as well as true effects.

3.1.1 Search Process

There are many key questions that needs to be considered when conducting and documenting the systematic literature review. These questions may be *where* to search, *which* part of the article should be searched, and *what* queries should be fed into search engines (Okoli & Shabram, 2010).

Literature reviews can be based on all sorts of information and found in scientific journals, books and the rest of the internet. We are, however, dependent of ensuring good quality in the review. Based on this dependence, we focus only on peer - reviewed articles, published in the IEEE Xplore, Science Direct, Scopus and Web of Science databases. Is it worth mentioning

that we used those databases because they are the ones introduced to us through the course IS - 420 - 1, and are those who have proven to giving us the best results regarding our topic. Other IS-databases have been tried out, without luck. One of the most important questions to consider is which queries should be fed into the search engines. According to Salleh, Mendes & Grundy (2011) balancing between too specific and too generic queries is very important. A too specific query will result in a very limited number of results, contra the too generic one which will result in hundreds of results. The strategy we chose was using boolean operators by combining search words in three different ways, and with different operators, with AND (to link major terms), OR (to include alternative terms) and NOT (to exclude non-relevant terms), searching only in the abstract in a non - predefined time span of published articles.

We used our research question as base to identify concepts and synonyms. Based on the identified concepts and synonyms we pre-defined which terminology to use in the queries. That being said - it is also important to consider that search words that suits one database, may not suit another one. As you may also notice, we have used different search queries in our databases. Even though most databases support Norwegian terms we chose to conduct the searches in english. If we would choose to use Norwegian words, we could potentially miss a lot of relevant articles because most of them are written and published in english and not Norwegian.

The keywords, together with search results are presented in *table 3: Results from the search process.*

Table 3: Results from the search process

Keywords	Database	Results
("Abstract":"augmented reality" OR "Abstract":"mixed reality") AND ("Abstract":"crisis" OR "Abstract":"emergency" OR "Abstract":"disaster" OR "Abstract":"catastrophe" OR "Abstract":"extreme event" OR "Abstract":"terror" OR "Abstract":"attack" OR "Abstract":"flood" OR "Abstract":"fire" OR "Abstract":"spill" OR "Abstract":"bombing" OR "Abstract":“explosion“)	IEEE Xplore	87
("augmented reality" OR "mixed reality") AND ("crisis" OR "emergency" OR "disaster" OR "catastrophe" OR "extreme event" OR "terror" OR "attack" OR "flood" OR "fire" OR "spill" OR "bombing" OR “explosion“)	Science Direct	19
("augmented reality" OR "mixed reality") AND ("crisis" OR "emergency" OR "disaster" OR "catastrophe" OR "extreme event" OR "terror" OR "attack" OR "flood" OR "fire" OR "spill" OR "bombing" OR “explosion“) Abstract	Scopus	89

("augmented reality" OR "mixed reality") AND ("crisis" OR "emergency" OR "disaster" OR "catastrophe" OR "extreme event" OR "terror" OR "attack" OR "flood" OR "fire" OR "spill" OR "bombing" OR “explosion“)	Web of Science	87

3.1.2 Selection Process

The total number of articles that were relevant for our study was 282. This was of course only based on the search - queries we applied in the databases. Our process was to read all the abstracts, and a total number of 33 articles were left for further analyses.
Most of our 249 excluded articles were excluded because the title was misleading (not really about what we searched for in the query or because they were duplicates and found in several databases. The duplicates were manually removed.

Table 4: Articles included for further analyses

Database	Relevant articles
ScienceDirect	8
Scopus	16
IEEE	9
Web of Science	5
Total articles	33

Inclusion criteria are a standard protocol used by most researches and a required practice to fulfil high quality research papers. These inclusion criteria are features that help us answer our research question. On the other hand, exclusion criteria are made to prevent features that possibly could interfere with the success of the paper or increase the likelihood of an unfavourable outcome. Inclusion criteria like *augmented reality, crisis management, augmented reality in emergency control rooms* and *crisis response* are criteria that represents the core of the research question, and are therefore used in our further analyses. Mixed reality is a synonym to augmented reality, and we need to include mixed reality in case of authors use it as a synonym. At first glance, *training with augmented reality* and *escape routines with augmented reality* may not be obvious inclusion criteria to use, but we see tendencies that the technology often is used in these-like situations, and therefore include them.

The exclusion criteria exclude papers out of our scope, such as papers with a high degree of mathematical and technical approaches and design-oriented papers. We do not focus on the technical and implementation-oriented parts of augmented reality, as our focus rather is on the user-oriented perspective of augmented reality in emergency control rooms.

Our inclusion and exclusion criteria are presented in table 5: *inclusion and exclusion criteria.* We have included the total number of 20 articles in our literature list after using the inclusion and exclusion criteria in table 6: *Final number of articles.*

Table 5: Inclusion and exclusion criteria

Inclusion	Exclusion
Augmented Reality	Papers that do not have a way of transferring existing theories to research question
Mixed Reality	Papers with a high degree of technical perspectives
Crisis Management	Papers where the core was not about augmented reality
Training with AR	Papers where the core was not about crisis management
Escape routines with AR	Mathematical paper
Augmented reality in emergency control rooms	Implementation oriented
Crisis Response with AR	Design oriented

Table 6: Final number of articles

Database	Final articles
ScienceDirect	4
Scopus	9
IEEE Xplore	5
Web of science	2
Total articles	20

3.1.3 Conceptual Matrix

In this section we intend to present the final articles from the search process in the systematic literature review. Although augmented reality is not an industry specific technology, all articles have its focus on crisis management. However, the technological industry has become more cross disciplinary over the years, which our systematic literature review also reflects, by for example examining augmented reality in disciplines like communication and medicine. We use the conceptual matrix in order to sharpen the focus of our research and to progress

from the initial state of incompetence (Klopper, Lubbe & Rugbeer, 2007, p. 264). At first glance, the conceptual matrix enables us to directly enable which articles deal with a concept (Webster & Watson, 2002). The concepts were predefined based on our theoretical background, and we added further dimensions inductively while reading the papers to handle the unit of analyses. For example, the concept "technology" is further dimensioned with "wearable technology", "mobile technology", "tablets" and "windshields". The process of analysing the literature is based on both of us analysing the papers. After reading the papers we discussed our disagreements until we agreed on everything. The discussions include both conceptualization, categorization and adding further dimensions. The result includes concepts described in the following:

Technology is our first category which aims to categorize technology-devices used to display augmented reality. The devices vary from wearable glasses to mobile phones and tablets. This concept provides a greater understanding of which devices are most commonly used in crisis management situations, and why; *Users* is our second concept, and gives us a better understanding of those who actively takes use of augmented reality in crisis management; *Application area* highlights which context augmented reality is used within crisis management; *Crisis type* is a concept that describes which types of crisis the focus is on. This helps us identify if any specific crisis are more applicable for augmented reality than others, or if different crisis types have different demands for augmented reality; What is displayed is a concept that gives us a overview over which objects are being displayed for the users of augmented reality; *Benefits* highlights which types of benefits that are more frequently mentioned than others; Challenges give an overview over challenges one could face with both implementation and use of augmented reality in crisis management. The concept give us a realistic picture over limitations in the field. We present the conceptual matrix in table 7:

Table 7: Conceptual matrix

CONCEPT																					
	Wearable	x	x	x		x		x		x		x	x				x			x	x	
TECHNOLOGY	Mobile						x		x		x				x			x	x	x		x
	Windshield				x																	
	Tablet										x											
	Response team	x	x	x		x	x				x		x	x			x	x	x	x	x	x
USERS	Citizens		x		x			x	x													x
	Single rescuer									x		x	x									
	Control room people			x		x	x							x		x	x	x				x
	Training	x	x											x	x	x						
APPLICATION AREA	Response	x		x		x	x	x		x	x	x	x		x		x	x	x	x	x	x
	Response planning													x			x					
	Support collaboration											x								x	x	
	Escape guidelines								x													x
	Preventive				x										x							
	Car				x																	
	Natural crisis	x		x		x	x	x			x	x			x			x	x		x	x
	Nuclear accidents								x													
CRISIS TYPE	Artificial crisis	x					x					x							x			x
	Healthcare emergency								x	x			x				x					
	Virtual Disaster	x	x									x				x						

	Geographical awareness	x	x	x		x	x		x						x		x	x	x	x	x
WHAT IS DISPLAYED	Social interaction																x		x		
	Magnitude	x																			
	Degree of disaster	x								x				x	x						
	Instructions	x	x		x				x					x							x
	Patient status			x						x							x				
	Supply status			x																	
	Responder status			x																	
	Games				x									x							
	Symbols					x	x			x					x		x				
	Scene status			x		x							x		x			x			
	Distance/GPS cordinates								x		x		x	x	x		x	x	x	x	x
	Compass								x						x					x	
	Warning message				x																
	Notable scenarios									x	x										
	Bird view of a location										x								x		x
	Measure images	x											x								

Table 7: Conceptual matrix

	Less mental workload																					x			
BENEFITS	Less information overload																				x				
	Situational awareness			x	x	x	x	x			x	x	x	x	x	x			x	x	x	x	x		
	Communication/collaboration						x				x	x	x	x	x		x	x				x	x		
	Scalability				x																	x			
	Kognition								x																
	Preparation								x									x							
	Resilliance								x							x									
	Easy to use												x		x										
	Accuracy																				x				
	Attitude								x																
	Recognize critical situations										x	x		x		x									
	More efficient																				x				x
	Better emergency response											x		x	x	x	x	x			x	x			
	Better decision making	x		x		x					x	x		x		x	x	x	x		x				
	Deep learning	x																							
CHALLENGES	Positioning the information					x																			
	Lack of focus on hands free systems										x														
	Bad signals									x															
	Lack of GPS accuracy											x												x	
	Implementation												x												
	Limited information																				x				
	Battery life													x		x					x				
	Privacy concerns													x											
	Lack of system design for cooperative work										x														

3.2 Expert Interviews

Johannesen, Tufte and Christoffersen (2010) characterizes the qualitative research interview as a conversation with a structure and a purpose. The structure is linked to the distributed roles of the actors in the interview. It is the interviewer who ask questions and follows ups answers from the interviewee. The two actors are not equal in the situation as it is the interviewer who asks questions and controls the situation. The purpose is to understand or describe something, and information that is collected depends on the questions the interviewer will ask. The questions are most often characterized as descriptive questions (questions related to specific events or actions), interpretive questions (how the interviewees consider, perceive and interpret events) or theoretical questions (questions aimed at illuminating, understanding and explaining actions/events) (Johannesen et al., 2010).

3.2.1 Sample of respondents

Choosing informant is deciding whom to investigate. Choosing the right interview subject has a great importance both in qualitative and quantitative studies. In this section, we will explain choices made in connection with the selection strategy, sample size and how we recruited our respondents.

As our intention is to reveal how augmented reality can be utilized in emergency control rooms, we need to get closer to the people we want to know something about; people working in emergency control rooms. We consider these types of informants to have good knowledge of the matter we are studying, and we want to know more about them. Right selection is important in all research, as it has a great influence on the data analysis. The selected informants also represent which conclusions to draw, and how much confidence one has to the results (Johannessen et al., 2010, p. 106 - 108). First, we chose to select informants based on their representativeness; but later chose to use a rather strategic approach where we selected informants based on expediency. Our strategy was to select informants who first and foremost work in emergency control rooms, in addition they need to be sitting in front of screens and function as a first-respondent in crisis situations; meaning that they also need to collect and process significant amounts of information in stressful situations. Such informants are found in 110, 112 and 113-control rooms. The respondents were collected based on recommendations from a Fire Chief. This type of recruiting is defined by Johannesen et al. (2010, p. 113-115) as the snowball-method.
In the early process of conducting interviews, three informants at the municipal level were interviewed. However, after getting in contact with a Fire Chief, and after formulating a strategy for choosing informants the three respondents were eliminated because of lack of relevance. In total, we have nine informants that are included for further analyses.
In chapter 4 Research Context, section 4.2 Table of informants, a table with additional information about our informants is presented.

3.2.2 Interview Guide

The goal of our interviews was to close a research gap found in our systematic literature review. The collection of data was intended to be carried out as interviews with few respondents. We used an interview guide as a template for all the semi structured interviews; making personal, individual interviews is time-consuming, and provides large amounts of data in the form of comprehensive notes and sound recordings (Jacobsen, 2005, p. 142). The interview guide, however, ensures relevant data while at the same time being flexible and providing great opportunities for making follow-up questions. It is also intended to encourage the informants to come up with more detailed information (Jacobsen, 2005, p. 145). It is worth mentioning that our interview questions are prepared with the help of researcher Jennifer Fromm from University of Duisburg-Essen, Germany.

Our interviews start with an introduction of the interviewer and an explanation of the informant's rights and the background of the study. The introduction is followed up by main questions divided in following sections: getting to know the respondent; understand how crisis response in an emergency control rooms works; and suggestions for integration of augmented reality.

When getting to know the informant, we asked question related to job titles, responsibilities and related experiences. However, the interesting questions are those in the following sections. When investigating and understanding how crisis response in emergency control rooms work, the key is letting the informant remember: we asked if the respondent could, in as much detail as possible, recall a previous experience with crisis response. In the following, the key goal was to derive information about roles, responsibilities, collection of information, visualization of information, and how they use their screens. When presenting suggestions for integration of augmented reality, the interview section started off with an explanation of what augmented reality is, so the informant understands the concept. In the following, we asked question about their own motivation and ideas of how augmented reality could be utilized in the emergency control room. We also presented our own ideas. However, the key was to reveal if there is a need for augmented reality, and which problems it could solve by being utilized in emergency control rooms.

We chose to conduct the interviews as individual interviews. At an open individual interview, we get the individual's attitudes and perceptions of the matter, as well as seeing how the individual interprets and makes sense in a phenomenon (Jacobsen, 2005, p. 143, 149). It is possible to clarify the individual's understanding and what kind of meaning is placed in the different conditions (Jacobsen, 2005). All interviews are conducted face to face; the informants are easier to talk to in that way, it is easier to achieve personal contact facing each other and trust can be created. The choice of making the interviews face-to-face was taken after an assessment of whether the respondent had time and opportunity to be interviewed. The timing was between 30-45 minutes per interview, and time spent on transcribing the interviews comes in addition.

3.2.3 Transcription

The first requirement for transcription of an interview is that it in fact is recorded (Kvale, 2007, p. 93-100). Taking notes during an interview could have been distracting and interrupting the free flow of conversation (Kvale, 2007, p. 93-100). A second requirement for transcription is that the recorded conversation is audible to the transcriber (Kvale, 2007, p. 93-100). This requires that we take measures to avoid background noise and are not afraid to ask mumbling informants to speak up (Kvale, 2007, p. 93-100). The time needed to transcribe an interview will depend on the quality of the recording, the typing experience of the transcriber and the demands for detail and exactitude. Transcribing also involves a series of technical and interpretational issues - in particular, verbatim versus written style - for which there are few rules, but rather a series of choices to be made. As there were two transcribers for the interviews of a single study, we had to make sure that the same procedures for typing was made. Hence, we transcribed our own interviews. Because we transcribe our own interviews, we learned much about our own interviewing style; to some extent we have the social and emotional aspect of the situation presented or reawakened during transcription, and already have started the analysis of the meaning of what was said (Kvale, 2007, p. 93-100). We transcribed word by word in a written style without pauses, emphases in intonation and emotional expressions. Different style in transcription makes it difficult to make linguistic cross-comparison among the interviews (Kvale, 2007, p. 93-100). The interviews are conducted in Norwegian, and therefore they are also transcribed in Norwegian. However, we have subsequently translated quotes we want to use in the assignment from Norwegian to English.

3.2.4 Qualitative Content Analysis

For the analysis of our interviews we applied the so-called qualitative content analysis approach of Mayring (2014). The approach is easier to understand than for example the hermeneutic approach to analyse the interviews, which is a very philosophical and difficult approach to apply when analysing interviews for the first time. Mayring (2014) proposes two different approaches for the qualitative content analysis: the inductive analysis approach (forming categories while reading the interview transcripts) and a deductive analysis approach (forming categories based on theory before reading the interview transcripts). In our case, the inductive category formation is most suitable because it is a faster, more economic and a more specific procedure (Mayring, 2014, p.79).

The aim with the inductive category formation is to arrive at summarizing categories directly, which are coming from the material itself, not from theoretical considerations, and true description without bias owing to the preconceptions of the researcher, and understanding of the material in terms of the material (Mayring, 2014, p. 79). Inductive category formation is a central process within the approach of Grounded Theory (Strauss, 1987), which in this context is called "open coding", and have a lot of rules of thumb for open coding; it is recommended to use a systematic, line by line procedure. For content analysis, nevertheless, inductive category formation must be more systematic. And it can use the same logic, the

same reductive procedures, as in summarizing content analysis. The process of our qualitative content analysis is illustrated in figure 4: *Steps of inductive category development*, and will be explained in the following.

Within the logic of content analysis, we had to define the theme of categories previously. This had to be a criterion for the selection process in category formation. This is a deductive element and is established within theoretical consideration about the subject matter and the aims of analysis. After the categories, selection criteria and level of abstraction was defined, we worked through the material (interviews) line by line. The first time, material fitting the category definition was found, a category was constructed. We used short terms as "mobile devices" and "wearable technology" to label the categories. One can define the following process (step 2 - 4) as a "reduction process"; each time a passage fitting the category definition was found it had to be checked whether it falls under a previous category, or if a new category must be formulated (Mayring, 2014, p.81). After a while, no new categories were to be found. Next step was to revise the whole category system to see if the logic of categories is clear, and if the level of abstraction is adequate to the subject matter and aims of analysis (Mayring, 2014, p.81). However, we also built some main categories: for example, categories like "mobile devices" and "wearable technology" was categorized in a main category called "devices". This step is processed more inductively by only enhancing the level of abstraction in the sense of summarizing, rather than processing it more deductively by introducing theoretical consideration in formulation of main categories (Mayring, 2014, p. 81). The categories are also coded in tables by the main principle in Grounded Theory: open coding (Strauss, 1987). However, if the categorization does not make sense, the process starts all over again from step 1. Luckily, with small modifications like using synonyms for already defined categories, we did not have to revise the whole quality content analysis.

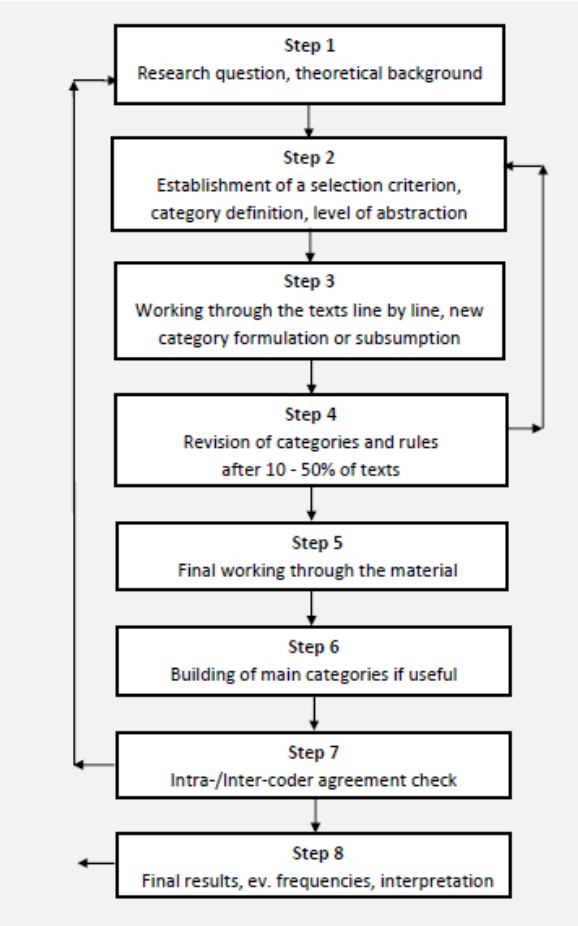


Figure 4: Figure 4: Steps of inductive category development (Mayring, 2014, p. 80)

Our results are displayed in tables in chapter 6: Expert Interviews, section 6.1: Categories coded from the interviews.

3.3 Validation of findings

Validation often involves a test of results (Jacobsen, 2005, p. 214). We have chosen to validate through control against other professionals (Jacobsen, 2005, p. 215). We can say that validity has been strengthened, but not that our investigation is true if other professionals come to the same conclusion as us, even though they have used another method (Jacobsen, 2005, pp. 214-215). In our case, it has also been relevant to validate our findings through a critical review of sources and information (Jacobsen, 2005, p. 216) where we have asked ourselves if we have got the right sources, if the sources provide the right information , when in the survey data is collected and how the information comes forward (Jacobsen, 2005, pp. 216-219). However, it is also necessary to validate relationships, because many qualitative studies not only aim to describe and understand a phenomenon, but also to explain why a phenomenon occurs (Jacobsen, 2005, p. 221). A critical approach is needed because we can never make conclusions for granted (Jacobsen, 2005, p. 221).

Reliability is about reproducing the informants' statements as correctly as possible, and spending time interpreting the content of the information we receive (Jacobsen, 2005). There are requirements for objectivity, so that we avoid managing the content in the direction of our experiences and our opinions on the problem (Jacobsen, 2005). Because of the informants' position and experiences, we find their statements as reliable and we have tried to reproduce their information as accurately as possible.

Understanding the reality is to interpret statements (Jacobsen, 2005). How to interpret will depend on what you have previously experienced. One can more likely prove a statement, and deny or confirm a hypothesis if it coincides with reality. This could lead to a deeper understanding of a phenomenon. However, one must interpret the informant's statement to compare. In this phase, it is a prerequisite for the validity of the study that the researcher has a neutral attitude (Jacobsen, 2005).

We have tried to be as objective as we can, but it has been somewhat challenging as we have much knowledge of crisis management and augmented reality. During the process, we have focused on being objective in relation to our study. Especially considering that some of the measures and results could be followed up later.

3.4 Research ethical guidelines

According to Jacobsen (2005, p. 44), social science studies are almost always about studying people. Further he says:

"When we do research on humans, we also commit a" break-in "to their lives, whether it concerns the private sphere (family, friends, buying behaviour, or otherwise) or a more public sphere (job relationship, voter behaviour). This puts everyone who wants to carry out studies of other people to some ethical dilemma" (Jacobsen, 2005, p. 44).

In our survey, the purpose has been to gather information that the selected group possess. The informants contribute their reflections on the topic through the research interview. The goal of the task is not to hang out or to make traps, so it is a prerequisite that data is anonymised. It is our role as researchers to preserve neutrality and not identify us too much with the people we are interviewing.

There are strict requirements regarding treatment of information about personal matters, which we must treat confidentially. The material has been anonymized to protect privacy and to avoid harm and unreasonable burden on the people being researched. Anonymization intends to protect the individual's privacy so that information is handled properly, and that personally identifiable information is processed by as few as possible.

We have used audio recordings and transcribed the interviews on computers. The source material will be destroyed after the master's thesis is censored.

3.5 Methodological limitations

There are several methodological limitations that can be listed in this section, both regarding the systematic literature review and the interviews. We have had challenges with collecting articles about emergency control rooms. At first glance, one can state that the challenge is only about the emergency control rooms, while it in fact also affects the availability of articles regarding operators and people sitting in front of screens at the emergency control rooms. Most articles that questions and defines how augmented reality can be used in crisis management only affects responsive actions, training and communication between responsive teams out in the field. This challenge sets limitations to our study, but also defines a research gap and suggestions for further research that needs to be further examined. However, we should have included a measurement such as Krippendorff's' alpha to assess intercoder ability. To close the research gaps found in the literature study we chose to supplement with expert interviews. However, getting informants to participate was a far greater challenge than we expected it to be. After a while we had relevant informants, but later chose to eliminate them because we realized that the recruitment process needed a far greater strategy than we first had. We also had to define a set of inclusion criteria for the informants. After this process we decided collecting informants from 110, 112 and 113 control rooms would fulfil the requirements, but could not manage to obtain a varied selection of informants: both the 112 and 113 centrals were eliminated, and we ended up with informants from a 110-emergency control room. The informants have the same sex, working task, age group and same previous experience.

4.0 Research context

In this chapter we intend to describe in which context our interviews are conducted. In section 4.1 we will describe the contextual information, while section 4.2 is left for describing the organization. Finally, in section 4.3 we will present a table of informants.

4.1 Contextual information

First, we need to be very careful about what we mean by context. We have to define context based on our research objectives, because it can mean different things such as a particular augmented reality team or group, an organization, community, society, country or culture. Second, the importance of context is that it gives meaning to our research. Simply, it helps shape our research. For example, if we are using multiple cases to explore a topic, using evidence from different countries, context is an essential means to help us explain why what can work in one context, and not necessarily in others.

We will specifically focus on our informants. This will form the basis to provide background information for our research results. All the data in our study is anonymous, so that you only will see the difference between how work is done in emergency control rooms, and not the various personal qualities of the interview subjects. We want to focus on the phenomenon we study, and not the various informants we have studied

The period we collected data extends from February to May 2019. In section 4.2 the organization we conducted interviews in will be presented, followed up by a presentation of informants.

4.2 Organization

Our informants are working in a 110 emergency control room of a large Norwegian City. The emergency control room is the coordinating link between fire stations, police, the ambulance service, the civil defence, the coastal authorities, NSB, the main rescue centre, Avinor, defence, and more. Their emergency control room is one of the most modern in Norway.

4.3 Table of informants

All our informants have experience with working in emergency control rooms. How and why these informants are selected is described in chapter 3: Research Design, section 3.2.1: Selection of Respondents. Our informants have roles in crisis management where they have varied job titles. The main rule is that all work with screens during crisis management. The figure below illustrates the role distribution, there is no distinction between organizations they work for. Due to requirements regarding anonymity only a simple table of informants will be presented.

Table 8: Table of informants

Sex	Job Title	Organization
Male	Chief operator	110 control room
Male	Operator	110 control room
Male	Operator	110 control room
Male	Chief operator	110 control room
Male	Operator	110 control room
Male	Operative leader	110 control room
Male	Chief operator	110 control room
Male	Operator	110 control room
Male	Operator	110 control room

5.0 Analysis results from the systematic literature review

Section 5.1 provides a description of key tendencies that appear in the data material, where the articles are put into context and compares. Chapter 5.2 presents an extended analysis of the central tendencies.

5.1 Description of central tendencies

Studies found in the articles are conducted in South Korea, Taiwan, Italy, Sweden, the United States and the United Kingdom. In the main analysis, five tendencies is identified as having significance for the subsequent interpretive analysis of how augmented reality can be used to support working tasks for operators in emergency control rooms.

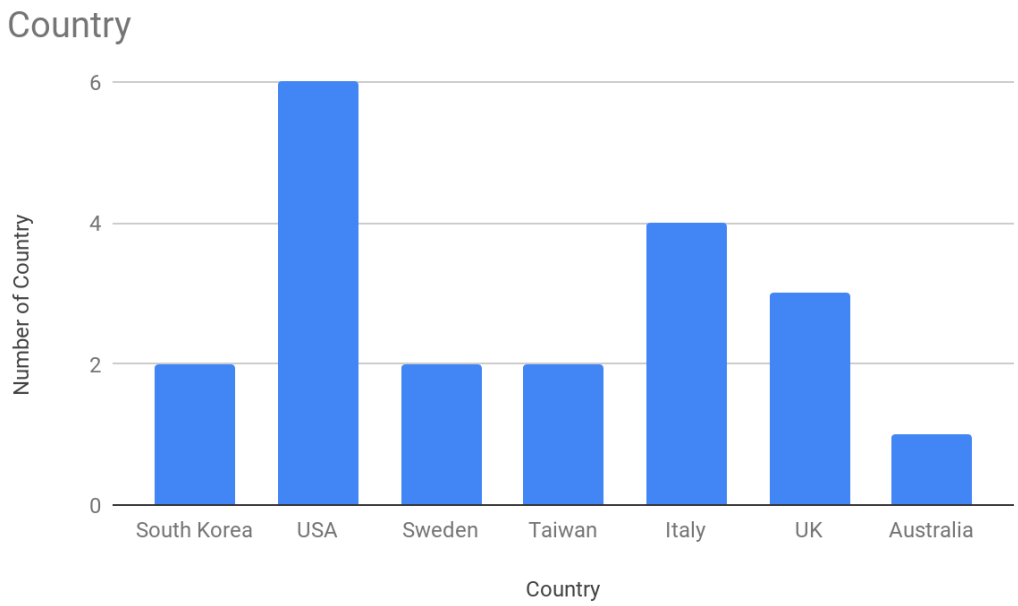


Figure 5: Distribution of land areas our articles are published in

In the introductory study, key tendencies such as user types, technological devices, application areas, displayed objects and benefits and challenges are important for the subsequent interpretive analysis of how augmented reality is understood as a tool in not only emergency control rooms, but overall crisis situations. By subdividing the study into tendencies, a pattern emerges: augmented reality is distributed through mobile or wearable devices used by gold commanders in crisis management, and is most frequently used for communication and collaboration in training and responsive actions.

Section 5.1.1 explains the users of augmented reality in crisis situations, while section 5.1.2 describes which types of technology most frequently is used in the context with augmented reality. By categorizing the application areas in section 5.1.3 we can clearly see that augmented reality can be utilized in different areas such as crisis responses, training and

communication and collaboration. There are also tendencies that show how different objects are displayed through augmented reality technology, this is illustrated in section 5.1.4. Finally, section 5.1.5 outlines the benefits of implementing augmented reality in crisis management, while it also highlights challenges and issues that may limit its application in crisis management.

5.1.1 User types of augmented reality in crisis management.

Our description of central tendencies shed light on the challenge regarding a lack of focus on augmented reality solely in emergency control rooms (Bacon, MacKinnon & Kananda, 2017). However, there are articles combining user types such as operators in emergency control rooms and response teams.

Nine of the focuses on a *combination of users*, four focus solely on *response teams*, three on *citizens*, two on *single rescuer*, and only one has focus on *emergency control rooms* (Figure 6: User types of augmented reality in crisis management).
When takin a closer look at the combinations of users, we see that six combine *emergency control room and response teams* in crisis management, while all the remaining combinations of *single rescuer and response team, citizens and response team, single rescuer. Response team and emergency control room* have one article each of the nine totals (Figure 7: Types of combinations of users).

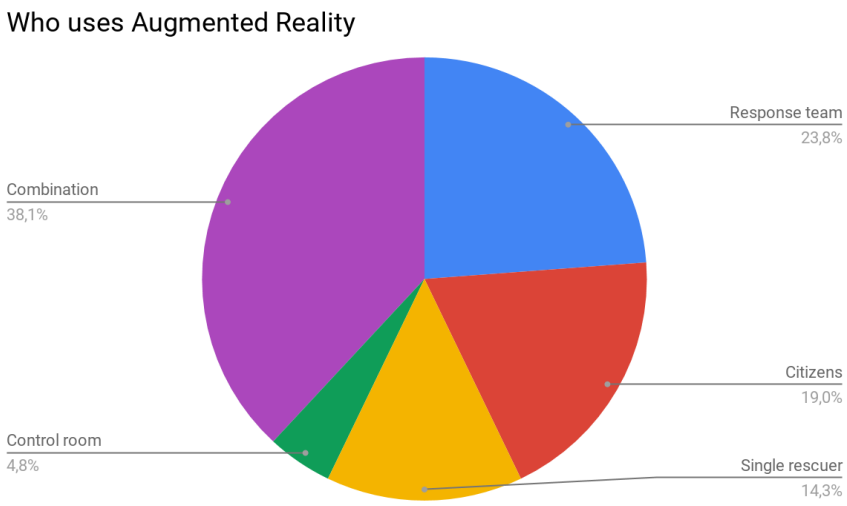


Figure 6: User types of augmented reality in crisis management

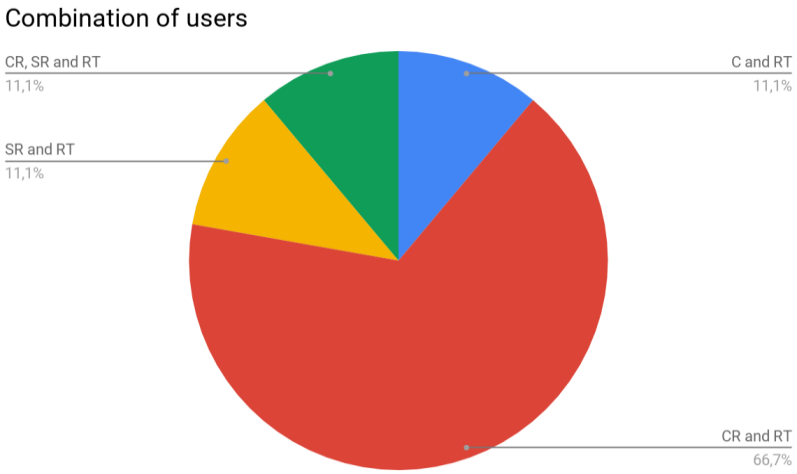


Figure 7: Types of combinations of users

5.1.2 A focus on devices in crisis management

To understand what device is suited for use in emergency control rooms, we investigated which are most frequently used and preferred. The types are categorized into *wearable technology*, *mobile phones* and *tablets*.

Looking at which technology is used to display the augmented reality; ten articles examine *wearable technology* to display augmented reality in crisis management. Seven articles focus on *mobile phones*, while only a fraction of one used *windshield* or *tablet* to display augmented reality (Figure 8: Devices used to distribute augmented reality in crisis management).

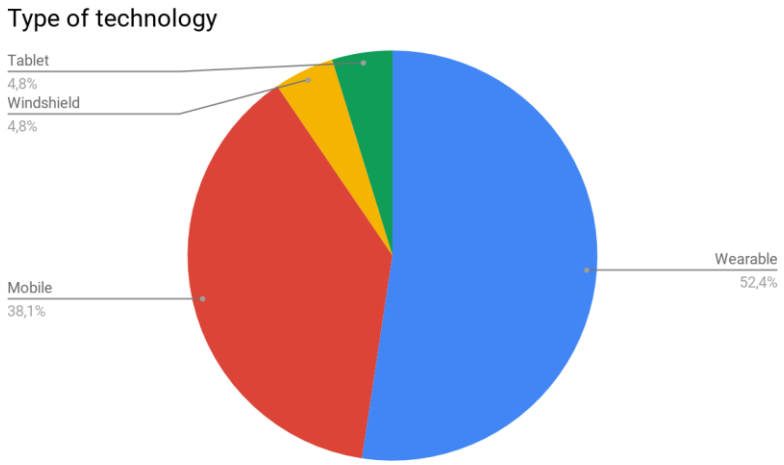


Figure 8: Devices used to distribute augmented reality in crisis management

5.1.3 Frequently used application areas of augmented reality

To understand how augmented reality can be used to support work done in emergency control rooms we investigated which application areas augmented reality is most frequently applied to. A prominent feature of the pattern is that the main part of the studies has focus on augmented reality on *emergency response planning* and *emergency response actions*, while five articles focus on *training activities* to be better prepared for emergencies. Two examine how augmented reality can be used to support *collaboration* and *communication* in crisis management. Both *escape guidelines* and *prevention* of new crises have been explored with a fraction of two articles each. Last, but not least; how augmented reality is used in *mobile vehicles* in context with crisis management have a fraction of one article (Figure 9: Application areas of augmented reality in crisis management).

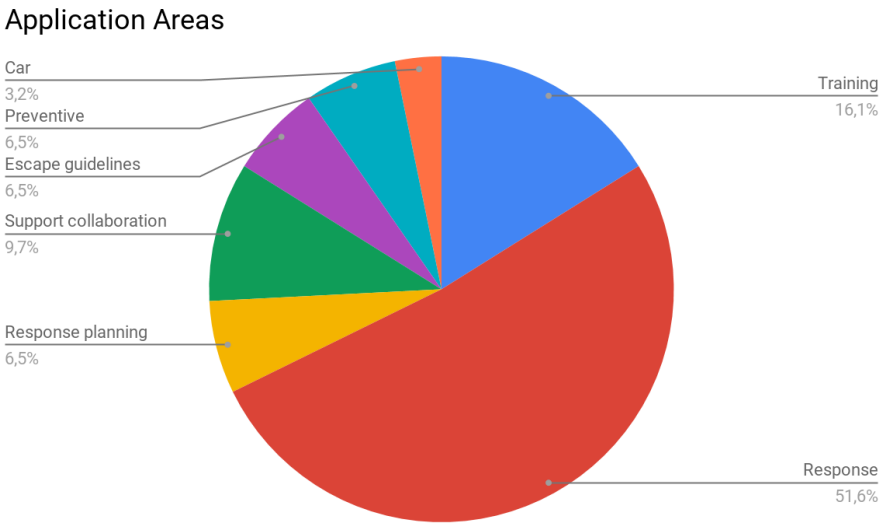


Figure 9: Application areas of augmented reality in crisis management

5.1.4 Objects typically displayed using augmented reality in crisis management

In this section we will describe findings regarding what is displayed with augmented reality devices. The aim with this section is to understand what type of information that is usually used in augmented reality, and which data is important in crisis management. 12 articles displayed *geographical awareness* through augmented reality. This is a broad term and could include features like maps, weather conditions, area of victims, are of crisis, dangerous paths and so on. 10 articles displayed *Distance/GPS coordinates* through augmented reality. Six articles displayed *instructions*, five displayed *symbols*, five displayed *scene status*, four displayed *degree of disaster*, three displayed *patient status*, three displayed *compass*, three displayed *bird view of location*, two displayed *social interaction*, two displayed *measure images*, two displayed *notable scenarios*, one displayed *magnitude* and one displayed *supply status* through Augmented reality in crisis management (Figure 10: Types of objects displayed by augmented reality in crisis management).

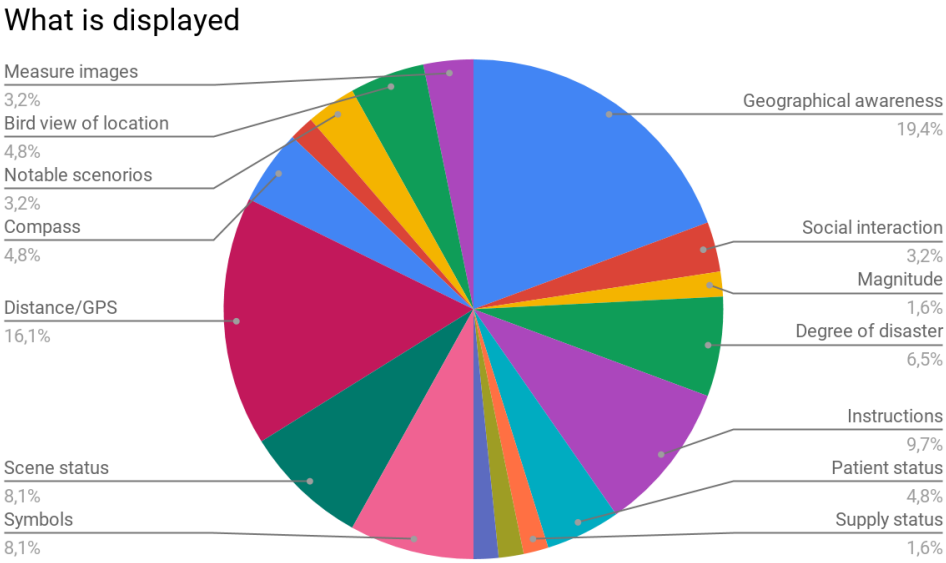


Figure 10: Types of objects displayed by augmented reality in crisis management

5.1.5 Benefits and challenges of using augmented reality in crisis management

A clear assessment has been made of the pros and cons while using augmented reality in crisis management. A clear distinction is shown in focus areas; most researchers shed light on benefits, while very few want to nuance challenges. However, 15 articles highlight *situational awareness* as a benefit. *Communication/collaboration* has been examined in nine articles. Our initial analysis shows a clear tendency that the benefit of increased situational awareness and communication/collaboration often go hand in hand. *Better emergency response* has a fraction of eight articles, and *better decision making* has a fraction of 11 articles. Six of the articles that discuss better emergency response as a benefit, also discuss how augmented reality can provide better decision making in crisis situations.

We point out that the categories challenges are particularly distinguished based on the argument that the disadvantages are not illuminated to the same extent as the benefits become. Nor is there any clear connection between the challenges mentioned. Regarding the challenges, *battery life* has been mentioned three times, *privacy concerns* has a fraction of one article, and *bad signals/lack of GPS accuracy* has also been mentioned one time.

5.2 Analysis results

As it can be read in the foregoing description of key tendencies in the data material, the focus of the analysed studies affects all the analytical categories of *users*, *preferred devices*, *application areas*, *display of objects*, and *advantages* and *disadvantages* of augmented reality in crisis management. An interpretation of the understanding and the use of augmented reality in crisis management found in the analysed articles is given here in the further analysis. This analysis is performed by extracting and interpreting the relevant meaning content in the various texts.

5.2.1 Commanders in crisis management

Commanders is a pseudonym discussed by several of researchers in our study (Bacon et al., 2017; Vessel et al., 2016; Nilsson et al., 2011; Weichelt et al., 2018). There is a distinction between gold, silver and bronze commanders, and incident commanders. Gold commanders are used to describe strategic planners which sets a strategy that all other plans must take account of in crisis management (Bacon et al., 2017), while incident commanders are used to describe persons responsible for several aspects of an emergency response, for example making the overall incident plan (Vessel, Apperson, Calyam, Gillis & Ahmad, 2016). It is also important to mention that gold commanders often give commands to silver and bronze commanders, making it a hierarchy.

The role of gold commanders is strategic, and they are often co-located with other gold commanders from other agencies in emergency control rooms and are rarely out in the field. Crises where gold commanders are involved are often complex, and require coordination and cooperation from several agencies. They propose solutions to and set the directions of the silver commanders which gives direction to the bronze commander. The bronze commander is the one in charge in the field, giving orders to the people solving the crisis (Bacon et al., 2017). The gold commanders' focus is to: save and protect life whilst ensuring the health and safety of their own staff; relieve suffering; contain the emergency; provide information to the public; safeguard the environment; protect property; maintain/restore critical services; maintain normal services appropriately; promote and facilitate self-help; facilitate the investigation/inquiry; facilitate community recovery; and evaluate lessons learned.

Today, there is a lack of integrated technology platforms that allow an incident commander to collaboratively sense disaster scene status events. Suitable technologies for efficient coordination can help them to strategically delegate triage responsibility to first responders and direct them remotely using audio-visual communication. They can also help with emergency response in disaster scenarios that requires all first responder groups such as fire, police, and health services to coordinate closely rather than act as isolated units (Vessel et al., 2016). However, the addition of augmented reality gives incident commanders and responders real-time information during the response (Weichelt, Yoder, Bendixsen, Pilz, Minor & Keifer, 2018). Improving shared understanding between commanders has the potential to speed up coordination work, something that may prove to be an important enabler of success in many real-world situations (Nilsson, Johansson & Jönsson, 2009). From this perspective, commanders from different organizations need personalized views of the same situational

map. Augmented reality has the potential to provide both aspects and in doing so it may improve initial common ground. Improving shared understanding between commanders has the potential to speed up coordination work, something that may prove to be an important enabler of success in many real-world situations. Given the distribution of responders across the physical space, different sub-teams will perform to different levels (as they need to travel different distances) and this poses a challenge for the commander to find the best teams needed to perform the tasks.

5.2.2 Devices that are preferred used for Augmented Reality in crisis management

Unlike laptops and computers, mobile phones support many communication protocols (Tsai & Yau, 2012). They also offer the advantages by being slim, handy, portable, and electricity conserving. In addition, mobile devices have become more powerful with additional sensors, high resolution cameras and related technology (Weichelt et al., 2018). However, Park, Kim, Jung, Lee & Lee (2016) argue for a higher user experience and high sense of reality are important issues in a system for disaster training and responses. The need for an augmented reality technology that provides the user with graphic images, real environments and an addition possibility for the user to freely use their own body with the use of head-up-display will facilitate for high sense of reality and high user experience.
Mirauda, Erra, Agatiello & Cerverizzo (2018) supports mobile applications for augmented reality which could help field workers quickly move into critical areas during an extreme event by communication information to the emergency control room in real time. This advantage is also highlighted by Luchetti, Mancini, Sturari, Frontoni & Zingaretti (2017) where mobile applications work like a real time pipeline and provides information (photos, images, animations and videos) about what's happening in the surrounded areas, which in fact was a major advantage for decision making. Brunetti, Croatti, Ricci & Viroli (2015) argues for that the approach with touch-screen could adversely affect mission efficiency and efficacy and highlights the importance of hands-free principles as an intuitive approach. Operators should have the possibility to interact with software systems without using their hands, with the reason that hands should be used to perform other actions, the interaction between operators and systems should use other supports than common mobile devices, like mobiles or tablets, for example introducing glasses for augmented reality. (Brunetti et al., 2015). Vessel et al., (2016) supports heads-up displays and argue that it allows for hands-free communication and force multiplications, enabling individuals to perform tasks that before needed to be performed by multiple people.

On the other hand, mobile phones, more specifically social media can be proposed as a critical data source for the emergency responders. Most people will have access to internet and mobile phones, and most citizens will use social media as a platform for information sharing, communication and a possible way to reach out for help during crises (Dave, Boddhu, McCartney & West 2013). Luchetti et al. (2017) gives an extended proposal for this approach, and suggests that it is possible to connect hashtags to establish a logical connection between the user and the critical event (Luchetti et al., 2017). Other data such as sensor data, forecasting of crisis, georeferenced tweets and GPS position would also allow operators to visualize information quickly. With such a use of mobile devices together with incoming

feeds from a control centre, the operator is in good position to make decision to best handle the crises situation in just a few seconds. However, even though mobile phones can be used as a very important device for the control centre, there is a possibility for the control centre to be overloaded by for example calls from victims, leading to a queue in the phone lines in the control centre (Dave et al., 2013). Worst case scenario the communication will collapse.

The figure below illustrates how a robust workflow with the combination of mobile devices from victims and mission control from control centres can help first respondents gain better situational awareness.

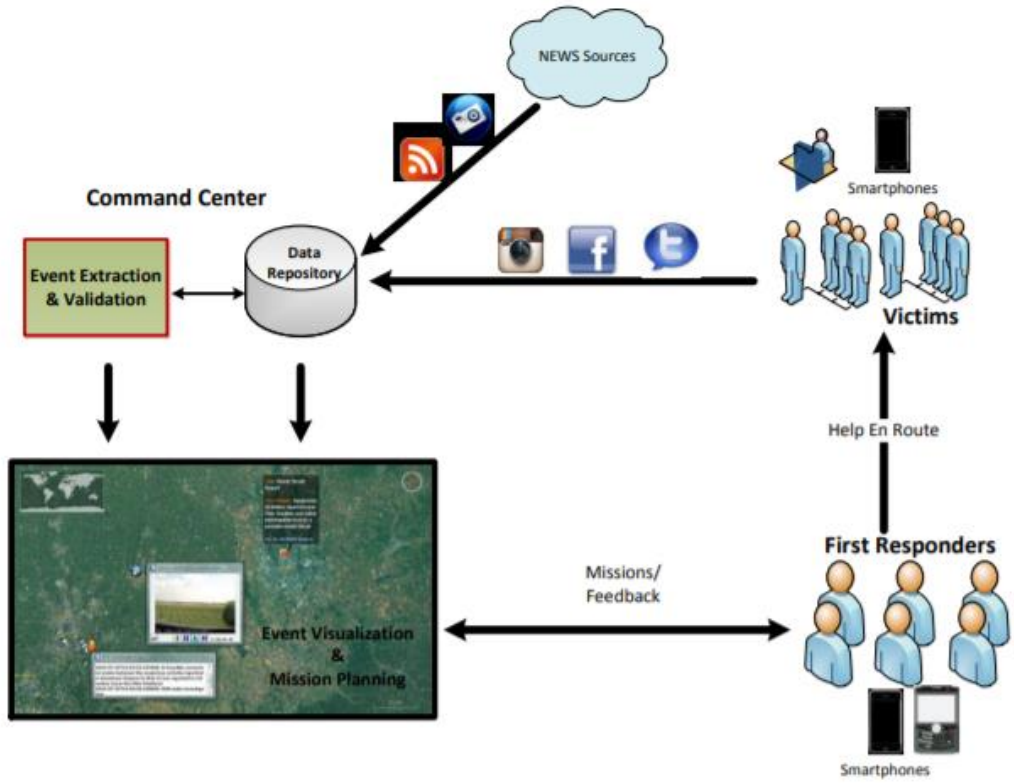


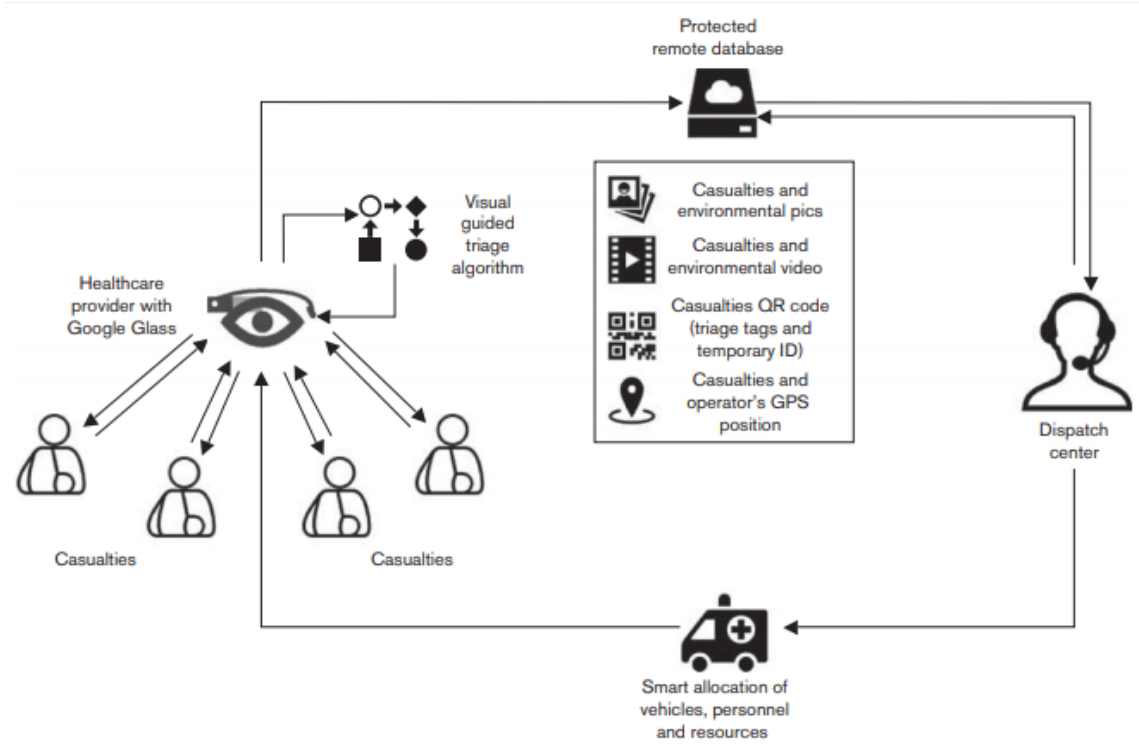
Figure 11: Workflow of information (Dave et al., 2009

A proposed application has been tested with two simulated crises: wildfire and earthquake. The results showed that response teams got filtered information from social media which helped them fulfil their missions, it also helped the planning team prioritize missions and execute them with well-informed situational awareness. The use of mobile phones increased both the situational understanding and the situational awareness in crisis environments. However, some points could jeopardize the use of mobile phones and social media in crisis management: cell tower communication fails, and satellite traffic becomes too heavy; social media data contains too much extraneous information for the search filtering algorithms to handle, and; the data collected is flawed and ultimately leads to erroneous actions by respondents.

Just like Park et al. did in 2016, Nilsson, Johansson & Jönsson (2011) proposed a training system in crisis management with the help of wearable technology. However, it turned out that lack of eye contact with the use of head-mounted-display did not affect the cooperation,

but using it for a longer period could be tiring because of its "front footed weight" (Nilsson et al., 2011).

Google Glasses have been tested as an augmented reality application. Carenzo, Barra, Ingrassia, Colombo, Costa & Corte (2015) describes in detail how health care commanders needed their hands free to operate other tasks, and therefore operated the Google Glass by voice command and sound that was converted through a headset. In figure 12, you can the flow of information from the Google Glass (Carenzo et al., 2015).



.

Figure 12: The flow of information from the Google Glass (Carenzo et al., 2015).

By forcing operators to follow a predetermined algorithm prompted by Google Glass, time spent triaging each single causality could be reduced, and the accuracy of the triage itself can be increased. Additionally, the most challenging part with Google Glasses is documentation in hectic situations. Regardless of how successful the test was, Carenzo et al. (2015) believes that the potential of such wearable technology in crisis - related situations is not entirely clear yet.

5.2.3 Application areas for augmented reality in crisis management

The analytical application area describes user dimensions and focuses on *response*, *training*, *communication* and *collaboration*. These dimensions are frequently presented in the data material as central application areas for augmented reality in crisis management, and will therefore be further analysed.

Responders rely on sensors, imagery and other form of intelligence to assess and monitor events. Humans affected by these events can also act as sensors to augment reality and provide additional information to the responders. These sources of information can include communications via public sources such as the citizens band, communications from individuals via social media such as Facebook, Twitter, Instagram and communications via law enforcement or other responders. When speaking of communication: traditional communication and coordination platforms and tools seem to have limited capability to enable effective collaboration among first responders in a crisis response. Aldunate, Schmidt & Herrera (2012) propose that augmented reality can be used to enable communication in emergency response environments. Such an environment could be a control centre. However, they vote for an augmented reality approach where user interaction is mainly based on hand and arms gestures and voice recognition. Their approach is also based on enabling basic language capabilities and communication in the environment by means of an intuitive and natural human-to-human interaction. Stressing this problem with traditional augmented reality approaches would result in flooding the first responders' vision with digital data (for example text and icons), which can be distractive to the rescue team. To succeed with augmented reality in first responder's communication, a novel interface concept is required. Augmented reality needs an interface that is equally fast and reliable in natural and in manmade hazards that allows first responders to act quickly, precisely and without harming themselves or putting their colleagues at risk. Augmented reality also supports cooperation as the actors can see each other and cooperate in a natural way (Nilsson et al., 2011).

Some researchers also propose that the use of escape guidelines could be an important resource in crisis management (Tsai et al., 2012), but only a handful exist. Tsai et al. (2012) has constructed guidelines for such a system that can be used. The guidelines are called Mobile Escape Guidelines (MEG), and adopts two techniques: geographical information and augmented reality. The objective of MEG is to enable users to access the escape guidelines by using their mobile phones when they perform self-evacuation from augmented reality accident sites. It is not the guidelines that are interesting, but the one specific outcome: through numerous communication protocols in the escape guideline system, the people needing assistance also can communicate with emergency management control centres and personnel. Vessel et al. (2013) also sheds light on the fact that suitable technologies for efficient coordination can help emergency control room workers to strategically delegate triage responsibility to first responders and direct them remotely using audio-visual communication. They can also help with emergency response in disaster scenarios that requires all first responder groups such as fire, police, and health services to coordinate closely rather than act as isolated units (Vessel et al., 2013). Altogether, Vessel et al. (2013) concludes that augmented reality can contribute to improve the situational awareness for effective coordination between involved staff in a disaster response situation. During a crisis response augmented reality betters the interaction and coordination between team members working in the field (Brunetti et al., 2015), and they have the possibility to follow the mission from remote emergency control rooms. Functionalities are targeted to ease the development and execution of real-time collaborative applications supporting teams engaged in some mission, taking place on the physical environment. These functionalities can be summarized

in: capability empowering, context awareness, implicit communication and coordination and mission tracking, monitoring and analysis. Augmented reality deployment can bring about an improvement of the response time and, hence, efficiency of the overall effort. There is much important information instantly available to the worker on demand, and as has been said earlier, this makes a difference to the quality of response that an agency can offer to any unforeseen situation (Luchetti et al., 2017).
For the sake of planning responses, an augmented reality system was utilized for supporting joint planning tasks by providing organization specific views of a shared map (Nilsson et al., 2011). One important observation from is that comparing the augmented reality map and the paper-based map shows that the augmented reality system is as good as or better than the paper map in many respects.

However, when a disaster occurs, people need to respond to the disaster as soon as possible, and the best way to do it is by training in advance. Park et al. (2016) proposes a disaster training and response system based on digital signage (DS) and augmented reality technologies. In this training system, it is proposed that augmented reality is used to provide realistic images for disaster training and response. The virtual generator provides information of location, magnitude and degree of the disaster. His suggestion of using augmented reality in training areas are further enhanced in a publication from 2017 (Park, Jung, Lee & Lee 2017). The disaster training with augmented reality allows users to watch images of disasters by using augmented reality devices to perform training by controlling a mouse or joystick. For example, a device shows images of an earthquake and instructions for the training, and a user moves to find an emergency shelter by controlling a joystick (Park et al., 2017).

5.2.4 Objects that are typically displayed through the augmented reality devices

Augmented reality supports rescuers by providing context data stored in a shared information space (Brunetti et al., 2015). This information is often used to display rescuer location, environment state and others to guide and make rescuer tasks. In situations where a wild fire is out of control the fire department needs help from other agencies, such as the police and the military (Nilsson et al., 2009). A possible platform for arranging such collaboration with augmented reality in crisis management is using digital maps where several emergency chiefs can collaborate. The police help with evacuating persons, traffic control and allocating missing persons while the military often helps the fire department on the ground or air. By having access to personal, organisation-specific symbol libraries, digital maps could also provide an increased understanding of the ongoing crisis (Nilsson et at., 2009). Examples of such symbols are police vehicles, fire trucks, helicopters, and personnel.

However, operators sitting in emergency control rooms which are making decisions to responders need unfiltered data to be shown. This means a rather chaotic approach with a lot of information and data (Dave et al., 2013). Another option for augmented reality devices can be social media enabled frameworks, which includes feeds from various platforms like Twitter, Facebook, Instagram and news feeds with content that includes text, images and videos and is collected from public or subscribed services. On the other hand, even though the

emergency control room is in need for unfiltered and chaotic information, first responders need the opposite. When speaking of maps and social media: there is also possible to use heat maps produced by tweets and their GPS coordinates to better understand the geographical are involved in an event, or to analyse events that already have affected a region (Luchetti et al., 2017).

Figure 13 presents the cloud architecture along with processing social media feeds, information and media, from news and social media ingestion services and from first responders with smartphone sensors.

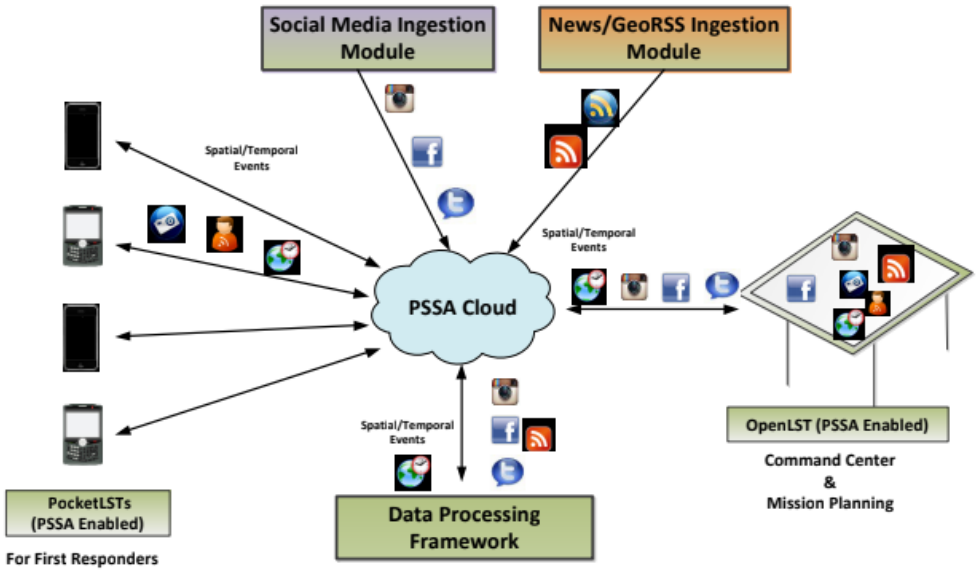


Figure 13: Cloud architecture with social media (Dave et al., 2013)

Augmented reality applications can also be used as evacuation applications where users can take a picture (stage 1) and the augmented reality application will generate two virtual images: and index point (stage 2) and an index board (stage 2). Finally, the application can show the location of (for example a shelter or evacuation route) on the screen of the mobile phone (Tsai et al., 2012).

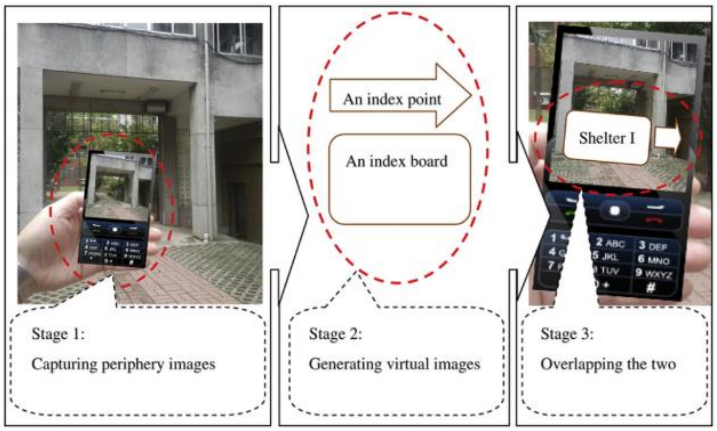


Figure 14: Escape routines with augmented reality (Tsai et al., 2012)

Additional elements could be added, such as how many kilometres you find yourself from an accident, compass, the region and total shelters to be displayed on the application (Tsai et al., 2012).

Another interesting way of displaying information through augmented reality is by scanning areas with mobile phones, tablets or QR - codes (Weichelt et al., 2018). An augmented reality map made by Weichelt et al. in 2018 shows that there is possible to use digital maps by using icons that represent items that are important in emergency events. In this case, this was a farmer map where the map included icons of fuel storage, access points, water sources and electrical shut offs. After the farmers or fire department drop their icons on the farm map, this information will be available for emergency responders by scanning the area with mobile phones, tablets or by scanning QR - codes. The figure below shows an early mockup for the farmer map with the augmented reality icons.

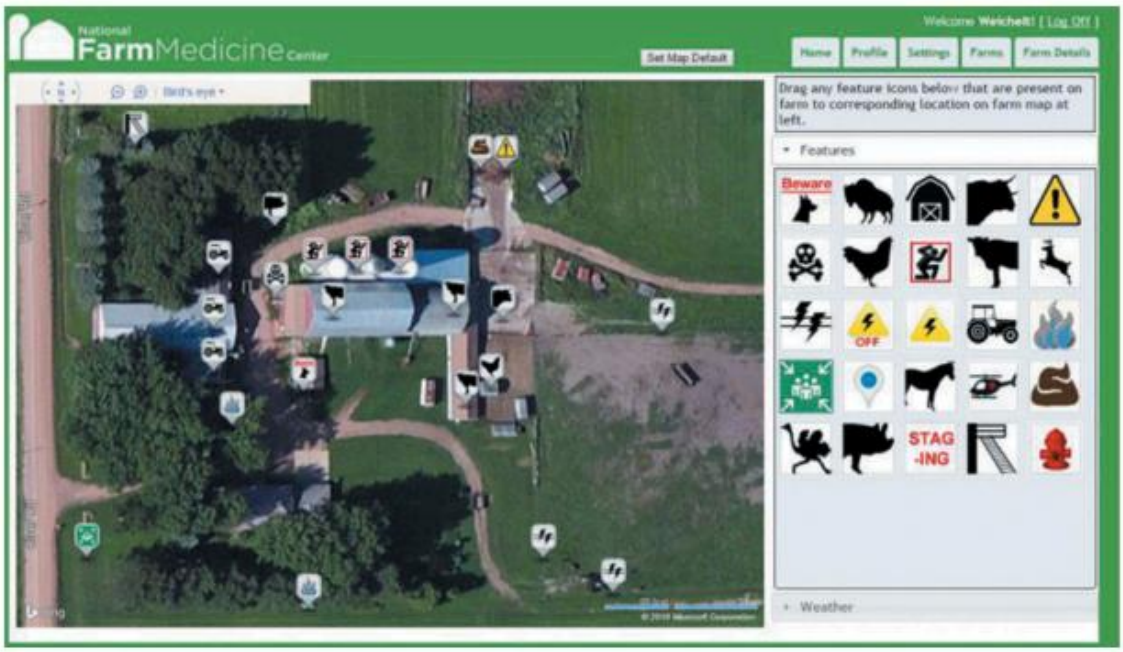


Figure 15: Bird view (Weichelt et al., 2018)

A very similar application is presented by Mirauda et al. (2018), where icons were used to show points of interest (POI). Such points could be hydrometric stations within flood-prone areas. The icons are displayed through billboards overlaid onto a scene captured by a device camera. The icons can be in different shapes and colours based on the POI, and are associated with a label that shows different data such as the distance between the mobile device and the POI.

5.2.5 Benefits and challenges of augmented reality in crisis management

Several benefits with implementing augmented reality - not only in emergency control rooms, but also regarding the interaction between people working in the emergency control room and the response teams in the field, have been identified.
Among the benefits, situational awareness, increased communication and collaboration, better decision making and better emergency response in crisis management are those who are listed most frequently. Augmented reality systems excel at offering users real time, situation aware information and their support users' decision making (Lutz, 2018), with pervasive and continuous streaming of raw information (Luchetti et al. 2017). Vessel et al. (2016) argues that wearable technology adequate situational awareness for effective disaster response. And by providing improved situational awareness, responders always have enough situation awareness to appropriately respond to the various events and incidents. Aldunate et al. (2012) propose that augmented reality can be used to enable communication in emergency response environments, and through numerous communication protocols, the people needing assistance also can communicate with emergency control rooms and personnel. By combining many of the technological advantages of geographical awareness and graphical overlays it was developed a system to give responders up to date view of situations to safely and efficiently conduct emergency response (Weichelt et al., 2018).
Generally speaking, functions regarding augmented reality with a high degree of benefits in both ongoing crisis responses and the aftermath of a crisis can also be summarized in mission tracking, monitoring and analysis: allowing the collection of continuous streams of data and events coming from the augmented field is important for keeping track of the real-time state of the response, and enabling a real time automated analysis of such streams in order recognize critical situations and record the mission, allowing for post-mission replay for analysis purposes (Brunetti et al., 2015).

Furthermore, we also want to discuss findings regarding challenges of using augmented reality in crisis management. It is important to emphasize that challenges are not presented and focused on equally as benefits, but they are nevertheless worth some space in the thesis. We can start with one challenge that is obvious: battery life. Both Mirauda et al. (2018) and Thomas, Quirchmayr & Piekarski (2009) state that some limitations and issues regarding battery life occurred when using augmented reality devices in their study. However, Mirauda et al. (2018) writes that those issues and limitations can be solved by using an external battery pack. Mirauda et al. (2018) also points that some limitations regarding privacy concerns and legal regulations are among the most common issues that could prevent the greater use of augmented reality. Having a tool that takes photos, videos or can collect large amounts of data and streaming them directly somewhere else is different from passing information from one hand to another. It must be ensured that only the relevant personnel can access sensitive or critical information. Tsai et al. (2012) also highlights that there could be some issues regarding implementation of augmented reality, but this is a known phenomenon from many digitization and technology implementation processes, and cannot be directly linked to the technology type.

Another challenge that can be listed are problems regarding weak signals (Tsai et al., 2012) which also can be in correlation with an issue regarding lack of low GPS accuracy (Weichelt et al., 2018).

6.0 Results from the interviews

This chapter presents results from our qualitative interviews. The predefined categories (Mayring, 2014) we are interested in in this section are based on *how operators carry out their work during crisis related calls, tools used in crisis management* and the *motivation to adopt augmented reality in emergency control rooms.*
The identified categories are deepened in the following sections: In section 6.1 we will present how many times predefined categories were mentioned by the interview subjects. Section 6.2 will examine how the operators are working in emergency control rooms: both routines, roles and responsibilities distributed among the employees will be highlighted. In section 6.3 we will present tools the operators use in emergency control rooms, while section 6.4 is reserved for challenges and barriers operators encounter in their work. In section 6.5 we will present results regarding operators' motivation to adopt augmented reality in emergency control rooms.

6.1 Categories coded from the interviews

Table 8: Coded categories

CATEGORY	TIMES MENTIONED
Routines	9
Tools	9
Challenges or barriers:	
Low quality maps	6
GPS coordinates/positioning	4
Motivation/ideas	
Pictures/videos	9
Devices	
Mobile applications	0
Tablets	1
Glasses	3
Screen	3

6.2 Routines in emergency control rooms

A part of our interview was based on mapping how the operators work, and which routines they rely on during crises.
Employees in emergency control rooms often work in small groups consisting of either two or three people. When they work in pair, they both have a role as operators, while groups of three people working together consist of one shift leader and two operators. The role of the shift leader is to have a general overview over all the incidents and make sure everything is done right by the operators, while the operators are the ones receiving the calls from the caller.
When a caller reports an incident, one operator is talking on the phone with the caller - conducting a so - called interview, to get as much information from the caller as possible, and also "*holding on the caller who is in a crisis and in an unpleasant situation as long as possible, preferably to the resources are on site".* The operators talking on the phone with the caller can also *"guide the caller to what they can do regarding the crisis, without them being in danger of themselves".* In short, the operators' main goal is to get a better picture of what it looks like at the crisis scene, so their main task is to collect relevant information from the caller, this is because *"the callers are the eyes of the operators on the crisis scene"*. Relevant information could be if there is someone at the crisis scene, if there is a fire, they may ask for the colour of the smoke and potential extent of damage. However, while one operator is talking on the phone with the caller, the other one is listening to the conversation, and communicating with the supporting departments and sending out resources to the crisis scene. The tasks are split up (one gathering information, the other sending resources) so both operators can be as effective as possible. When the resources have come to the crisis scene the job of the operators and shift leader is done and the responsibility is left to the resources.

"We get the message in the central and secure help as fast as possible and choose the correct resources. That's our job, when we have done our job it's entrusted to the fire department. When we have done our job, it's the ones out there who takes care of the rest".

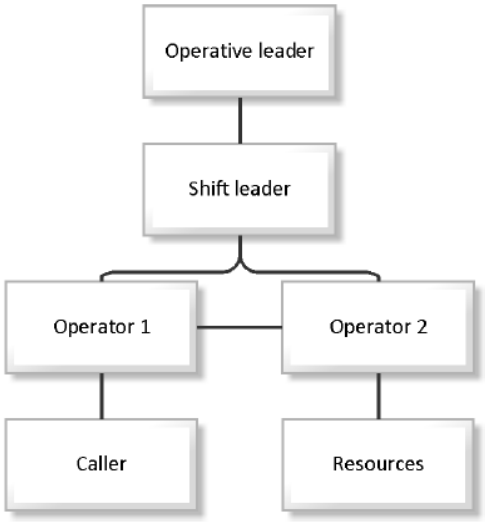


Figure 16: Operative leaders, shift leaders and operators' roles and responsibilities

6.3 Tools used by the employees in emergency control rooms

The operators and shift leaders use several tools during their work in emergency control rooms. The most obvious tools are their computer stations. There are five such stations, with five screens on each: a work screen, a screen for incoming alarms, a screen for maps, a screen (called X) showing the caller's name, phone number and address, and a screen for the system "Vision" where operators can report the incoming call and have a direct callout to the fire department.

Figure 17: Screen set up from the control centre

The operators also use tools such as thermal imaging cameras, interview guides and surveillance photos from the Norwegian "Vegvesen". However, the interesting tools are on the screens, photos and cameras, because it is precisely those who can be replaced by augmented reality technology.
All our respondents highlight that their work PC is frequently used during an incoming call, as they "*mostly use Vision and work PC"*. The operators have, what they call, reserve plans on their work PC where they also can use the web. Many point out that they often use maps on 1881.no or Google Maps rather than screen 5 to get a better overview of the topography, type of buildings involved in the crisis, and to see potential risk of fire spreading:

> "*Our system for maps is really bad, if you compare it to google and 1881.no. We miss pictures, google has fly photo, in our maps we only have yellow and green fields where yellow is a house. We don't see much around".*

On the second screen they have a system called Vision which they use for reporting incoming calls and incidents. Many of the routines are predefined in Vision. By reporting incoming incidents and details, they automatically get a quantity of allocated resources, or instruction to which instances they need to contact:

> "*Alarm from us to the crisis response is automated, its predefined what cars and resources which shall respond to different type of crisis and location".*

Most often it is the fire department, but sometimes, for example in situations where they need to send resources to traffic accidents, they need to contact the police, ambulance or vehicle rescue. They will also see if the resources have gotten the message and whom is responding. The third screen is displaying alarms. These are typically alarming from buildings or blocks which are connected to the emergency control room, and the operators are obligated to send

resources if an alarm is set of. And on the fourth screen, called X, the operators say that the callers' name, address and phone number is displayed. In short, we can say that the X is a phone: *"We use four screens, plus the phone, X"*. However, the most interesting screen is the one displaying the map. All operators and shift leaders highlight that this map have defects, because it displays low quality topography. The informants also say that many important features are phased out, and year by year the map gets lower in quality, in return it will stay the same speed even though its old:

> *"The map system we are using now is going to be phased out, so it gets worse and worse. The system is taken apart to make it as fast as it was before, it is getting old. Much could have been better there, we should have more detailed maps".*

The emergency control room is also equipped with screens displaying information from thermal cameras, which are stationed in some of the big cities the control centre has responsibility for. The cameras catch up heat signals, and an alarm will go of directly to the emergency control room. The operators can also manually use the cameras if a fire is nearby to get an overview over the situation. Operators can zoom in and out and change directions of these cameras with high quality camera lenses.

6.4 Challenges and barriers operators encounter during their work

Throughout the course of the interviews we identified several challenges, or barriers regarding how operators work in the emergency control rooms. More precisely, the informants often highlight that it is not the working method itself that poses challenges, but the quality of the tools the operators have available. Although results show that most operators are not only open, but highly motivated to both implement and use new technology in emergency control rooms (See section 6.5: Motivation to adopt augmented reality), the barriers lie on upper authority, such as law and guidelines from the Data Protection.

Challenges	Law and guidelines from the Data Protection
	No precise GPS localization
	Low quality maps

Figure 18: Challenges and barriers

Another challenge that was frequently mentioned by the operators, was regarding the amount of available information through their systems. We asked the informants if they lacked any information they need, but did not have, and they often gave similar answers regarding GPS

localization: it was highly sought for precise GPS localization of the caller, but unfortunately not available:

> *"I miss that we cannot get an exact localization from the callers, when I know the technology is capable of it. That we cannot get their location when they call from the telephone with a slack on a few meters, that's odd when you are an emergency service provider".*

Others felt the need for cameras on the crisis scene, preferably for those who arrive at the crisis scene first:

> *"We have talked about that we wish to have cameras on they who were first on the crisis scene, so we could see what's out there".*

However, the challenge which is clearly most frequently mentioned, is the bad tools for the map system they are expected to use:

> *"In Vision we use a terrible map, so it's clear we could have had better maps and pictures from the crisis areas".*

The need for a better way to gain a situational picture, rather than talking to the caller over the phone was also sought for:

> *"I hope that we could get it live from real time photos instead of someone explaining it to you, so we can take a better decision or redistribute how it looks like to those who shall go to the crisis scene".*

Some respondents were very specific when it came to what they would like to see, like *"type of house, roadmap and materials".* When asked why this would be helpful, one responded:

> *"You can see the house, get an overview. Wow, it's a big treehouse, or its a block, what is it? You could see it right away in the map, share this information with those responding, look, this is how it looks like".*

6.5 Motivation to adopt augmented reality

Our wish for the interviews were not only to map how the operators work in emergency control rooms, but also to find out how they relate to technological changes in their environment. Our respondents gave the impression that they were open for new technology. Those who said they were open for it, also had the impression that their colleagues were as open as themselves:

"*Here I think we are really good at it. We are really positive with much of the tools we can get. The technology with GPS positioning is something new, and something we are positive for works. It's a place where it's a lot of technology, and we have to be open to receive".*

However, some were more sceptical to how the elders would react to changes:

"I think the young ones would be more positive to it than the elders which is used to that things should be done in a certain way. They would maybe not be so positive to the evolvement, while the young would appreciate more widgets".

It is not uncommon to see divisions in openness for technological changes, as we know that younger generations have grown up with the never-ending technological development while elder generations are more thrown into the phenomenon. However, many lacked the imagination of how they could view augmented reality in emergency control rooms, even after getting explained how augmented reality could be displayed.

When asked if they would prefer glasses, tablets or phones, they had a high variety of answers, but were clearly curious and positive when it came down to the new technology in the emergency control room. One respondent said: *"I would've liked looking at the screen, using a tablet or something".* Another respondent was thinking of something all the employees could use together for collaboration: *"Would maybe have a screen wall, where you could sort things you wanted for everyone to see. Because we are all trying to work cross functionally"*. However, another respondent was positive to the use of glasses, with a compromise:

"Glasses very okay, if you could communicate with those around you". While others had a hard time answering the question: *"Hard to answer, glasses maybe? Getting it up on the screen would be the easiest"*.

Motivation	Communication and collaboration
	Better GPS localization
	High quality maps with topography
	Better overview over situation
	Pictures from the scene, live stream
	Videos

Figure 19: Motivation to adopt augmented reality in control rooms

The informants had several ideas about how augmented reality could be utilized in emergency control rooms, and what it could be used for. Something that was mentioned several times was that pictures from the scene, or live streams would be helpful for decision making:

> "*Live stream from the scene or GPS location or pictures of the houses would be useful, to look how the fire burns, how it looks like in the area and if it's danger of spreading", and "It's a really big difference between one house and a eightmanshouse".*

Another respondent added another dimension to the idea, and thought that live stream from the firefighters would be a good addition: *"I think it would be useful if we could get live pictures from the ones calling, but also they out in the field"*. Another also highlighted the overview over the crisis as an important factor even though it was not live:

> *"Get an overview over the place, we don't really know what's happening though. But how the area is around the crisis, is it a forest right by, a barn or how far from the fire is the garage. You could gain a much better situational picture. Because the picture we create is from the eyes of the ones calling us, and that could be far from the truth".*

The respondents also had ideas of how they could get these features into reality. A respondent proposed that the callers could film the incident while on the phone: *"If it's possible start filming while you speak in the telephone, so you could see what's happening is a benefit for us"*, the use of satellites: *"If you have in real time pictures like in Bergen, with satellites or whatever they are using",* and drones: *"It would've been something with drone pictures",* was proposed. One respondent expanded the idea of pictures and live stream by proposing to get pictures or live streams of an incident without a person taking it: *"Look at the incident before anyone could film it"*.

Even though most responders were open for augmented reality, and many had their own idea about how it could be utilized in emergency control rooms, they also had ideas of which kind of functions that would not be helpful. Images would be helpful, but sound would be disturbive.
The reason why it would be disturbive is because the operators place great emphasis on conversation with the caller, and "samband": *"I believe that sound would be disturbing because we have so much communication through "samband"".*

7.0 Discussion

This chapter is divided in three separate sections. In section 7.1 we will present a summary of results found in the systematic literature review and in the interviews. In section 7.2 the theoretical contribution will be discussed, whereas practical implications will be discussed in section 7.3.

7.1 Summary of Results

Our most important finding from the systematic literature review is that there is a significant research gap on prior research on augmented reality in emergency control rooms (See chapter 3: Research Design, section 3.5 Methodological Limitations). However, the results also show that the field of research of augmented reality in crisis situations is up and coming with operators and response teams communicating and collaborating through AR – technology. Furthermore, the literature review arguments between the use of mobile devices and wearable technology whereas mobile devices are quite agile, and often used as a good source for information for those involved in crisis, while wearable technology provides the possibility to have free hands, something that is not possible with handheld devices (Chapter 5: Analysis Results from the Systematic Literature Review, Section: 5.2.2: Devices that are preferred used for Augmented Reality in crisis management). Further, results of object displayal in augmented reality focuses on providing situational and geographical awareness, and finding the distance between objects, as well as GPS coordinates (Chapter 5: Analysis Results from the Systematic Literature Review, Section: 5.2.4: Objects that are typically displayed through the augmented reality devices). The possibility to gain a better situational and geographical awareness with augmented reality in crisis situations is a great benefit, as well as benefits like communication, collaboration, better decision making and responses (See chapter 5: Analysis Results from the Systematic Literature Review, section 5.2.5 Benefits and challenges of augmented reality in crisis management). However, the barriers or challenges that are mentioned are battery life - both for the mobile devices, and wearable technology, privacy concerns and bad signals as well as inaccurate GPS coordinates (See chapter 5: Analysis Results from the Systematic Literature Review, section 5.2.5 Benefits and challenges of augmented reality in crisis management).

Findings from the interviews highlight that the operators working in emergency control rooms have a hard time utilize their map system on screen five. The map system is defective, and is also phased out to maintain the same speed as before. However, operators solve this issue by using Google Maps or 1881.no, sites that obviously have better map with topography (See chapter 6: Results from the interviews, section 6.3: Tools used by the employees in emergency control rooms)
A significant result found is that the operators are not involved in the crisis management after the resources are allocated and the response team have arrived at the crisis scene.
A high motivation to use augmented reality in emergency control rooms was found, primarily to make the work done in emergency control rooms more efficiently: the operators saw the need for live streaming from the crisis scene, pictures from the scene (the pictures do not need

to be live), and exact GPS positioning of callers (See chapter 6.0: Results from the interviews, section 6.5: Motivation to adopt augmented reality). However, some challenges were also found: as mentioned earlier, laws and the Data Protection have strict rules in connection with the use of personal information, therefore there will also be challenges with privacy concerns.

7.2 Theoretical Contribution

We have advanced research on augmented reality in crisis management. First and foremost, by identifying a research gap through our systematic literature review: there is little prior research on augmented reality in control rooms. Hence, this gap was addressed through interviews with operators in emergency control rooms. Through the process of doing a literature review and conducting several interviews we have identified similarities and contradictions on augmented reality in emergency control rooms.

The respondents highlighted the use of mobile phones as an important source of information that could help them gain better situational awareness than they had from vocal information gathering, by providing pictures and videos from the crisis scene. This is supported in the literature where Aldunate, Schmidt and Herrera (2012) says humans affected by events can also act as sensors to augment reality and provide additional information to the responders. Luchetti et al. (2017) highlights the use of mobile applications as a real time pipeline and provides information (photos, images, animations and videos) about what's happening in the surrounded areas, which in fact was a major advantage for decision making. The benefits are highlighted by Dave et al. (2013) who says that the use of mobile phones increase both the situational understanding and the situational awareness in crisis environments.
Regarding what technology to use to display augmented reality, some had desire of using Head-up-display, but had a concern regarding communication and cooperation with the use of it. According to Nilsson et al. (2011) lack of eye contact with the use of head-mounted-display did not affect the cooperation, but would rather by tiring because of its "front footed weight". The informants also highlight the need for communication and in need of being effective, thus why they work in pairs. Literature support use of heads-up-display to increase communication and efficiency where Vessel et al. (2016) argues for that heads-up-display allows for hands-free communication and force multiplications, enabling individuals to perform tasks that before needed to be performed by multiple people.
The desired features to be displayed in the emergency control room with videos, pictures and GPS is supported by most of the literature. This includes geographical awareness, distance and GPS coordinates.
An interesting thing to notice is how the functioning map system is being teared apart to maintain the desired speed of the system. This tells us that the possible features is less important than speed, something that has to be thought of during the design process of a possible new system or an addition with augmented reality.
According to results from our systematic literature review and the interviews, there is a division in which application areas augmented reality can be used in. The systematic literature review argues for application areas such as collaboration, communication and responsive actions, while the operators argue that augmented reality would be useful to obtain and

visualize information. The argumentation for using it for collaboration between operators in emergency control rooms and response at the crisis scene has a clear and dominate role in the systematic literature review, but very few arguments for that augmented reality can be used solely by operators in emergency control rooms. The contradiction is the division between theory (systematic literature review) and practice (interviews). The operators have shared opinions on the question if augmented reality can be used to promote communication and collaboration between operators and field workers. On one hand, some operators argue that this promotion would be great, while others argue that the operators' role in the crisis management situation is over when the response team has arrived at the crisis scene. Brunetti et al. (2015) argues that operators would have the possibility to follow a mission from emergency control rooms, and collaborative applications could support teams engaged in missions. Such AR - deployment can bring improvement of the response team and, hence, efficiency of the overall question. If we take into account the operators view of what their role in emergency control rooms is, some questions regarding the collaboration and communication arises: will operative and shift leaders have to release resources from the phone so operators can use the augmented reality technology for collaboration with response teams in the field during a crisis, and will this affect the operators availability and quality of services for other callers? The operators' argumentation for using augmented reality for obtaining and visualizing information from the caller supports that there is a significant research gap regarding augmented reality in emergency control rooms.
Mirauda et al. (2018) highlights that some limitations regarding privacy concerns and legal regulations are among the most common issues that could prevent the greater use of augmented reality. The operators support those limitations by describing how laws and regulations from The Data Protection prevents technological tools that - to some extent, could be a solution to significant challenges that arise in the emergency control room, such as inaccurate positioning of the caller.

7.3 Practical Implication

Our results are helpful for practitioners such as emergency control room people or system developers because we have shed light on a research topic that concerns them. We have identified missing and possible improvements of the technological tools in emergency control rooms, and facilitated for further research of augmented reality in emergency control rooms by covering a research gap found in our systematic literature review. By doing the literature review in combination with expert interviews we are able to derive some key design guidelines that would give operators the possibility to utilize augmented reality in emergency control rooms.

Design Guideline 1: An AR application for emergency control rooms should include maps with detailed topography.
The idea to expand the already existing map with augmented reality to visualize extended features is highly motivated by the operators' strong expression of their dissatisfaction with

the map they are using on their fifth screen. By having more and detailed information about the crisis scene and its surroundings the operators can use extended augmented reality features to make better decisions.

Design Guideline 2: An AR application for emergency control rooms should include pictures of the crisis scene.
The picture of the crisis scene is something the operators in the control rooms meant could help them to gain better situational awareness, to be able to identify possible objects such as forests or garages that the fire could spread to.

Design Guideline 3: An AR application for emergency control rooms should include filtering of information.
With extended features there is also a possibility for information overload, meaning that the operator simply cannot process all the information he or she has at hand. We suggest that an AR application should include tabs or buttons so the operators can filter the information they would like to be visible on each picture or map.

Design Guideline 4: An AR application for emergency control rooms should include accurate GPS positioning.
An accurate GPS location from the crisis scene is something the operators sought after, which could reduce time wasted by localizing the crisis scene. The challenge will be to get permission from the data protection law or find a way of bypassing it.

Example:

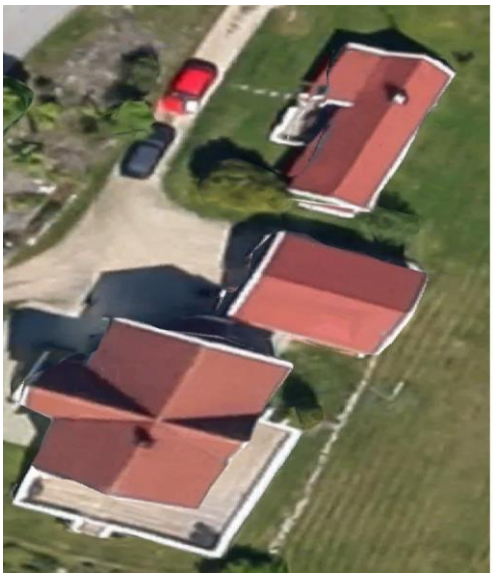


Figure 20: Bird view without augmented reality application

A first tab could be wind measurements, to gain knowledge about the possible direction of the fire spreading.

Figure 21: Bird view with augmented reality application

These two pictures would give operators knowledge about possible spreading of fire. They would see the exact location of the incident, a garage close to the main house and another house right beside the garage. Let's say the main house is on fire, that and that they see the wind is in direction of the garage and the other house. They would immediately know about the possible danger of the fire spreading and could inform the fire department about this insight. For example, one could add a second tab or button that could display videos, and supply with a third that could be a roadmap. Ideally, one would want to gain as much information as possible without adding additional screens for the operators to handle. Without augmented reality this is obviously the case. However, with an implementation of augmented reality one can eliminate the need for many separate screens, because one can change/swipe screens as one pleases. Augmented reality can also supply the operators with important information directly from the crisis screen, such as wind measurements and direction, providing an increased situational awareness.

8.0 Conclusion and Implications

This thesis presents an exploratory qualitative study conducted to investigate how augmented reality can used to support work done by operators in emergency control rooms. In our systematic literature review we found a research gap that shows how augmented reality in emergency control rooms is still in early stages of research. However, we conducted expert interviews to close the gap.

The results found in our study highlights that the operators are highly motivated to take advantage of however tool that helps them gain more information about a crisis; the more information the merrier. The expert interviews also highlight the need for better technology and tools that provide increased situational awareness in stressful situations. By using pictures, drones or live-streams as important sources of information, the operator can in fact see the crisis scene, rather than using own imagination for a perception of reality based on the callers' information. The pictures or live-streams can be provided from the caller by his or her mobile device, or can come from the response team that is out in the field. By using the callers' mobile device as a source of information, one can also position the caller at the right place.

Other features provided by augmented reality that are proven to be helpful are features that illustrate roadmaps or topographical data. The tools the operators take into use need to be fast and easy to use, in contrast to those they have today. However, we cannot constantate that augmented reality is a technology that will provide better efficiency or easen their working tasks in the emergency control rooms. To prove this, one needs another type of approach like testing and prototyping, which we did not have. The same goes for mobile devices versus wearable technology.

Issues regarding the general data protection have been examined, and in order to position the caller on the maps with augmented reality one needs to find out how to bypass the laws and restrictions both from the Data Protections and Norwegian laws. However, one can also raise questions about how the operators work related task and routines could be affected by the implementation of augmented reality: will they need to expand their responsibilities, or will they need to allocate more resources than they already have? And is it even helpful for both the response team and the operators that they can collaborate and communicate through augmented reality technology in crisis situations? We propose that these questions are left for future researchers to examine.

9.0 References

A, S. (1987). *Qualitative analysis for social scientists.* Cambridge: University Press.

Aldunate, R., Schmidt, K., & Herrera, O. (2012). Enabling Communication in Emergency Response Environments. *Sensors 2012*, ss. 6380-6394. doi:10.3390/s120506380

Azuma, R. T. (1997, August). A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments 6, 4*, ss. 355-385.

Bacon, L., MacKinnon, L., & Kananda, D. (2017, February). Supporting Real-Time Decision-Making under Stress in an Online Training Environment. *IEEE REVISTA IBEROAMERICANA DE TECNOLOGIAS DEL APRENDIZAJE, VOL. 12, NO. 1*, ss. 52-61.

Brunetti, P., Croatti, A., Ricci, A., & Viroli, M. (2015). Smart Augmented Fields for Emergency Operations. *Procedia Computer Science 63*, ss. 392–399. doi:10.1016/j.procs.2015.08.358

Carenzo, L., Barra, F., Ingrassia, L., Colombo, D., Costa, A., & Corte, F. (2015). Disaster medicine through Google Glass. *European Journal of Emergency Medicine 22*, ss. 222-225. doi:10.1097/MEJ.0000000000000229

Chan, E., Anslow, C., Seyed, T., & Maurer, F. (2016). Chapter 15: Envisioning the Emergency Operations Centre of the Future. I *Collaboration Meets Interactive Spaces (CMIS)* (ss. 349 - 353). Calgary, AB, Canada: Springer International Publishing Switzerland. doi:10.1007/978-3-319-45853-3_15

Characteristics of a crisis. (2017, July 18). Hentet May 2019 fra Queensland Government: https://www.business.qld.gov.au/running-business/protecting-business/risk-management/incident-response/crisis

Clawson, J. J. (1989, October - December). Emergency Medical Dispatching. *Prehospital and Disaster Medicine*.

Creswell, W. J. (2014). *Qualitative, Quantitative, and Mixed Method Approaches.* London: Sage Publications.

Dave, R., Boddhu, S., McCartney, M., & West, J. (2013). Augmenting Situational Awareness for First responders using Social media as a sensor. *12th IFAC Symposium on Analysis, Design, and Evaluation of Human-Machine Systems*, ss. 133-140.

Department of Homeland Security. (u.d.). *Incident Management*. Hentet 2019 fra Ready: https://www.ready.gov/business/implementation/incident

Direktoratet for samfunnssikkerhet og beredskap. (2019). *Analyser av krisescenarioer 2019*. Hentet fra Hva er de mest alvorlige hendelsene som kan ramme Norge?: https://www.dsb.no/reportasjearkiv/hva-er-de-mest-alvorlige-hendelsene-som-kan-ramme-norge/

Fink, A. (2005). Conducting Research Literature Reviews: From the Internet to Paper (2nd ed.). Thousand Oaks, California: Sage Publications.

International Federation of Red Cross and Crescent Societies. (2003). *Word Disasters Reports: Focus on ethics and aid.*

Jacobsen, D. I. (2005). *Hvordan gjennomføre undersøkelser? Innføring i samfunnsvitenskapelig metode, 2. utgave.* Høyskoleforlaget.

Johannessen, A., Tufte, P. A., & Kristoffersen, L. (u.d.). *Introduksjon til samfunnsvitenskapelig metode.* 2010: Abstrakt forlag.

Kaplan, B., & Maxwell, J. A. (2005). Chapter 2: Qualitative Research Methods for Evaluation Computer Information Systems. I *Evaluating the Organizational Impact of Healthcare Information Systems* (ss. 30-55). Reseach Gate. doi:0.1007/0-387-30329-4_2

Kitchenham, B., & Charters. (2007). Guidelines for performing Systematic Literature Reviews in Software Engineering. Durham: Keele University and Durham University Joint Report.

Kitchenham, B., Brereton, P. O., Budgen, D., Turner, M., Bailey, J., & Linkman, S. (2008, November 12). Systematic literature reviews in software engineering – A systematic literature review. Durham, United Kingdom.

Klopper, R., Lubbe, S., & Rugbeer, H. (2007). The Matrix Method of Literature Review. *Alternation 14,1*, ss. 262 - 276.

Kvale, S. (2011). Transcribing Interviews. I *Doing Interviews* (ss. 93-100). Sage Publications. doi:https://dx.doi.org/10.4135/9781849208963

Lee, I. (2009, September 4). Towards Wireless Augmented Reality A Review of its Enabling Technologies. doi:10.1109/ISUVR.2009.19

Luchetti, G., Mancini, A., Sturari, M., Frontoni, E., & Zingaretti, P. (2017). Whistland: An Augmented Reality Crowd-Mapping System for Civil Protection and Emergency Management. *ISPRS Int. J. Geo-Inf.*, ss. 1-18. doi:10.3390/ijgi6020041

Lutz, R. (2018). Safe-AR: Reducing Risk While Augmenting Reality. *2018 IEEE 29th International Symposium on Software Reliability Engineering*, ss. 70-75. doi:10.1109/ISSRE.2018.00018

Major Incident Procedure Manual. (2007). I *LESPL Manual: Seventh edition* (ss. 21-25). London: The Stationery Office.

Merritam-Webster. (1992). *Augmented Reality*. Hentet May 27, 2019 fra Merritam-Webster: https://www.merriam-webster.com/dictionary/augmented%20reality

Milgram, P., & Kishino, F. (1994, December 12). A Taxonomy of Mixed Reality Visual Displays. *IEICE TRANS. INF. & SYST., VOL. E77-D, NO. 12*.

Mirauda, D., Erra, U., Agatiello, R., & Cerverizzo, M. (2018). Mobile Augmented Reality for Flood Events Management. *Int. J. Sus. Dev. Plann. Vol. 13, No. 3* , ss. 418-424. doi:10.2495/SDP-V13-N3-418-424

Myers, M. D. (2018). *Qualitative Research in Business & Management.* London: Sage Publications.

Nilsson, S., Johansson, B., & Jönnson, A. (2009). Using AR to support cross-organisational collaboration in dynamic tasks. *Science and Technology Proceedings.* Orlando, Florida, USA: IEEE International Symposium on Mixed and Augmented Reality 2009.

Nilsson, S., Johansson, B., & Jönsson, A. (2011). Cross-Organizational Collaboration Supported by Augmented Reality. *IEEE TRANSACTIONS ON VISUALIZATION AND COMPUTER GRAPHICS, VOL. 17, NO. 10.*, ss. 1380-1392.

Nivedha, S., & S, H. (2015, August 24). Enhancing user experience through physical interaction in handheld Augmented Reality. *IEEE: 2015 International Conference on Computer Communication and Informatics (ICCCI).* doi:10.1109/ICCCI.2015.7218127

Okoli, C., & Shabram, K. (2010). A Guide to Conducting a Systematic Literature Review of. Sprouts: Working Papers on Information Systems.

Park, H., Jung, E.-S., Lee, H., & Lee, Y.-T. (2017). Context-Aware Platform for Disaster Training and Response. *Electronics and Telecommunications Research Institute*.

Park, H., Kim, J., Jung, E.-S., Lee, H., & Lee, Y.-T. (2016). Disaster Training and Response based on Digital Signage and Augmented Reality Technologies. Electronics and Telecommunications Research Institute.

Philipp, M. (2014). Chapter 6: Specific Techniques of Qualitative Content Analysis. I *Qualitative content analysis: theoretical foundation, basic procedures and software solution* (ss. 79-87). Klagenfurt, Austria: Ssoar.

Ramchurn, S., Wu, F., Jiang, W., Fischer, E. J., Reece, S., Roberts, S., . . . Jennings, R. N. (2016). Human-agent collaboration for disaster response. Springer Science+Business Media. doi:DOI 10.1007/s10458-015-9286-4

Salleh, N., Mendes, E., & Grundy, J. (2011). Empirical Studies of Pair Programming for CS/SE teaching in higher education: A systematic literature review. *IEEE Transactions on Software Engineering, 37(4)*, ss. 509-525.

Samoes-Marques, M., Correia, A., Teodoro, F. M., & Nunes, I. L. (2017). Empirical Studies in User Experience of an Emergency Management System. *International Conference on Applied Human Factors and Ergonomics*, (ss. 97-108).

Shaluf, I. M. (2007). Disaster Types. Emerald Group Publishing Limited. doi:DOI 10.1108/09653560710837019

Shirer, M., & Torchia, M. (2018, May 2018). *Worldwide Spending on Augmented and Virtual Reality Forecast to Reach $17.8 Billion in 2018, According to IDC*. Hentet January 2019 fra ICD: https://www.idc.com/getdoc.jsp?containerId=prUS43248817

Thomas, B., Quirchmayr, G., & Piekarski, W. (2009). Through-Walls Communication for Medical Emergency Services. *International Journal of Human-Computer Interaction*, ss. 477-496. doi:10.1207/S15327590IJHC1603_6

Tsai, M.-K., & Yau, N.-J. (2013). Using Augmented Reality and Mobile-Three Dimensional Graphics Techniques in Relief Work on Radiological Disaster Sites. *Nuclear Technology & Radiation Protection: Year 2013, Vol. 28, No. 3,*, ss. 332-340. doi:10.2298/NTRP1303332T

Tønnessen, S. (2018, February 20). *Empiri*. Hentet fra Store norske leksikon: https://snl.no/empiri

Vessel, M., Apperson, O., Calyam, P., Gillis, J., & Ahmad, S. (2016). Intelligent Dashboard for Augmented Reality based Incident Command Response Coordination. Missouri, Colombia: 13th IEEE Annual Consumer Communications & Networking Conference.

Webster, J., & Watson, T. R. (2002, June). Analyzing the past to prepare for the future: writing a literature review. *MIS Quarterly Vol. 26 No. 2*.

Weichelt, B., Yoder, A., Bendixsen, C., Pilz, M., Minor, G., & Keifer, M. (2018). Augmented Reality Farm MAPPER Development: Lessons Learned from App Designed to Improve Rural Emergency Response. *JOURNAL OF AGROMEDICINE 2018, VOL. 23, NR. 3*, ss. 284-296.

Yazdanifard, Rashad, & Siang, K. M. (2013, September). The Review of Crisis Management Facing Natural Disaster. Hentet 2019

10.0 Appendix

Appendix 1: Articles included in the literature review

	Num	Title	Author	Year	Country
	1	Context Aware Platform for Disaster Training and Response	Park H., Jung E., Lee H., Lee Y.	2017	South Korea
	2	Disaster Training and Response based on Digital Signage and Augmented Reality Technologies	Park H., Jung E., Lee H., Lee Y.	2016	South Korea
IEEE	3	Intelligent Dashboard for Augmented Reality Based Incident Command Response Co - ordination	Vessel M., Apperson O., Calyam P., Gillis J., Ahmad S.	2016	USA
Explore	4	Safe - AR: Reducing Risk While Augmenting Reality	Lutz R. R.	2018	USA
	5	Using AR to support cross - organizational collaboration in dynamic tasks	Nilsson S., Johannson B., Jönsson, A X	2009	Sweden
	6	Augmenting Situational Awareness for First responders using Social media as a sensor	Dave R., Boddhu S., McCartney M., West J.	2013	USA
Science	7	Effects of 360° video on attitudes toward disaster communication	Julia Daisy Fraustinoa., Ji Young Leeb., Sang Yeal Leea., Hongmin Ahnc	2017	USA
Direct	8	Integrating geographical information and augmented reality techniques for mobile escape guidelines on nuclear accident sites	Ming-Kuan Tsai a et al.	2012	Taiwan
	9	Smart Augmented Fields for Emergency Operations	Brunetti P., Croatti A., Ricci A., Viroli M.	2015	Italy
	10	Augmented Reality Farm MAPPER Development	Weichelt B., Yoder A., Bendixsen C., Pil M., Minor G., Keifer M	2018	USA
	11	Cross-Organizational Collaboration Supported by Augmented Reality	Nilsson S., Johansson B., Jönsson A	2011	Sweden
	12	Disaster medicine through Google Glass	Carenzo L., Barra F., Ingrassia P., Colombo D., Costa A., Corte F.	2015	Italy
	13		Ramchurn et al.	2015	UK
	14	MOBILE AUGMENTED REALITY FOR FLOOD EVENTS MANAGEMENT	MIRAUDA D., ERRA U., AGATIELLO R ., CERVERIZZO M.	2018	Italy
Scopus	15	Supporting Real-Time Decision-Making Under Stress in an Online Training Environment	Bacon L., MacKinnon L., Kananda D.	2017	UK
	16	Trough-Walls Communication for Medical Emergency Services	Thomas B., Quirchmayr G., Piekarski W.	2009	Australia
	17	Using Augmented Reality And Mobile Three Dimensional Graphic Techniques in Relief Work on Radiological Disaster Sites	Tsai M., Yau N.	2013	Taiwan
	18	Whistland: An augmented Reality Crowd-mapping System for Civil Protection and Emergency Management	Luchetti G., Mancini A., Sturari M., Frontoni E., Zingaretti P.	2017	Italy
	19	Enabling Communcation in Emergency Response Environments	Aldunate R., Schmidt K. N., Herrera O.	2012	USA
Science	20	Improving information access for emergency response in disasters	Tsai M., Yau N.	2012	UK

Appendix 2: Interview guide

AUREAS Interview Guide

Introduction of the interviewer

Interviewer introduces him/herself and explains the background of the study (master thesis, University of Agder, broad topic of the thesis)

- Interviewer informs the respondents about the interview and his/her rights as a respondent length of the interview
- structure of the interview
- there are no right or wrong answers → open, qualitative, exploratory approach
- participation is voluntary
- interview can be stopped at any time without having to give reasons
- interview will be recorded (will be deleted once it has been analysed)
- respondent has the right to request a deletion of the data at any time
- anonymous data analysis

Recording starts (only approved devices)

Interviewer asks the respondent whether he/she was informed about the rights as a respondent and wants to participate in the interview
Interviewer asks the respondent whether he/she agrees with being recorded

→ If the respondent answers "No" the interview will end, otherwise the questioning can begin ☺

Main interview questions

Part 1) Getting to know the respondent

Please tell me a little bit about yourself.
→ What is your job title?
→ How long have you been working in this position?
→ For which types of emergencies are you responsible?
→ Are there any other related experienced you want to mention?

Part 2) Understanding how crisis response in an emergency control center works

Explain that the focus of the interview will be on general crisis response. Give an example for such an event in the past (September, 2018 in Kristiansand). Ask whether the respondent has already responded to a crisis event in the past. If yes, let the respondent describe this experience. If no, the respondent should imagine such an event and describe how he/she

would deal with it. It could also be an event in the local environment. → let the respondent remember

If you think back to the heavy rainfall event last year, please describe how your wordays looked like during this event. // Imagine a heavy rainfall event: How would your workday look like?
→ How are the responsibilities, roles or tasks partitioned?
→ Which tasks would you have to perform?
→ With whom would you have to communicate?
→ Which decisions would you have to make?

An important part of your work seems to be collecting relevant information during a crisis event. Please describe how you would proceed to get information about the ongoing situation.
→ How would you get information about the ongoing situation?
→ From whom would you get information?
→ Which tools would you use to get information?
→ How exactly would you use these tools to get information?
→ What kind of information is important for you during a heavy rainfall event?

Do you use screen as an tool to get information during a crisis event? Could you describe in detail how the screens would help you to respond to a heavy rainfall event? If not, please imagine.
→ Do all employees look at the same screens?
→ How many screens would you use?
→ What kind of information would be displayed on each screen?
→ How would this information differ during other types of crisis situations?

Now, I understand much better what kind of information you can use during a crisis event. I'm also interested in how exactly you process the available information. Please describe in detail how you would use the information on the screens to make decisions during a heavy rainfall event.

→ How would the information displayed on the screens influence your decisions?
→ How would you filter out false or irrelevant information?
→ How would you proceed to figure out what the most important information is?
→ Is there any kind of information that you would not really need?
→ What kind of additional information would help you to improve your decision-making?
→ What problems are there with information processing / visualization?

Part 3) Suggestions for an AR integration of useful information from Twitter
Start the interview with an explanation of what AR is so the interview subject can understand the concept, give some examples.

"Utvidet virkelighet (engelsk: augmented reality) er en teknologi som kombinerer data fra den fysiske verden med virtuell data, for eksempel ved bruk av grafikk og lyd. Man får et ekstra lag med informasjon. Den ekstra informasjonen vil typisk ikke erstatte virkeligheten, men utvide den på en eller flere måter. Pokemon Go er et eksempel på utvidet virkelighet, og det er også filtrene du bruker på Snapchat. "

We would like to know more about how augmented reality can be used in crisis control centres. Furthermore, we want it investigate if there are certain ideas that could be considered as helpful in a crisis control centre. This section is all about how devices and functions could be utilized in a crisis control centre.
→ Would implementation of new technology in the crisis control centre be considered as a constraint or a resource?
→ AR can be used in many ways. Would you prefer glasses, tablets or phones as an extra tool in crisis management?
→ Would there be some challenges associated with the implementation of new wireless devices in the crisis control centre?

Imagine a real life crisis situation where you either use glasses, a tablet or a phone as an AR - tool in the crisis control centre.
→ Can you describe how augmented reality can affect/change communication between teams?
→ Text pattern matching is a method that often is used to sort information. How important would you consider textual information in crisis management?
→ What kind of information can you get from videos of a crisis event?
→ Would such information be helpful through a crisis event?
→ Visual effects can indicate a status (red, yellow, green) through a crisis, for example if there are people lying on the ground. How helpful would you consider these visual effects?
→ Would those effects influence your decision through a crisis?