**Cartography M.Sc.**

# Master thesis

## Supporting enhanced disaster management with interactive 3D and Mixed Reality Maps

Kevin Patrick Helzel

Technical University of Munich — TUM

TU WIEN — TECHNISCHE UNIVERSITÄT WIEN — Vienna University of Technology

TECHNISCHE UNIVERSITÄT DRESDEN

ITC — UNIVERSITY OF TWENTE.

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# Supporting enhanced disaster management with interactive 3D and Mixed Reality Maps

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Author:              Kevin Patrick, Helzel
Study course:        Cartography M.Sc.
Supervisor:          Dr.-Ing. Mathias Jahnke
Reviewer:            Dr.rer.nat. Nikolas Prechtel
Cooperation:         GAF AG, Alexander Klaus (2nd supervisor)

Chair of the Thesis
Assessment Board: Prof. Dr. Liqiu Meng
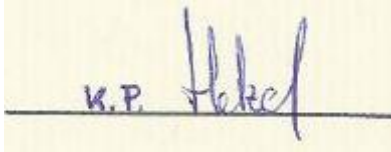
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# Statement of Authorship

Herewith I declare that I am the sole author of the submitted master's thesis entitled:

*"Supporting enhanced disaster management with interactive 3D and Mixed Reality Maps"*

I have fully referenced the ideas and work of others, whether published or unpublished. Literal or analogous citations are clearly marked as such.

Munich, 10.09.2019                                                      Kevin Patrick, Helzel

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# Abstract

This research is about the evaluation of benefits and usability of cartographic 3D and Mixed Reality approaches for the field of disaster management. It involves developing an own visualization approach for the use in disaster response planning based on a mixed methods approach combining quantitative and qualitative methods.

KEYWORDS: Mixed Reality, 3D, Disaster Management, Use Case Modelling, Tabletop, Mixed Methods

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## Abbreviations

**3D** – Three-dimensional

**AOI** – Area of Interest

**AR** – Augmented Reality

**BBK** – Bundesamt für Bevölkerungsschutz und Katastrophenhilfe

**Copernicus EMS** – Copernicus Emergency Management Service

**COTS** – currently-off-the-shelve

**CRED** – Centre for Research on the Epidemiology of Disasters

**ERCC** – European Response Coordination Centre

**EU** – European Union

**GIS** – Geographic Information System

**GMLZ** – Gemeinsames Melde- und Lagezentrum von Bund und Ländern

**IDE** - Integrated Development Environment

**IRDR** – Integrated Research on Disaster Risk

**MR** – Mixed Reality

**NIFC** – National Interagency Fire Center

**PDF** – Portable Document Format

**SAYSO** – Standardisation of Situational Awareness Systems to strengthen operations in civil protection

**UAV** – Unmanned Aerial Vehicle

# 1. Introduction

## 1.1 Motivation and problem statement

In the seemingly safe environments of the 21th century's modern industrialised nations, most people's sporadic experience with disasters happens through media news outlets and fundraising campaigns for affected people and destroyed areas.

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*"A DISASTER IS A SUDDEN, CALAMITOUS EVENT THAT SERIOUSLY DISRUPTS THE FUNCTIONING OF A COMMUNITY OR SOCIETY AND CAUSES HUMAN, MATERIAL, AND ECONOMIC OR ENVIRONMENTAL LOSSES THAT EXCEED THE COMMUNITY'S OR SOCIETY'S ABILITY TO COPE USING ITS OWN RESOURCES. THOUGH OFTEN CAUSED BY NATURE, DISASTERS CAN HAVE HUMAN ORIGINS."*

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[IFRC, 2019]

As a disaster itself is not a measurable physical variable but rather a man-made expression, the term "disaster" could be seen more like a subjective definition of an event that poses an existential threat to an individual or a certain group of individuals (Siriwardena, Haigh & Ingirige, 2006, 257). The ultimate catastrophe as seen from a human perspective would therefore culminate in the extinction of the entire human race (Fig. 1).



*Figure 1: "God of Chaos"-asteroid, expected in 2029*

[SOURCE: Cape Business News 2019]

One of the great advantages of having eyes in space or in the sky is the possibility to anticipate, monitor and evaluate crisis scenarios like the appearance of natural disasters. The effective communication of "critical" information not only saves many lives during emergency situations but also helps to prevent future damage by coordinating preventive as well as recovery measures before and after the event (Copernicus EMS, 2019). However, modern disaster mapping products still find themselves at a very early stage. Most of the communication of disaster information nowadays still works in the form of mostly static, non-interactive 2-D paper and web maps (Fig. 2).
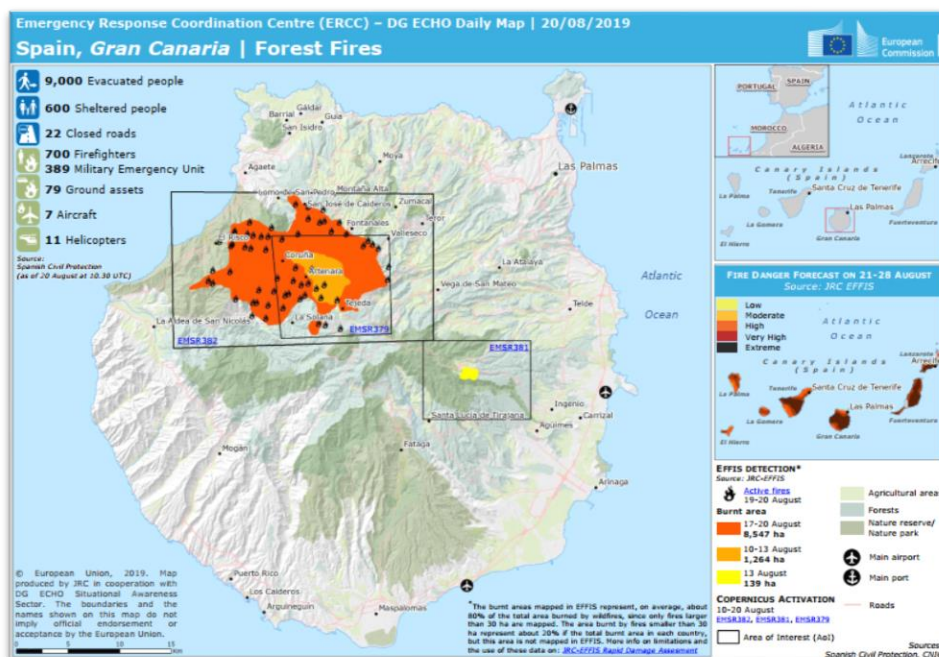


*Figure 2: ERCC Daily Map*

[ERCC, 2019]

Meanwhile, new cartographic visualization trends and techniques like 3D maps, Mixed Reality (MR) and Augmented Reality (AR) are already being established and on the rise (Thomas et. al., 2014; Wrld 3D, 2019). Recent developments show the potential of up-to-date cartographic visualization techniques for natural disaster management, e.g. the Fire Globe from the National Interagency Fire Centre (NIFC) in the United States (Richardson, 2016). Additionally, these modern cartographic approaches are considered potentially useful in the field of disaster response activities (Fierro, 2017; Fig. 3). Whereas a lot of mapping tools and

technologies are already on the market and available, they remain unknown or unused by most practitioners due to different reasons (SAYSO, 2017, 101; chap. 2.2.2).



*Figure 3: Disaster Augmented Reality (Drone-vision)*

[Shaw, 2018]

Considering the very nature of disasters as sudden, dynamic and potentially overwhelming events it seems to be of great importance that mapping products which depict them resemble their characteristics. Progressive, live, interactive and quickly updated cartographic visualizations of ongoing crisis situations up to the latest standards can provide an essential tool to stay ahead of every disaster.

## 1.2 Research identification

This research is about innovative cartographic visualization strategies in the field of disaster management. A special focus of this thesis is going to aim at providing a new visualization model of disasters by using state-of-the-art and experimental cartographic presentation mediums in 3D and Mixed Reality.

### 1.2.1 Research objective

The main objective of this thesis is to test and investigate the benefits as well as the usability of 3D and Mixed Reality Maps facilitating crisis communication of disaster information and planning of disaster response during the process of disaster or emergency

management. As a primary audience for this work, the staff of crisis committees, control rooms, special action groups or field leaders can be identified who oversee disaster response activities as the head of operation.

Keeping the centre of attention on a cartographic foundation, this research intents to enhance the communication and visualization of "critical", (near) real-time disaster information in combination with maps. It is not about revising or improving the current disaster infrastructure on any other level. Besides, this thesis will illuminate the field of disaster management and immediate disaster response rather than risk and recovery programmes in the form of pre- or post-disaster assessments and rebuilding measures.

### 1.2.2 Research questions

To structure the investigation workflow of this master's thesis, the main research objective has been divided into several research questions:

a. Which kind of cartographic visualization techniques are currently being used in disaster management?

b. Are the current visualization techniques adequate and capable of facilitating an effective management of disasters?

c. Does it make sense to incorporate additional dimensions (beyond 2-D) into the communication process of disaster information?

d. Can these dimensions help the decision-makers on scene to more quickly grasp the extent of the catastrophic event and make better choices?

### 1.2.3 Hypotheses

In order to conduct this scientific work, the research questions have been merged and condensed into 2 main hypotheses to be tested:

1. Present cartographic products in the field of disaster management do not facilitate an effective management of disasters.

2. Mixed Reality and 3D maps are useful tools for disaster visualizations and planning of response during disaster management activities.

### 1.2.4 Innovation

Primarily, the main innovation of this thesis for the domain of geo-information science is the integration and combination of new and existing visualization technologies and georeferenced data sources of disaster data to generate an added value in terms of the communication of disaster information. The practical result of this research is an own visualization approach developed by the author for the usage in disaster management. It tries to modernize disaster management maps by examining the potential of cartographic 3D and MR visualization techniques in relation to disaster management.

## 2. Literature Review

This chapter elaborates in detail on the theoretical foundations of this master's thesis. With the study of underlying base literature, the author wants to elucidate the scientific background of this work and provide an interdisciplinary framework for the thesis research. Besides, similar research projects and scientific concepts will be introduced.

### 2.1 Disaster Science

Disaster science encompasses all research which deals with the nature of disasters, the reduction of disaster risk and the mitigation of their effects (Elsevier 2017, 7). The impacts of disasters are followed by immediate as well as long-term consequences.

### 2.1.1 Disaster Types

Generally, disasters can be divided into two subgroups: natural disasters and anthropogenic disasters (Jha 2010; Fig. 3). The seriousness of a disaster impact is usually captured by indicators like death toll rates, economic losses and the population's capability to rebuild after the catastrophic event (Journal of Earth Science & Climate Change, 2019). Therefore, incidents occurring in unpopulated spaces where nobody got hurt or lost property are not technically labelled as a "disaster" (→ hazards, p. 7; e.g. an earthquake in the desert).

Figure 4 shows a comprehensive approach in the classification of different disaster types. Koc & Thieken (2016, 3) combined the categorization scheme of natural disasters from the Integrated Research on Disaster Risk (IRDR) classification system and the technological disaster classification from the international disaster database EM-DAT provided by the Belgian Centre for Research on the Epidemiology of Disasters (CRED). Natural disasters differentiate themselves from anthropogenic disasters as they utilize more enormous powers, cause huge losses in terms of life and property and are usually bigger in scale (Jha, 2010, 2). "Man-made" disasters can theoretically be averted before occurring by thoughtful planning and prevention methods whereas mankind has nearly no control over the appearance of natural disasters. The plan of action for natural disasters focuses more on preparedness and minimizing their negative consequences for the affected population.
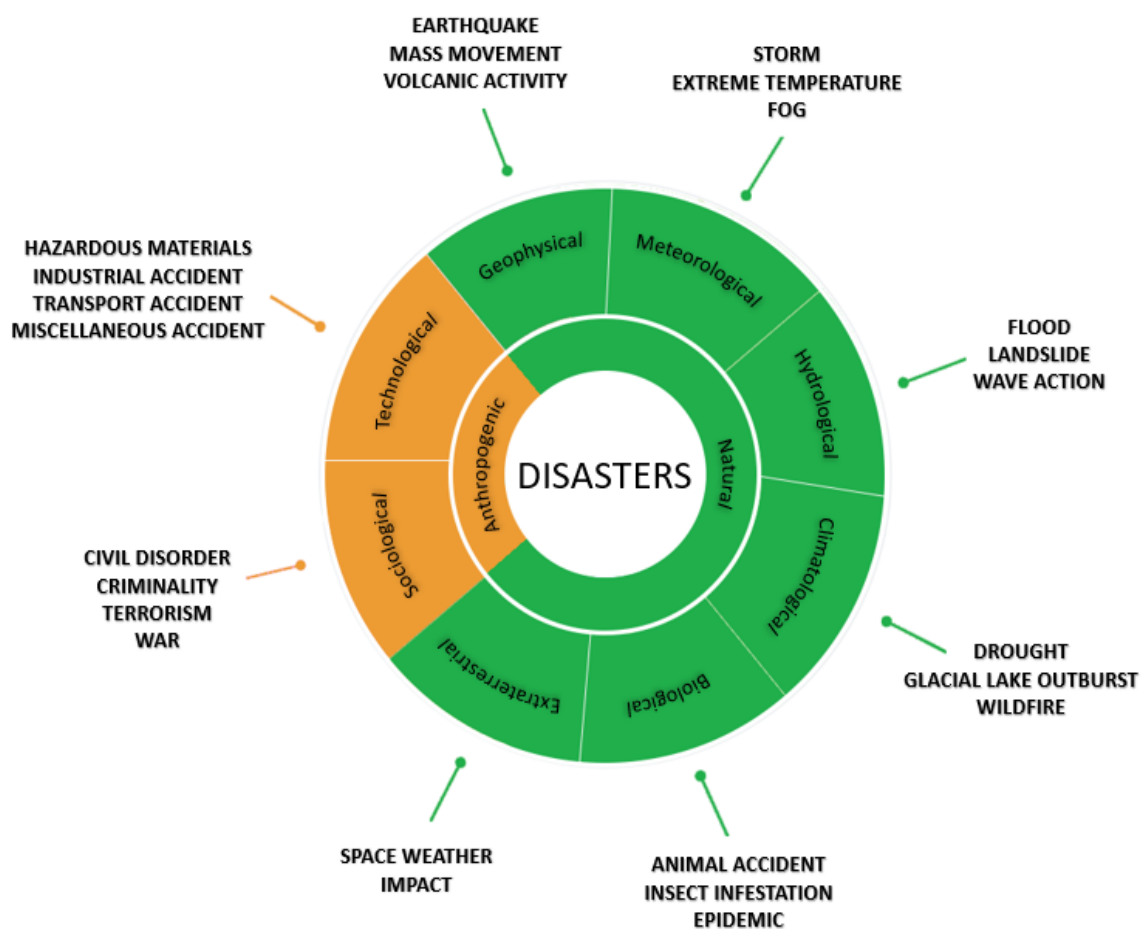


*Figure 4: Disaster types*

[adapted from: Koc & Thieken, 2016, 4]

*Natural* disasters (e.g. droughts, earthquakes, floods, hurricanes, wildfires, landslides) occur mostly due to geological, atmospherical or hydrological origins (Prasad & Francescutti, 2017, 215-216). Anthropological influences can trigger (e.g. wildfire sparked by a thrown cigarette) or exacerbate (e.g. drought caused by overly extensive agriculture) natural disasters. The consequences of these events are more devastating the more vulnerable a community or society is. Every year natural disasters kill around 90.000 people and affect close to 160 million people worldwide (WHO, 2019). Additionally, since more than 10 years there is evidence that the process of global warming amplifies or contributes to the probability, quantity and severity of natural disasters (Van Aalst, 2006).

*Human-made* disasters are caused either by intentional or unintentional human actions (US Legal, 2019). They involve an element of conscious or unconscious behaviour of a human or the failure of a man-made system. A well-known man-made disaster was the 2011 terrorist attack on the twin towers in New York. Just like the other way around, man-made disasters can be stirred by natural ones (e.g. nuclear accident of Fukushima 2011 triggered by a Tsunami) as part of a chain reaction (World Nuclear Association, 2018).

Two more distinctions are important when dealing with precise terminology in disaster science. A *hazard* is mostly defined as a "potential source of danger or risk" (Lexico, 2019) and is therefore not yet a disaster. Many events (e.g. floods, wildfires but also driving a car) can be considered hazards and potentially devastating. Nevertheless, they remain potential threats until they collide with the anthropogenic space and specific behaviour. In these cases, those hazards are turning into *emergency* situations. Whereas it is possible to handle emergency situations by using available resources on the spot, disaster situations exceed the ability of local responders to counteract the event and there are not enough resources close-by to stabilize the environment's conditions (UN-SPIDER, 2019). Hence, external assistance is needed to cope with the consequences of its impact. Next to *disaster* there is the term *crisis* which is widely used for the definition of a timespan of chaos following disaster events (e.g. a humanitarian crisis; Jeong & Jungwon, 2017). With similarities in their meaning, the terms hazard, emergency, disaster and crisis are closely linked and overlapping (Al-Dahash, Thayaparan & Kulatunga, 2017). In this thesis, the expressions "emergency management"

and "disaster management" are being used interchangeably since the management process consists of the same steps (Fig. 7), despite the severity of the event might vary.

### 2.1.2 Disaster Risk

Plenty of factors play a role in the origin of a disaster. It takes more than a hazard for a situation to get out of control. Disaster risk can be described as the intersection between the hazard space as a potential source of danger and the community space which contains assets from the anthropogenic space (Fig. 5). The more these two spaces overlap the higher is the amount of disaster risk. Each community lives therefore under different circumstances than others. A so-called risk assessment is a collaborative and inclusive process in order to measure the unique risk exposure of a community (Planning for Hazards, 2019). It involves and requires expertise from different sectors (e.g. emergency managers, community planners, city engineers, law enforcement, regulators, natural resource and hazard experts, GIS specialists, community leaders, residents, community organizations etc.) to develop a preparedness and response plan by analysing disaster risk.



**Natural Hazards**
Location
Extent
(Magnitude/Strength)
Previous Occurrences
Future Probability

RISK

**Community Assets**
Population
Built Environment
Natural Environment
Economy
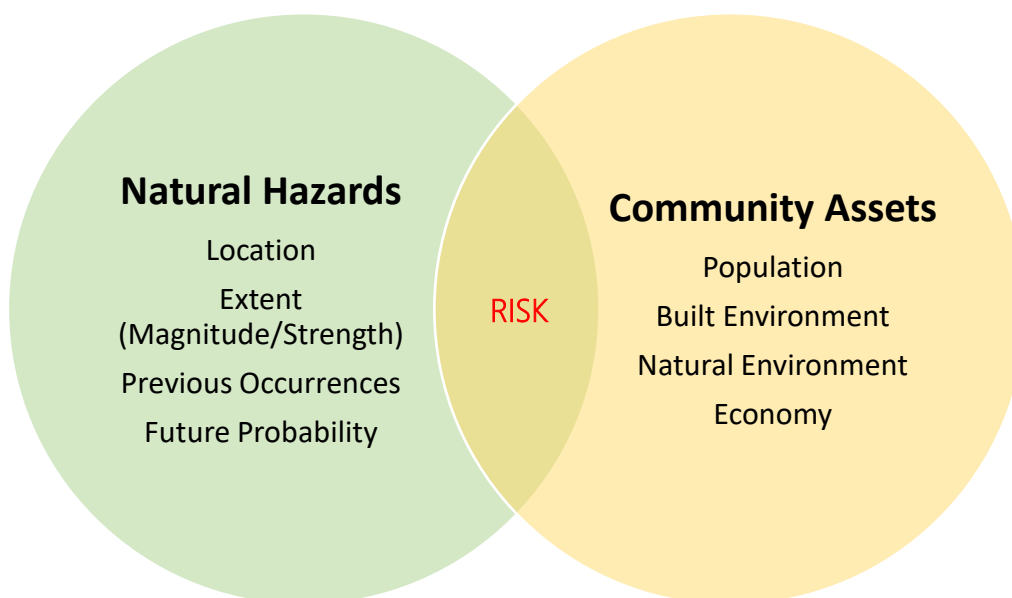
*Figure 5: Disaster Risk*

[adapted from: FEMA, 2013, 5-2]

The level of preparedness towards a possible disaster situation for a certain community is called population resilience. If the exposure of a community is naturally very high, the

resilience should be increased to alleviate disaster impacts. Multiple factors can strengthen and increase community resilience (Haworth et al., 2018, 4):

- Understanding risks & uncertainty
- Preparation engagement
- Effective communication
- Capacity for self-organisation
- Developing flexibility
- Collaboration between stakeholders
- Use of local knowledge & resources
- Social connectedness
- Empowerment

In case a disaster cannot be averted by means of thoughtful planning, three main factors have added up as shown in Figure 6. A high vulnerability and exposure of a community in combination with low population resilience and the occurrence of a hazard eventually lead to a disaster which might evolve into a crisis.



*Figure 6: Disaster Risk Equation*

[adapted from: Gill, 2015]

## 2.2 Disaster Management

Disaster management comprises the organization, planning and application of actions aimed at the preparation for, response to or recovery from disasters (UNDDR, 2017). The complex, multi-actor process revolves around four interdependent, primary steps (Fig. 7): preparedness, response, recovery and mitigation. As illustrated the hazardous event appears between the steps *preparedness* and *response*.
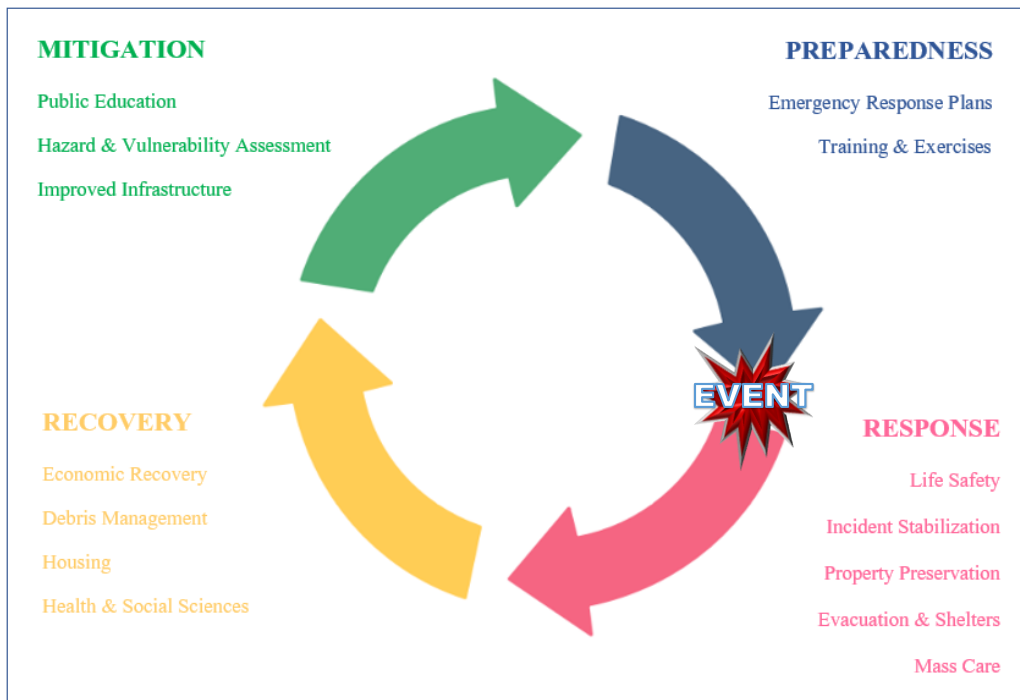
*Figure 7: Emergency Management Cycle*

[Onslow County, 2019]

Given a rapid case of emergency the disaster management has to quickly communicate, plan and coordinate between local, state and federal emergency response agencies as well as incorporate municipal and private sector agencies (Onslow County, 2019). These different levels of government and hierarchies contribute to the complexity of disaster management.

### 2.2.1 Situational Awareness

Situational Awareness is by definition "all knowledge that is accessible and can be integrated into a coherent picture, when required, to assess and cope with a situation" (Sarter & Woods, 1991, 45-57). One key factor to effective disaster management is to have an updated overview of the situation and resources available in order to respond in the best way possible. Geospatial information is of vital importance for all steps of the emergency management cycle (Wibowo, 2013). Disaster mapping products have a critical influence on the success of disaster relief operations because they majorly affect the situational awareness of the emergency management staff and first responders. Hence, for an effective management of disasters, used maps should raise the situational awareness of practitioners in charge to support their decision-making through accurate visualizations of disaster data.

## 2.2.2 Cartographic products in current use

Depending on each disaster case and management hierarchy level a range of cartographic products is used for specific purposes. The following sections show current examples of disaster maps existent in disaster management and immediate disaster response that have been categorized according to thematic aspects.

Delineation and Grading Maps

The purpose of *delineation* and *grading* maps is to provide an at-a-glance overview of the geographical space and strength of a disaster situation at a particular moment in time (Fig. 8). Since 2014 the Copernicus Emergency Management Service (EMS) established by the European Union (EU) can be requested from authorized users (Copernicus, 2019). Figure 8 shows the Area of Interest (AOI) of a flood incident. The map outlines the affected (flooded) areas based on remote sensing satellite imagery acquired prior or during the disaster.
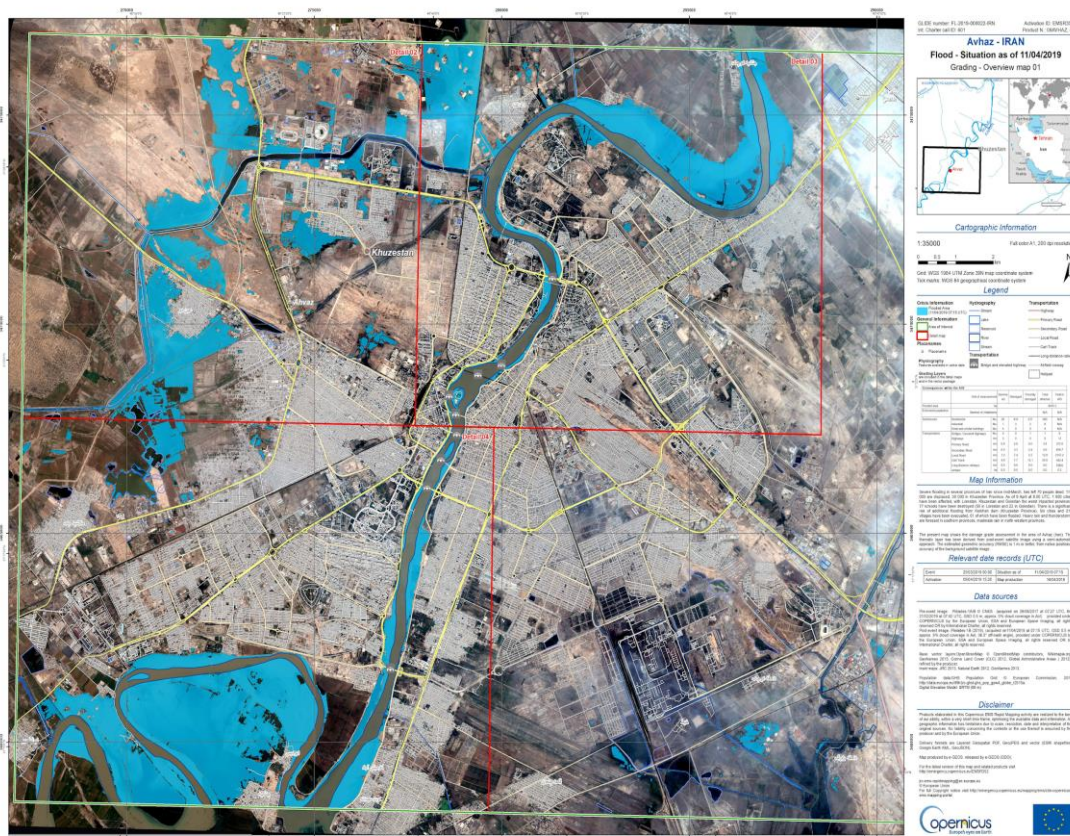


*Figure 8: Copernicus EMS Delineation Map*

[Copernicus EMS, 2019]

Due to the instability of disaster scenarios, these maps must be updated in very short time intervals. Copernicus maps are available as static PDF files, JPEG files or shapefile vector packages, which means they are produced multiple times. *Grading Maps* deliver additional information next to the disaster extent concerning the magnitude of the event (Fig. 9). They classify the event into several intensity categories (here: dryness level of a drought). Moreover, these maps are made to locate disaster impacts like destroyed building or unpassable streets and grade their level of affection (e.g. moderately damaged). Some basic information and rough statistics about the event complement these maps on the side.
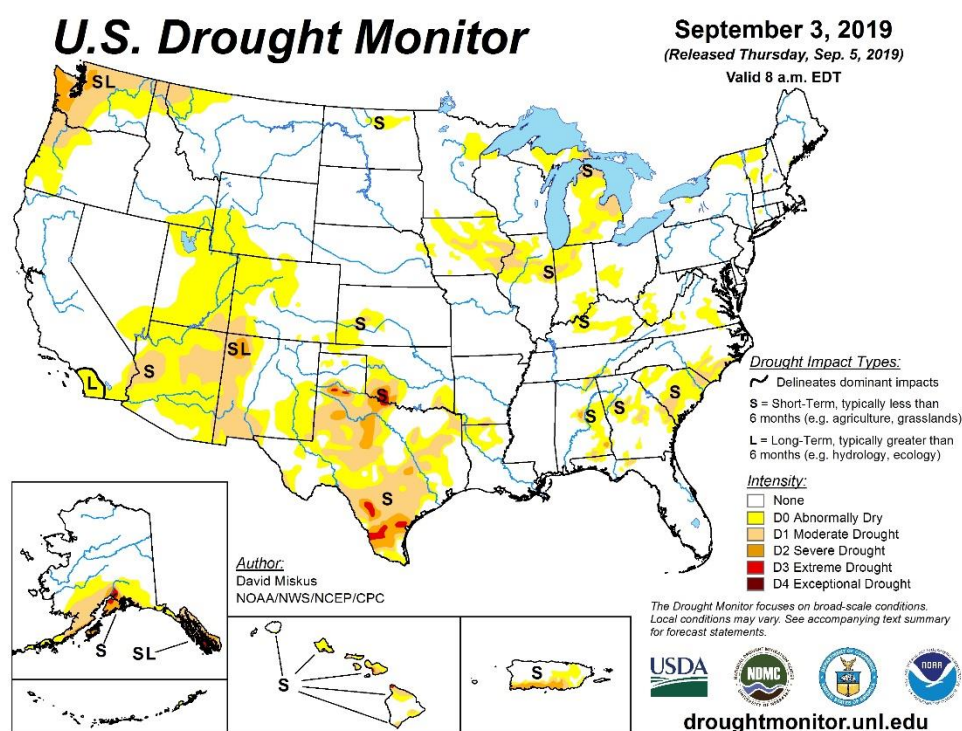


*Figure 9: NDMC Grading Map*

[NDMC, 2019]

All in all, delineation and grading maps facilitate the observation and monitoring of disasters on a small scale. Without going too much into detail they are the first maps produced after an event during a process called *rapid mapping* (Copernicus, 2019). Because of the adverse environmental conditions (e.g. strong wind, heat) that accompany disaster impacts, remote sensing technologies (especially from satellites) are the fastest and only way

to obtain information about the extent and magnitude of a disaster shortly after the event. Once the conditions allow for it, aerial vehicles like drones or helicopters can be used, too.

Resource Maps

Maps of available resources fulfil the function of locating assets that can be utilized for disaster response (Fig. 10). The example below is a snapshot of the *San Francisco Disaster Assessment and Assistance Dashboard* which displays local police and fire stations, hospitals and other resources which are relevant for disaster management.
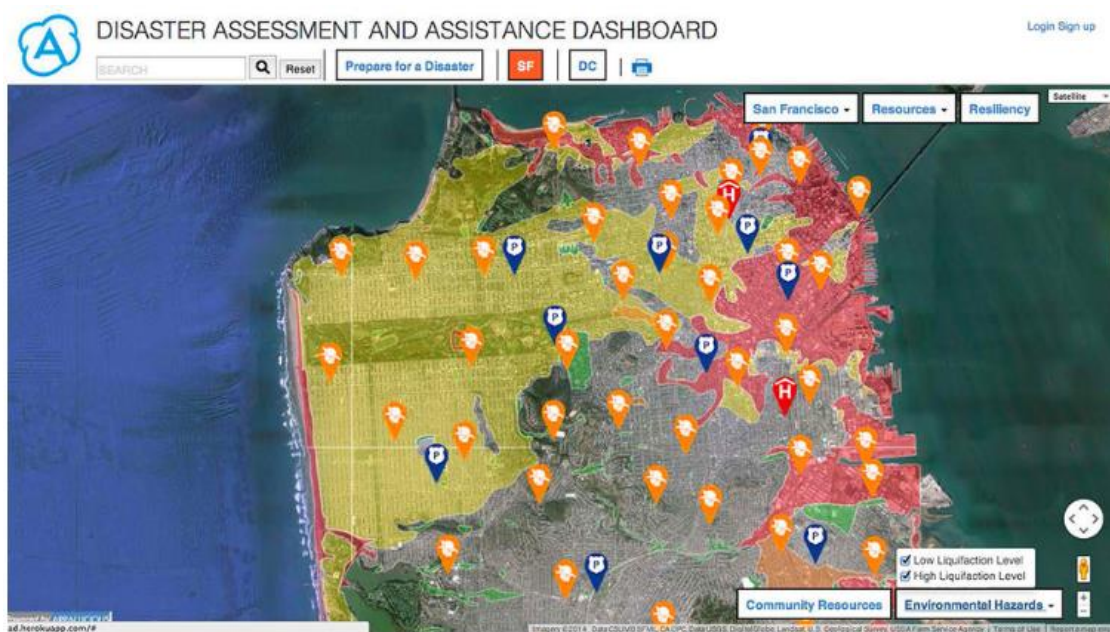


*Figure 10: Disaster Response Resource Map*

[Shueh, 2014]

The geospatial information about resources today is increasingly being stored inside of Geographical Information Systems (GIS). Another local example is the Bavarian Geographical Disaster Information System *GeoKAT* launched in 2016 (GDI-BY, 2016). This catalogue lists the quantity and location of over 200.000 objects including water pumps, vehicles, sandbags or camp beds. Additionally, this data is saved offline on local laptops and a special mechanism keeps the data up to date. Resource Maps hold mission-critical information and are existential to field of disaster management. Since these maps deal with sensitive information, they are commonly not publicly accessible and stored secretly.

Object or Area Detail Maps

Depicting the internal structure and layout of an entity (in most cases: a building), object detail maps visualize disaster or emergency relevant information connected to the entity (Fig. 11). A typical example is a fire safety plan as shown below. These plans are usually created after a buidling has been built (VisuBrand, 2019). In the map, emergency exits, elevators, smoke protection doors, fire extinguishers, electricity ports or smoke detectors can be identified. For the purpose of locating the fire source, firefighters can know which of the smoke detectors rang the alarm (Appendix 4).
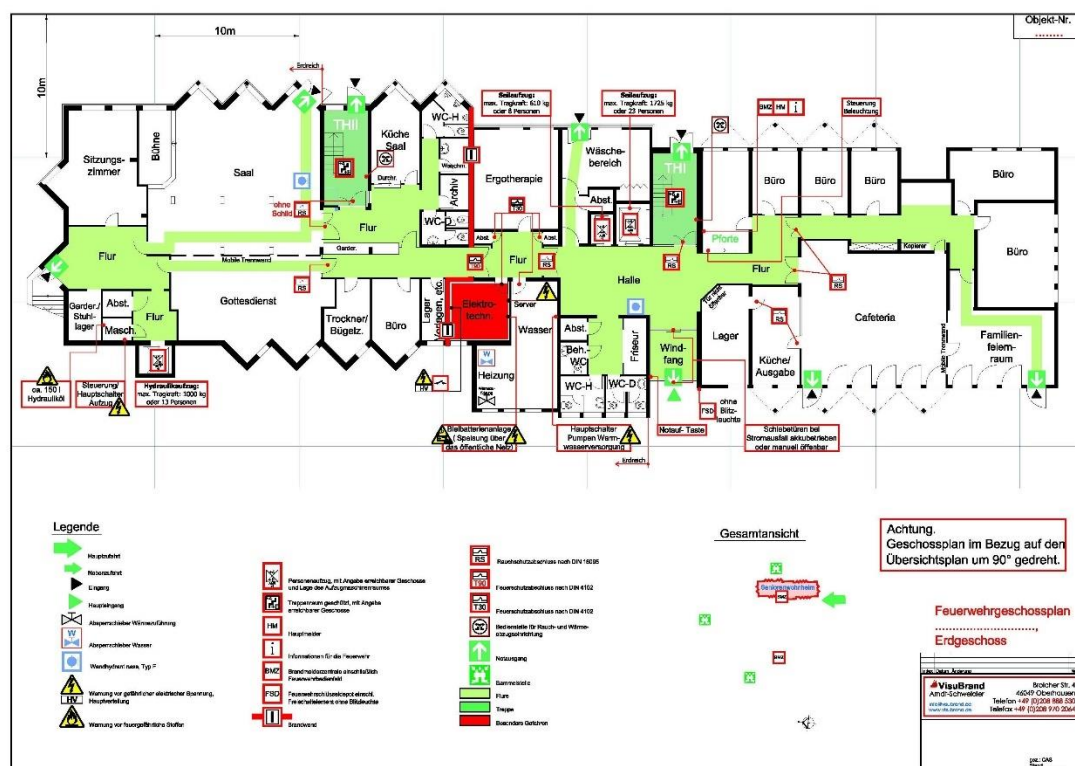


*Figure 11: Fire Safety Plan*

[VisuBrand, 2019]

Comparable to fire safety plans are escape and rescue plans which are more designed for civilians than for first responders. The second type of map in this category are city evacuation plans (Fig. 12). Designed with a specific scenario in mind (here: Tsunami) the map shown in Figure 12 outlines the predicted flooding zone, evacuation routes and safe zones as a guideline for evacuation measures in respect to the local population. They serve as a foundation for disaster impact and response planning.

*Figure 12: City Evacuation Plan*

[Garay, Rosas & Hidalgo, 2017]

Disaster GIS applications

Remote sensing imagery in combination with GIS are objectively a beneficial tool in all steps of disaster management (Fig. 7). With means of advanced wireless communication and many new web-based GIS applications entering the market, disaster management as a process is being "revolutionized" (Pushpendra, 2018). The complexity in the field of disaster management offers a wide range of possible applications that are progressively being developed. One of the most ambitious applications in this regard makes up the I-React (Improving Resilience through Advanced Cyber Technologies) project funded by the European Commission with a 6.5m € budget and coordinated by the Istituto Superiore Mario Boella from Turin (JoinPad, 2018). The goal of the project is to create a real-time prevention and management system for natural disasters to promote more secure and resilient societies in Europe. In a very sophisticated approach, the base concept of I-React consists of the combination and modelling of data from multiple sources (Fig. 13). Technologies involved in the I-React project range from Earth Observation, Unmanned Aerial Vehicles (UAVs), Big Data Analysis, Social Media data streams, Advanced Positioning Systems, wearable AR devices for first responders and a cross-platform application for mobile devices to report events and share situational awareness information (Pos Driver Project, 2019). Up to the date of submission, the project was still ongoing.
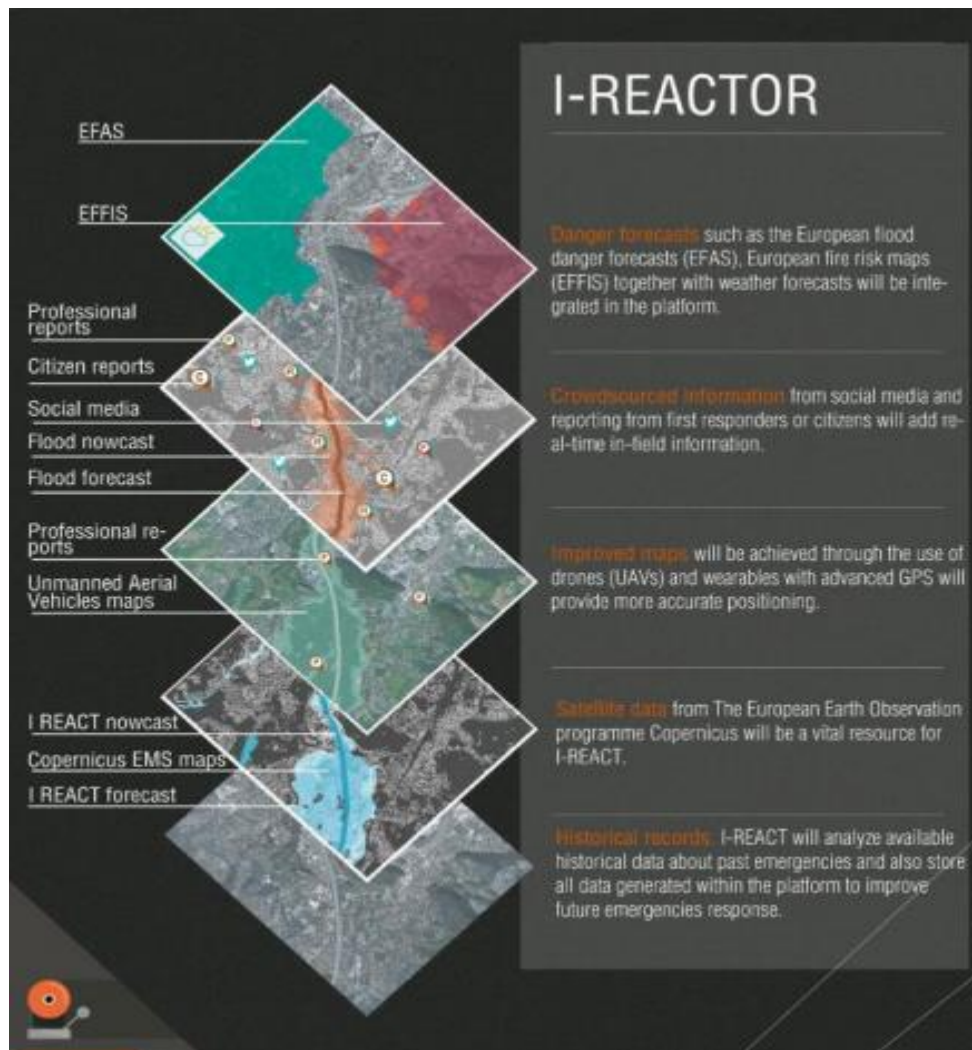
*Figure 13: I-React Project*

[I-REACT, 2016]

Another EU funded program the SAYSO project for the Standardisation of Situational Awareness Systems to strengthen operations in civil protection. The goal of SAYSO is "to define the reference architecture and specifications for future innovative European cost-effective and user-friendly situational awareness tools that fulfil end-user requirements and can be used across different organisations, hierarchical levels and national borders" (SAYSO, 2019). The SAYSO preliminary gap analysis (SAYSO, 2017, 81-84) states that current technological and cartographic solutions facilitate the whole bandwidth of practitioners' requirements, but most of the tools are not known or not integrated into EM. In addition, the report suggests that the innovation process in EM is very slow and goes along with a lack of resources, namely time, money and personnel (SAYSO, 2017, 84). These conditions prevent practitioners

from investing into state-of-the-art situational awareness systems. Moreover, this situation is amplified, and changes are obstructed by different competency and responsibility levels among practitioners between states or within a state (SAYSO, 2017, 84). The consequence is the occurrence of individual, non-standardized situational awareness systems.

## 2.3 3D Maps

Three-dimensional maps or 3D maps have been around for some time now. With their capability to visualize geospatial data in an easily understandable manner, they have become popular because 3D is the way how humans perceive the world (Shepard and Field, 2017). By displaying the height (z-) variable, physical objects from the real world take on their original (minimized) shape. Other characteristics in favour of 3D maps are the possibility to customize the virtual camera position and viewing direction and to overlay thematic or photo-realistic information on the map (Schobesberger and Patterson, 2015). Furthermore, 3D maps have been assessed to have the potential of enhancing the disaster management process through being able to overcome perception problems and present data in a more realistic and clear fashion (Bandrova, Zlatanova & Konecny, 2012, 249).
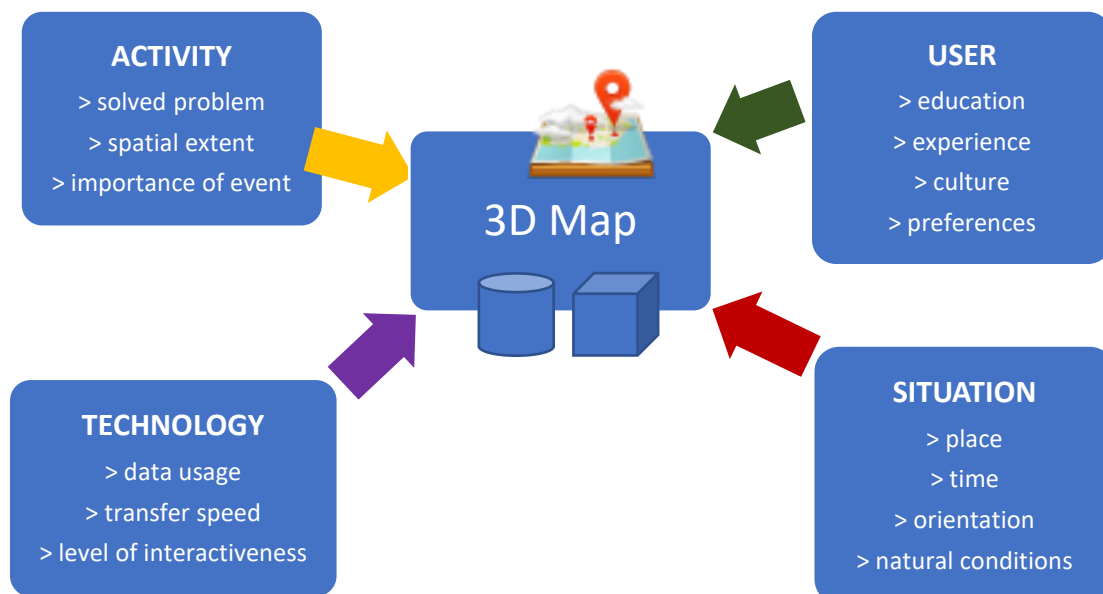


*Figure 14: Context-Influence on the visualization of a 3D map*

[adapted from: Bandrova, Zlatanova & Konecny, 2012, 247]

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Several design considerations (Fig. 14) should be acknowledged when a 3D map is created because contextual influences shape the visualization result of a 3D map significantly. With major improvements in 3D modelling and the creation of very detailed 3D objects a new cartographic term is being established phrased "digital twin". These digital twins represent real-world objects so accurately that they become an almost perfect copy (Conway, 2017).

## 2.4 Reality Technologies: Mixed Reality

*Mixed Reality* technologies as a standalone concept create immersive environments and visualizations which are characterized by "physical and digital objects co-existing in space and interacting with each other in real time" (Reality Technologies, 2019). But MR also refers to all kinds of possible combinations of real and virtual objects which are summarized by Milgram's Reality-Virtuality Continuum (Fig. 15). This means that any technology which moves in between the boundaries of a completely synthetic, digitally created world and the real physical world can be considered MR. One subclass of Mixed Reality as a continuum is *Augmented Reality*. AR technologies overlay or "augment" the real world with virtual content to enhance the perception of the user's environment (Milgram et al., 1994).
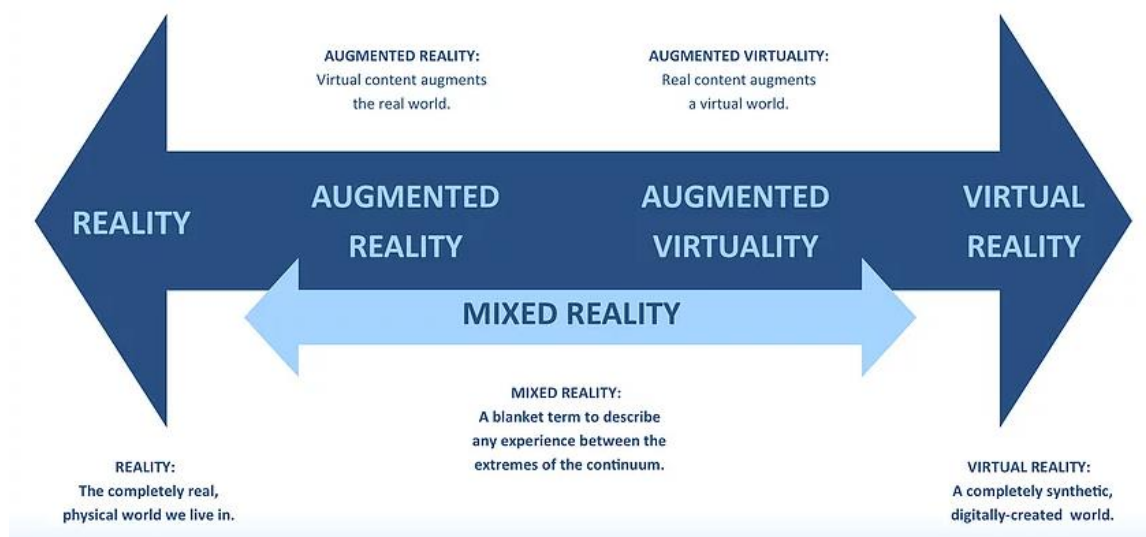


*Figure 15: Reality-Virtuality Continuum*

[Milgram et al., 1994, 283]

Whereas Virtual Reality (VR) immerses the user into a fully artificial world, MR and AR combine real and digital content to a new viewing experience. The key difference between

VR, MR and AR is portrayed in figure 16. Besides, the figure illustrates the distinction of MR as an independent concept. In MR, digital content interacts with the physical environment which is not the case in AR. Therefore, MR technologies merge VR and AR concepts to benefit from features of both ends of the Reality-Virtuality Continuum.
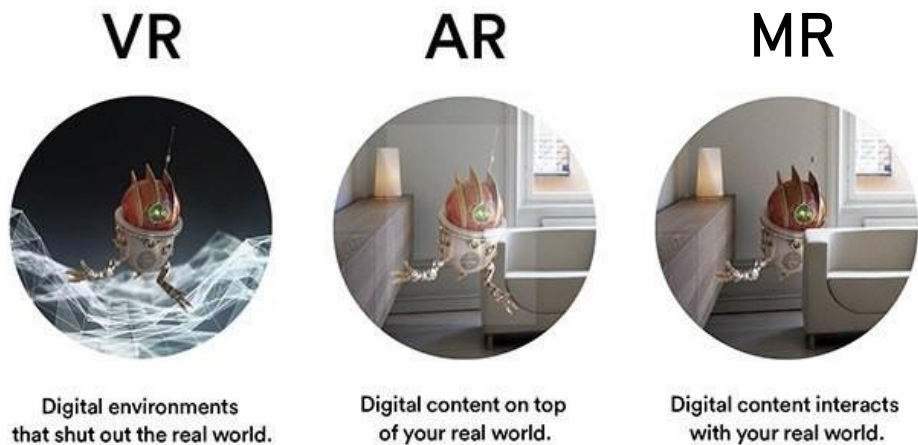


*Figure 16: Differentiation between Reality Technologies*

[adapted from: Valendu, 2018]

In cartography, there is a current boom about the integration of Reality Technologies into maps (Anderson, 2018). Many prototypes are being developed and tested for potential use cases. Figure 17 depicts a MR application for the viewing of underground structures.



*Figure 17: MR application for the detection of underground objects*

[ArcNews, 2018]

## 2.5 User-centred design

Defined by current literature as an iterative design process, user-centered design (UCD) focuses primarily on the user's needs in every step of the design process (IDF, 2019). The term was initially introduced by Norman and Draper (1986) as Human-Centred Design and deals with conceptual ideas about human-computer interaction. According to them, Human-Centred Design as described should not be about following a process but rather about involving the end-user of a product into the individual design steps. For this reason, many alterations of the concept exist. The basis principles of a UCD process consist of (HHS, 2019):

(1) Specification of context of use

(2) Specification of requirements

(3) Creation of design solutions

(4) Evaluation of designs

## 2.6 Mixed-methods research design
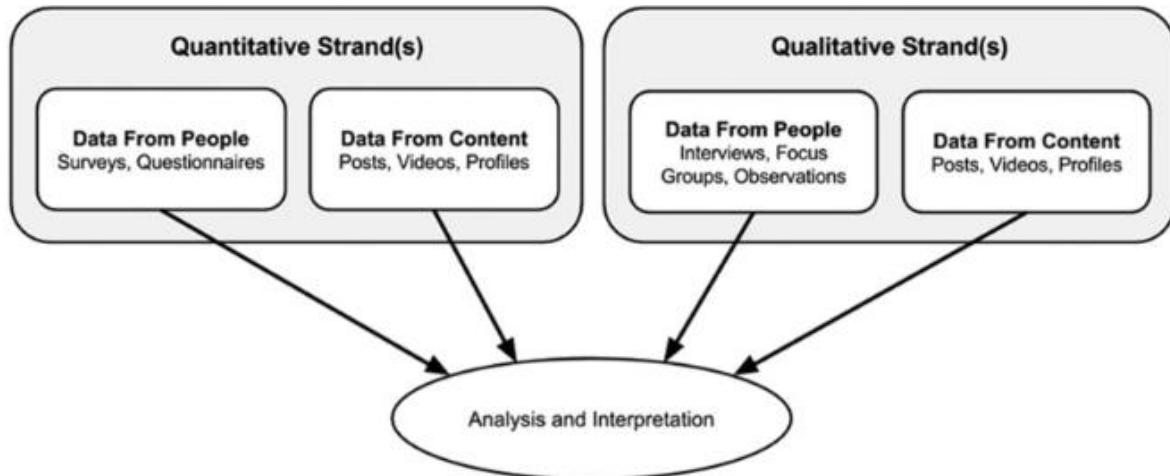


*Figure 18: Mixed-Methods Research Design*

[Snelson, 2016]

The mixed-methods approach in research design combines the strengths of qualitative and quantitative research methods into a combined amalgamation (Fig. 18). Quantitative research methods generate quantitative data that can be counted and evaluated by descriptive statistics (ABS, 2019). Usually this data is gathered by surveys using a large number

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of randomly selected participants. The advantages of quantitative research are that the data is relatively easy to analyse, and the results can be generalised if the sample reflects the study population and the selection process was well constructed (Better Thesis, 2019). Qualitative research methods on the other hand produce qualitative data which is categorical data that describes and estimates a thing or phenomenon but doesn't directly measure numerical attributes and characteristics (Moltzau, 2019). This kind of data is used to "complement and refine quantitative data" (Better Thesis, 2019). Especially for complicated issues qualitative data delivers a deeper insight into a topic and provides more meticulous information which goes beyond numbers and statistics.

## 3. Methodology

Combining different research methods this part explains the scientific toolset which is used to tackle the research questions (chap. 1.2.2) and their associated hypotheses (chap. 1.2.3). All the single parts of this research are interconnected and serve the purpose of fulfilling the main research objective (chap. 1.2.1). In summary, the plan of execution for this research features 4 major steps which provide an outline for the case study (chap. 4):

(1) Description of the present situation in the domain

(2) Analysis and use-case selection process

(3) Production of a self-made cartographic application

(4) User Evaluation of the developed approach

Based on the literature review (chap. 2) and a user requirement's survey (chap. 4.1), stage one is setting the foundation for the self-made cartographic application. The combined results influence the development of the visualization approach by fulfilling current needs and demands of the domain's community. Eventually, the created mapping application is being evaluated by real actors from the field.

## 3.1 Research workflow
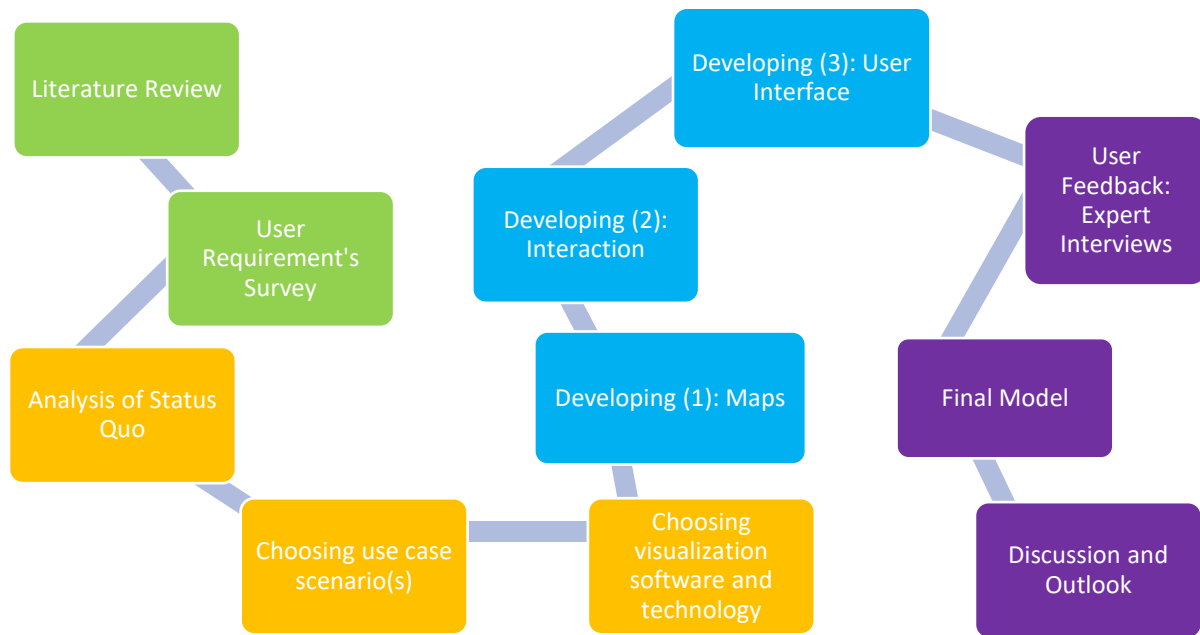


*Figure 19: Research Workflow*

Following user-centred design principles (chap. 2.5) the thesis research's workflow identifies the individual milestones from A to Z (Fig. 19). The colours respectively highlight coherent building blocks inside the workflow. As a foundation this research is based on a mixed-methods approach which contains quantitative and qualitative elements (chap. 2.6).

## 3.2 Phase I: Description of present situation

Aside from the review of existing projects and literature it is essential to conduct a quantitative user study generating an up-to-date overview of current practices and problems in the domain that might be overlooked in the literature. By picking a broad and diverse but as a whole homogeneous audience for the user requirement's survey it will be ensured that the research covers the whole spectrum of the domain.

## 3.3 Phase II: Status-Quo analysis and use-case selection process

With the results of the user requirement's survey and literature review available, the conceptual task is to define a use case which allows for the realization of an alternative visualization approach. This approach should discard major shortcomings in existing

mapping products as well as introduce new and experimental features. According to the developed ideas an adequate technology and software must be chosen which facilitates the execution of the concept in an optimal way.

## 3.4 Phase III: Application development

The development part of the mapping application deals with the technical implementation of the maps and their individual features into a comprehensive model accompanied by a user interface. Here the emphasis should rest on the desired purpose which was generated in Phase 2.

## 3.5 Phase IV: Expert interviews

After the model is finalized chosen experts from the targeted audience give their professional opinion upon to evaluate the potential use of such an application in practice. Their qualitative feedback will initiate a discussion revealing and contrasting the advantages and disadvantages of the model.

# 4. Case Study and Results

In this section the focus is on the practical work conducted for the master thesis. Primarily, it will be described and illustrated how the methodology was executed, what the major findings of the single components were and what problems had to be overcome along the way. The case study will describe 3 main elements: User Requirement's Survey, Application Development and User Evaluation.

## 4.1 User Requirement's Survey

For the user requirement's an online questionnaire was set-up using the German online survey platform "SoSci Survey" (Fig. 20). In contrast to other online survey platforms, "SoSci Survey" (soscisurvey.de) offers a free student version with full functionality. Questions can be designed choosing from a wide range of question types and there are no limitations regarding the number of questions or participants. Furthermore, questions can be sorted into multiple categories and different question blocks can appear on different pages.
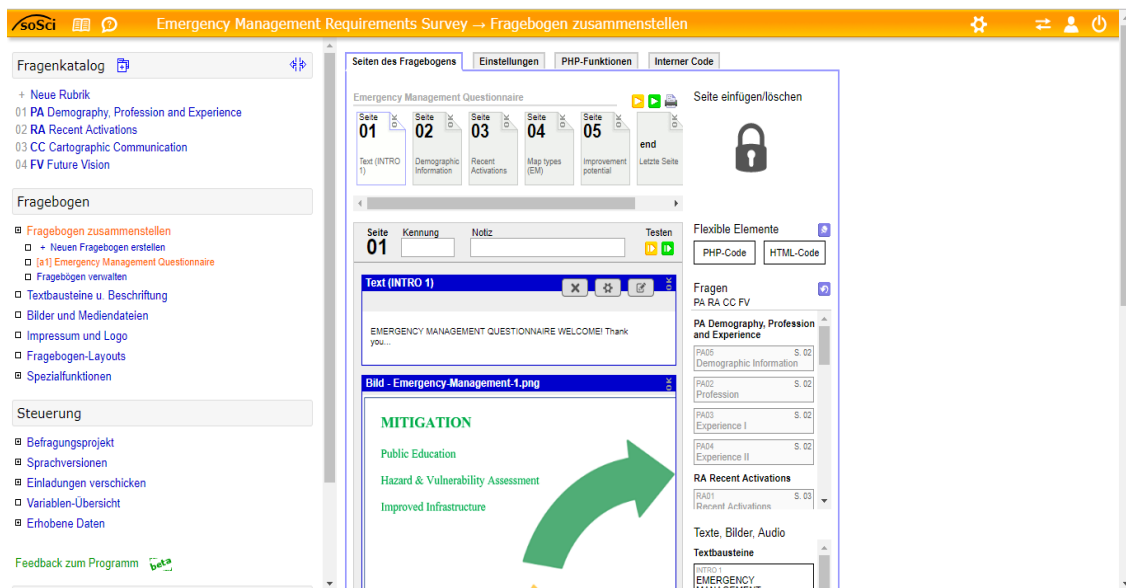
*Figure 20: SoSci Survey platform*

[Sosci Survey, 2019]

The output of the "SoSci Survey" platform is a coded table listing all answers which can be downloaded in different formats. For the visualization of results diagrams and tables were created (chap. 4.1.3). After setting up the questionnaire with the title "Emergency Management Survey" (App. 2) a time span of 2 months was set in order to gather the required information.

### 4.1.1 Description and Outline

The main concept of the survey was to get an idea of the everyday routine from practitioners itself. For this reason, the questionnaire was separated into 4 parts.

1. Demography, Profession and Experience

2. Current problems and biggest challenges

3. Disaster maps, information and technology

4. Future vision

To get a first impression of the current state and demand level of cartographic products in disaster management, the first two building blocks of the survey investigate how disaster

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management practitioners work and what experiences they had recently. Subsequently in block three, the questionnaire examines what maps are being using, what information is being retrieved from them and how they are being used. At the same time the participants rate the quality of their maps. Finally, the survey concludes with questions about future improvements and introduces Reality Technologies (chap. 2.4) as a cartographic medium.

### 4.1.2 Survey Population

Giving credit to the various actors that can be associated with emergency or disaster management (chap. 2.2), the survey population was chosen from a broad selection of professions (full list: Appendix 1). The addressed recipients who were contacted for this survey via Email can be assembled into three categories:

a)  Public Authorities/Offices

b)  Voluntary Organisations/Institutions

c)  Insurance/Risk Intelligence

It must be mentioned that no one of the insurance or risk intelligence companies replied to the invitation emails for this survey. The reasons remain speculation as they could be strict company guidelines or secrecy about working practices. From the other 2 groups respondents were much more willing to give information and assist to this study project. Ultimately, out of 40 received questionnaires, 30 have been selected which serve as the final population of this survey. This cut was made due to comparability reasons because only 30 recipients filled out the survey with a percentage of 95% or higher of answered questions. Main institutions and recipients with a high respondence rate have been visualized in a word cloud (Fig. 21).

The average age of all the respondents was between 36 and 45 years inhabiting various professions in disaster management. 96% of the addresses judged their experience level as "Experienced" or "Very Experienced" which is reflected in the timespan they have been occupying their current positions. More than 50% have been working in their current jobs for more than 5 years and almost 40% for more than 10 years.

*Figure 21: Word Cloud of survey participants*

Recent activations of the respondents echo the diversity of their professions. The disaster types they have dealt with include floods, fires, storms and snow but also anthropogenic disasters like bomb discoveries, gas leaks, mass casualty incidents and refugee problems. Most of them worked in the sector of management, coordination and analysis of disasters while some were first aid responders or educators.

### 4.1.3 Overview of Results

On the following pages the outcomes of the user requirement's survey are illustrated and described in detail using tables and figures. This chapter begins with part two of the questionnaire as part one has already been presented in the previous section.

<u>Current problems and biggest challenges</u>

The main problem areas in the field of EM named by the participants can be seen in Figure 22. In the Top 3 are "Missing human resources", "Internal Communication" and "Lack of significant decision-making information". Maps only play a secondary role in this diagram as only 1/5 of the participants labelled them problematic.

Among repeatedly mentioned biggest challenges prevailing in EM, participants stated the facing of unexpected situations in unexpected environments, missing human and financial resources, slow process of digitalization and clean communication without any information loss. Moreover, the lack of acceptance of EM and disaster protection in politics,

society and administration was flagged. All the answers were gathered by an open question type without any suggested answers.
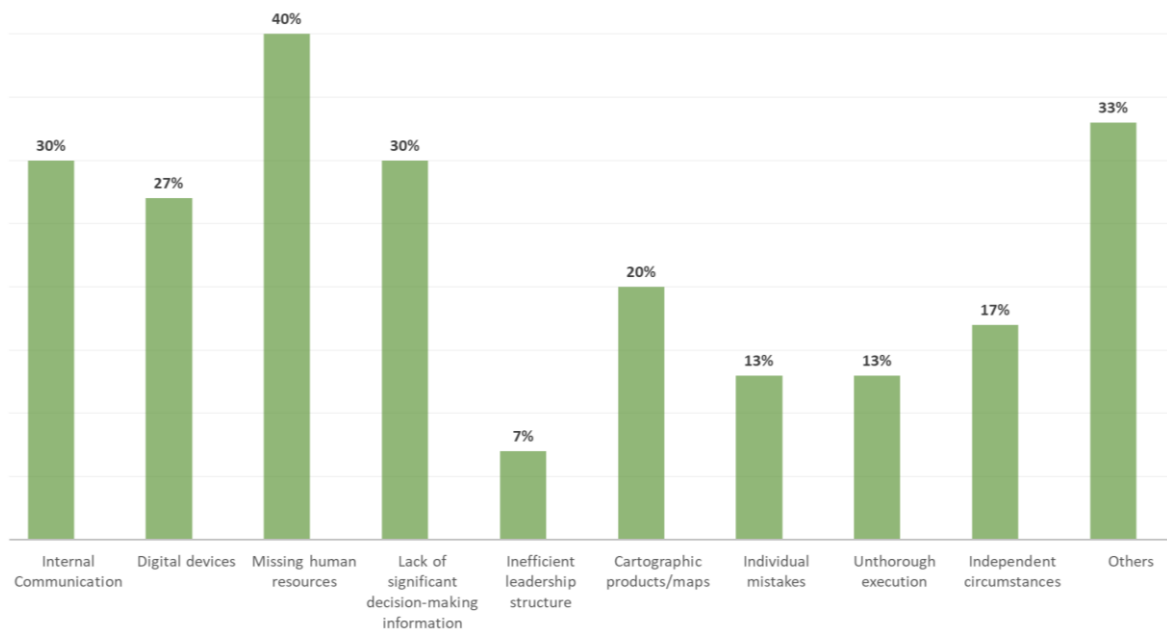


*Figure 22: Problem areas in EM*

## Disaster maps, information and technology
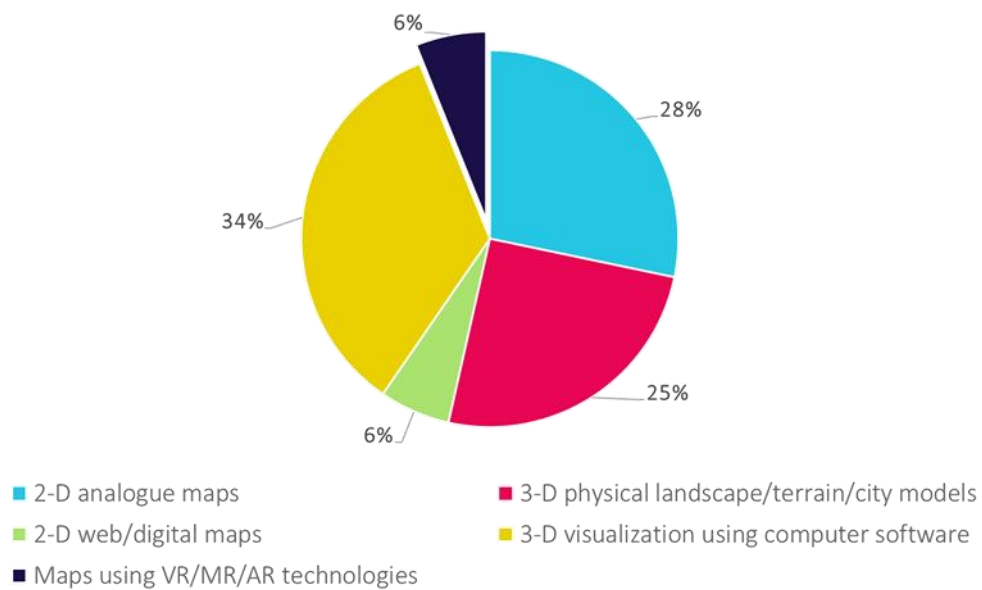


*Figure 23: Map types used in EM*

Map types used by the survey participants reveal that 3D visualizations are the most common map type followed closely by 2D analogue maps and physical 3D models. Reality technologies and 2D web/digital maps only take small shares.

The used maps are mostly being viewed on a regular desktop PC and on advanced digital screens as the proportional tree map below indicates (Fig. 24). Outreached by analogue maps, mobile screens and reality technologies are less common.
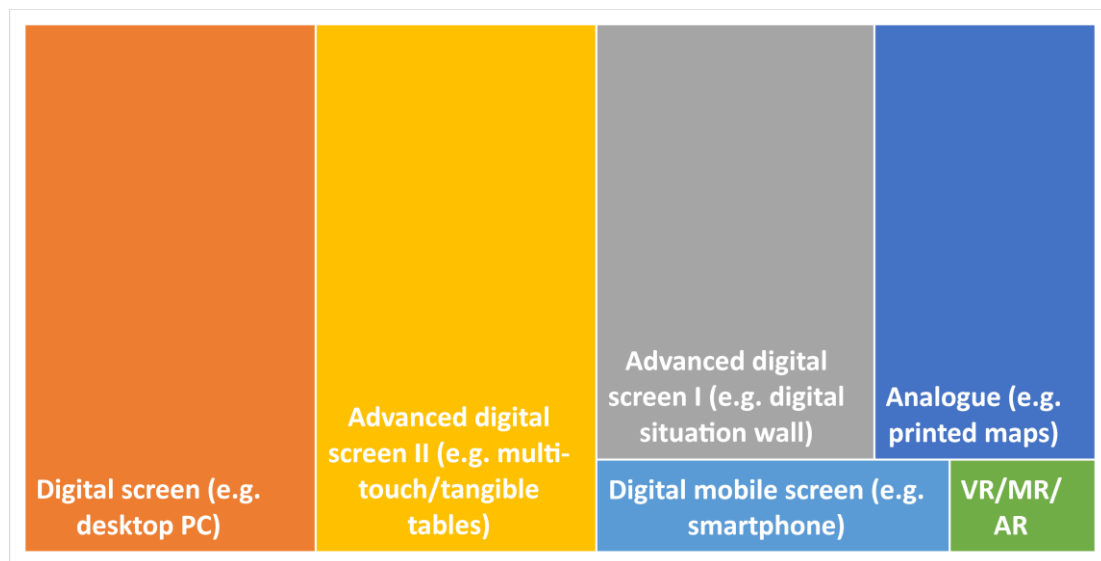


*Figure 24: Viewing devices in EM*
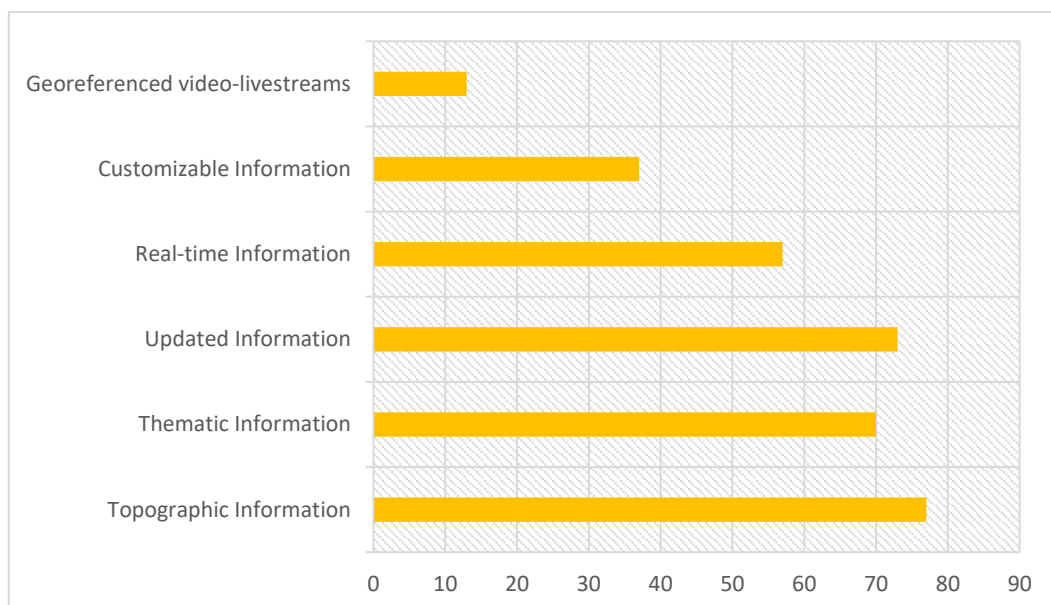


*Figure 25: Displayed/Shared Information by EM maps (in %)*

When asked about their working experience with 3D, VR, MR and AR visualizations participants replied rather less. Only very few made tests with VR, MR and AR technologies yet, while 3D as a map medium appeared to be more widespread.

Figure 25 shows the displayed and shared information on EM maps in % of the participants. Real-time and customizable information are less integrated than classic, regularly updated topographic and thematic information.
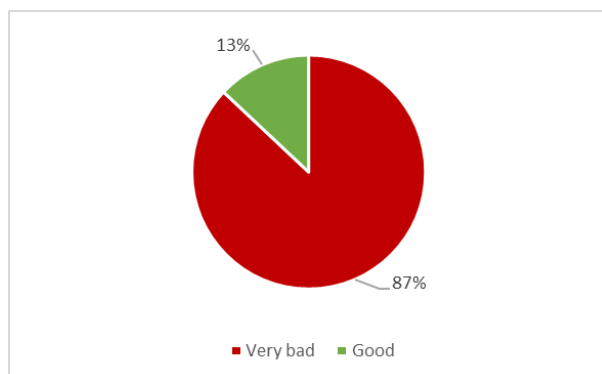


*Figure 27: Quality of EM maps*    *Figure 26: Information Quality of EM maps*
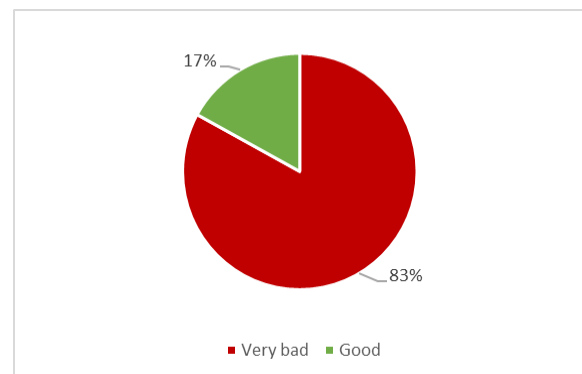
The quality of used EM maps as well as the quality of information contained by them was rated significantly negative (Fig. 26; Fig. 27). In order to find out which kind of information participants would like to have access to, an open question was added.

One dominant request by many participants was access to real-time disaster information (e.g. flood waves) and live data about objects (e.g. critical infrastructures). Pictures and videos from the scene were named, too. Another main flaw EM practitioners perceived is the lack of trustworthiness and completeness of disaster information.

Future vision

Table 1 visualizes the result of a ranking question about the urgency of several aspects to be improved soon. Participants could rank 8 given items from 1 (most important) to 8 (unimportant). According to the results, the highest percentage of participants voted for human resources to be increased and real-time information to be integrated into maps.

*Table 1: Improvement necessity in EM*

| | Internal/external communication | Cartographic products/maps | Real-time information sharing | Combination of maps and real-time information | Combination of maps and internal/external communication | Technical equipment | Human resources | Digital devices |
|---|---|---|---|---|---|---|---|---|
| **#1** | 16% | 13% | 13% | 3% | 7% | 10% | 20% | - |
| **#2** | 10% | 3% | 17% | 23% | 7% | 7% | 13% | 3% |
| **#3** | 9% | 7% | 13% | 20% | 7% | 7% | 13% | 16% |
| **#4** | 16% | 3% | 13% | 17% | 10% | 3% | 7% | 10% |
| **#5** | 3% | 20% | 7% | 7% | 7% | 13% | 7% | 17% |
| **#6** | 10% | 10% | 13% | 3% | 10% | 10% | 13% | 10% |
| **#7** | 10% | 10% | - | 7% | 10% | 26% | 3% | 10% |
| **#8** | 10% | 13% | - | - | 23% | 3% | 10% | 17% |

Most participants see advantages in the use of VR, MR and AR technologies for being used in disaster management. Some mention these technologies as a step too far or state concerns about their usability and failure proneness. Also training and education will be needed to employ them effectively. In general, 67% of participants see benefits in applications driven by Reality Technologies.

## 4.2 Disaster Management Application (DiMAN)

The development of a comprehensive approach for the visualization of disasters in the framework of disaster management activities is a complex task. Due to numerous variables (e.g. disaster type, use-case situation, technology) the outcome can look very different. In the following paragraphs the evolution and functionality of the cartographic application "DiMAN" (Disaster Management) is being explained. DiMAN was created by the author during the thesis semester as part of the conducted research.

### 4.2.1 General approach

Multiple elements were in integrated into an overall disaster model. Originating from the main research objective (chap. 1.2.1) the developed application makes use of cartographic 3D

and MR frameworks. Android was chosen as the development platform because of the availability of a Google Pixel 3 smartphone with ARCore capabilities at the university. Figure 28 illustrates the three main conceptual components of DiMAN.
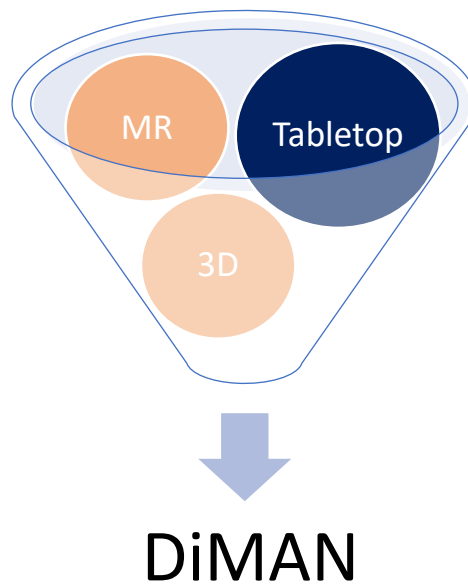


*Figure 28: Conceptual Elements of DiMAN*

DiMAN is based on a *tabletop approach* that visualizes the map on top of a table or other rectangular flat surface (e.g. carpet, floor) using the device's camera. The map is being generated by MR technologies as a hologram that is anchored to the table. It creates a three-dimensional map and is therefore subject to context influences like situation and user (chap. 2.3). The primary goal of the application is to enhance the situational awareness (chap. 2.2.1) of disaster management practitioners, specifically those working in control or crisis rooms. For this purpose, two main disaster maps were created and three different scales were considered which will be explained in detail in the following chapters. As a consequence of the status-quo-analysis (chap. 3.3) the developed maps integrate and combine real-time and customizable information in an experimental, interactive, three-dimensional mobile MR map design.

The existing tabletop mapping application using reality technologies are usually tagged by the industry as *Tabletop AR* not *Tabletop MR*. Related to still not mature definitions of reality technologies and the fact that AR is a subform of MR as a continuum this term

variations exist. Nevertheless, sticking to aforementioned definition of MR and its distinction to AR (chap. 2.4) the technology in this thesis will be called Tabletop MR because the map interacts with the table or the plane as part of the physical environment.

*Unity* was chosen as the Integrated Development Environment (IDE) for MR because it is one of the most stable and functional IDEs for creating MR experiences (Unity, 2019). Moreover, Unity has a free version which enables the programmer to use most of the required tools and is essentially a game development platform. The software basically constructs a layer-stack scene package which is a set of 3D scenes that are connected to each other. Inside of a scene different kind of worlds and environments can be built and filled with so called *Game Objects*. Every item in Unity is a Game Object. To these objects so called *Behaviours* can be attached that defines their appearance, their mobility and their interaction among each other or in respect to user interaction. Interaction and behaviours are initiated and modified using scripts of the object-based programming language C#.

Two main SDKs were utilized for the development: the *Mapbox Maps SDK* (Mapbox, 2019) for the tabletop MR creation and the *WRLD 3D SDK* (WRLD 3D, 2019) for the crafting of an indoor map. Integrated into Unity the core functionality of them turns the map and its elements into Game Objects so they can be accessed and modelled. Additionally, they serve the function of transforming geographical coordinates into Unity's world space coordinate system which origin is the centre of each scene.

Chronologically, the order of technical implementation for DiMAN was as follows (named in brackets are the software tools deployed for each point):

1) Set-up of the tabletop-MR framework (Unity and Mapbox Maps SDK)
2) Construct/Upload disaster layers (Mapbox Studio)
3) Create indoor maps (WRLD 3D SDK, QGIS)
4) Integration of disaster layers and indoor maps into the tabletop-MR-model (Unity, Mapbox Maps SDK, WRLD 3D SDK)
5) Modelling the appearance of single map elements (Unity)
6) Adding interaction and animation to single map elements (Unity)

7) Designing a user interface for the Tabletop-MR model (Unity)

8) Building for the Android platform (Unity)

Step 8 can be modified as required. Unity offers the export of its application packages to various platforms such as Android, iOS and Windows.

### 4.2.2 User Interface

Mainly, the user interface consists of two types. First, the menu interface organizes the different scenes in tabs and makes them individually accessible (Fig. 29).



*Figure 29: Main Menu of the application*
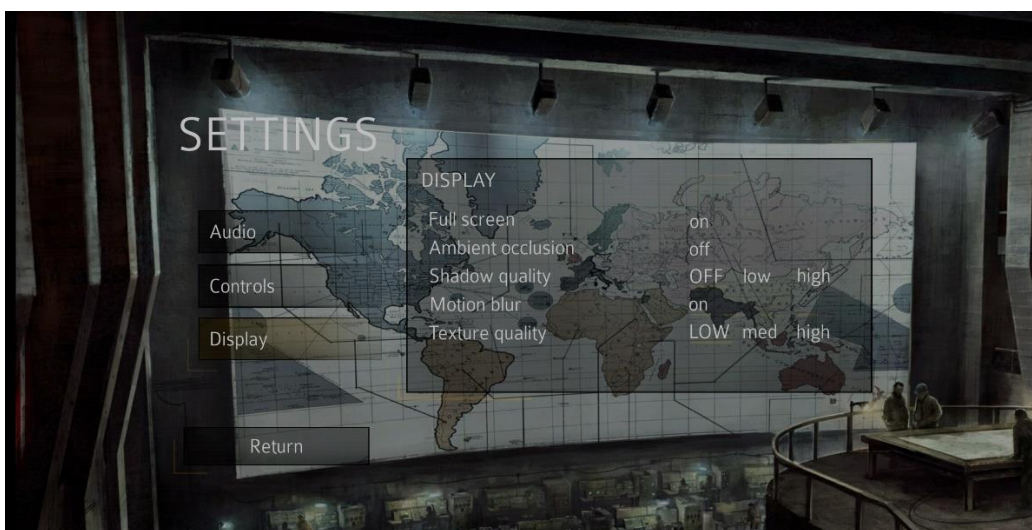


*Figure 30: Settings Menu of the application*

Nested in the main menu is a settings menu (Fig. 30) where audio, controls and display settings are customizable. The settings menu is considered to make general changes to the viewing and interaction experience of the application. At the time of submission not all settings are yet connected to fulfil their functionality. For the menu, a free menu template of the Unity Asset Store was used called "3D Modern Menu" by the creator Slim UI (Slim UI, 2019). It was then modified in the context of a disaster management application.

After entering a scene, the second type of the user interface, the map interface, will become visible and is described further in the upcoming sections.

### 4.2.3 Tabletop-MR-Scene 1: Forest Fire in Castelo Branco (POR)



*Figure 31: Tabletop-MR-Scene 1: Castelo Branco*

The first scene created for the DiMAN application is an overview scene of a forest fire event in Castelo Branco, Portugal (Fig. 31; Fig. 32). Except the vehicles all the layers are taken from a real Copernicus EMS activation of July 2019 (Copernicus EMSR372, 2019). In the top-left an info window is displayed which gives basic information about the event like the "event time" or "last update". Below the info window a small-scale overview map is placed which was produced inside Mapbox Studio as a static map image. A home button in the bottom-left corner takes the user back to the main menu. On the top of screen is the map legend which explains the meaning of the layers. All other map interface elements are scene-specific and will be elaborated on later. This kind of an L-shaped layout leaves a rectangular part of

the screen as a window for the Tabletop-MR experience. Scene 1 is the smallest scale created for the DiMAN application as part of a 3 scales strategy. It will now be referred to as *"area scale"* and is meant for the visualization of wide-spread disasters.

### 4.2.4 Tabletop-MR-Scene 2: Earthquake in Istanbul (TUR)



*Figure 32: Tabletop-MR-Scene 2: Istanbul*

On a bigger scale, the second scene shows a fictional earthquake event that impacts on some of the core quarters in Istanbul, Turkey (Fig. 32). The *"city scale"* allows for a visualization of point events that are close together. Based on the structure of a grading map (chap. 2.2.2) this map depicts buildings that have been affected by the earthquake and are damaged or destroyed. Moreover, the map shows hospitals and safe zones for civilians to gather safely. The Istanbul-scene uses the same L-shaped layout than scene 1.

### 4.2.5 Feature Description

Focusing on the individual features of the DiMAN application this chapter describes the functionality of the maps in each of the disaster scenes.

Change of base map/satellite layer

Both scenes feature a dropdown-menu in the top-right corner which holds a list of base maps that the user can select (Fig. 33). Instead of base maps, this feature could allow for the integration of consecutive satellite imagery monitoring a disaster event.
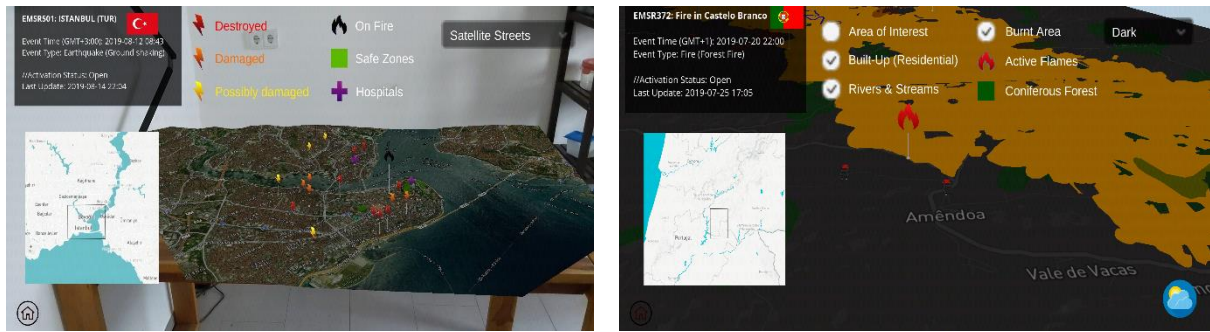
*Figure 33: Different base maps: "Satellite Streets" and "Dark"*

## Different map sizes and Zoom-feature
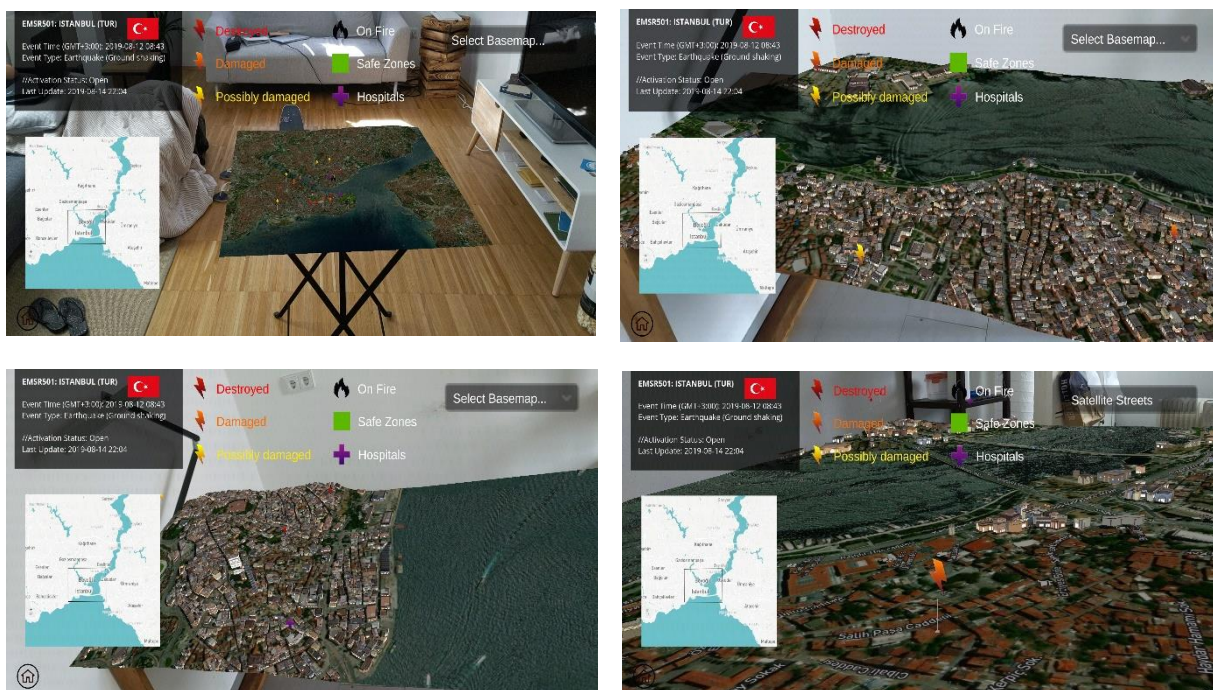


*Figure 34: Different map sizes and Zoom-feature*

According to the prevailing situation the user can flexibly zoom and pan the map using regular mobile touch controls (Fig. 34). The map will adjust to the available space of the rectangular surface, too. In this way the user can customize the map extent to his preferred settings and tasks.

## Integration of pictures and videos

Most of the markers in the maps hold a visual display (image or video) as well as descriptive textual information (Fig. 35). These components can be made visible by touching with one finger. Repeating this action with two fingers will close the popup-window.
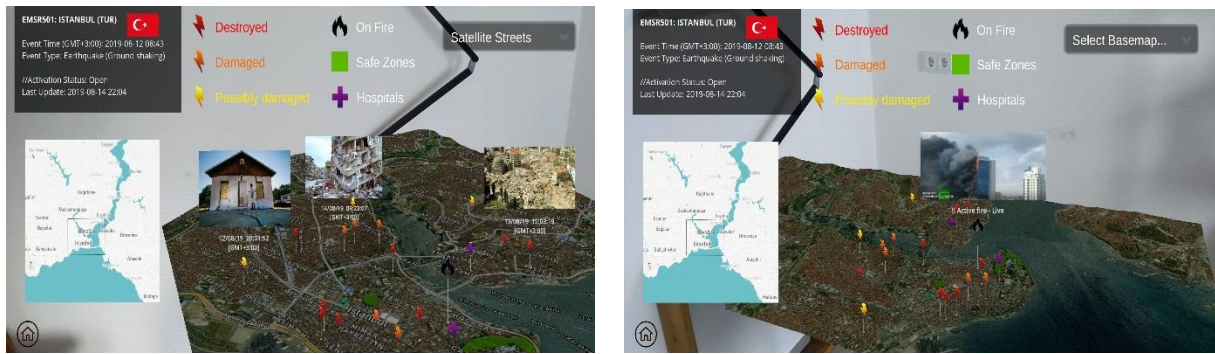
*Figure 35: Integration of pictures and videos*

Setting layers active or inactive

The legend of scene 1 has been made interactive so that the user can toggle each of the layers on and off (Fig. 36). In practice, this can be a useful tool for the customization of disaster maps and the visual analysis of disaster data.



*Figure 36: Displaying/Hiding of layers*

Real-time data integration

Every disaster layer is connected to one Mapbox Studio account. When changes are made in Mapbox Studio the layer inside the application will automatically be updated. This could serve as a model for continuously updated disaster maps backed by a disaster GIS service provider. Figure 37 shows vehicles from the fire department indicated by green circles. It is possible to connect these vehicles to GPS devices and animate them in real time.

*Figure 37: Real-time data integration*

In addition, by touch on the "weather"-button in the bottom-right corner the user will be taken to the "Windfinder"-website (Windfinder, 2019) which provides real-time information about wind speed and direction but also temperature and precipitation data.

3D Indoor Map

In the same scene a 3D indoor map was integrated which can be opened through a button-click (Fig. 33). The map was created from floorplans of an existing hotel in Istanbul aiming at realizing a "building scale" for first responders in case of an emergency. Because of data right issues, the name and the location of the hotel can not be given. Inspired by digital twin modelling (chap. 2.3) the indoor map outlines the interior structure of a building by displaying walls, doors, stairs, elevators and rooms. The level of detail can be increased as required. A dynamic slider lets the user choose the level he wants to display.

*Figure 38: 3D indoor map*

## 4.2.6 Technical problems

Few technical problems remained at the end of the DiMAN development cycle. One major issue is about re-opening or switching scenes via the main menu. The home button in the scenes takes the user back to the main menu which is working fine. When a scene is opened for a second time or another scene is chosen, the plane finder of the camera doesn't restart, and no map is displayed or a freezed map appears. Several attempts to fix this error were not successful. The app works well again when it is closed and restarted.

Another point relates to the lighting conditions of the environment. If the area is not well-lit or the conditions are dim, the performance of the Tabletop-MR decreases. For the worst case, no map is being generated. Sometimes the plane finder also doesn't function in good lighting conditions when it has problems detecting the immediate surroundings.

Panning the map leads to the situation that markers move out of bounds but are not cut off the sides of the table like the map itself. Although the base map or the satellite layer disappears, the markers are not fading and hover "in the air". This is a bug from the Mapbox Maps SDK and might be solved in the near future. During the thesis semester the Mapbox support team was contacted but didn't reply on this concern.

## 4.3 Expert Interviews

With the goal of a qualitative evaluation of the created application, 3 experts from disaster management were chosen. The idea of selection was to cover different competency and hierarchy levels to better understand their specific needs and information demands. The chosen EM professionals were asked to give their opinion on the disaster model itself and involved in a discussion about the research questions. Regarding the execution, the interviews were planned as one-on-one, semi-structured interviews with room for discussion. The disaster model was presented in the middle of the interview.

### 4.3.1 BBK – Bundesamt für Bevölkerungsschutz und Katastrophenhilfe

The first interview on the 06.08.2019 was carried out at the GMLZ (Gemeinsames Melde- und Lagezentrum für Bund und Länder) inside the BBK in Bonn with ▮▮▮▮▮▮▮▮▮▮▮. After a tour through the GMLZ, which is the national contact point of Germany for emergency and disaster situations, the conversation took place in an office close to the situation room (Fig. 39). The situation room features a digital situation wall composed of many screens depicting various relevant disaster information including maps. One of the key functions of the GMLZ is data collection and dissemination to EM practitioners.
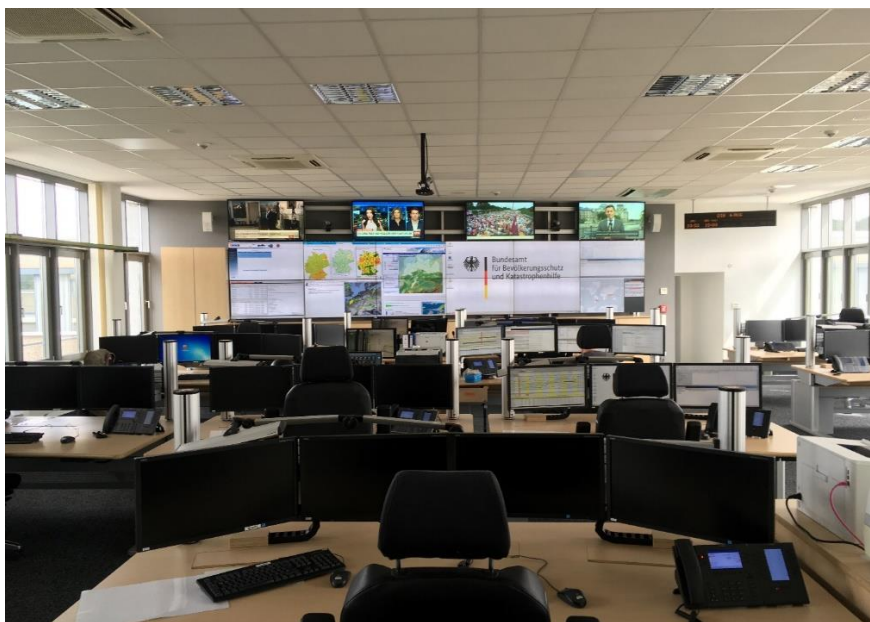


*Figure 39: GMLZ situation room inside the BBK*

[Own photograph]

Core statements of the interview at the BBK were as follows (App. 3):

➢ Used map types: *2D maps* (but: no map creation at the GMLZ)

➢ Used maps are *rated badly* qualitywise (assumed reasons: slow innovation in German federal offices, sporadic appearance of disasters → no investment in better maps, lack of human resources, no cartographic competence inside the GMLZ)

➢ *No interaction* with used maps

➢ DiMAN *evaluation positive*, assumed benefits on all management levels

➢ *Benefits of MR* were not clearly visible to the expert at first

➢ Concerns about *error proneness*

➢ Tabletop-MR approach declared as *science fiction* (not yet deployable at the BBK)

## 4.3.2 Fire Brigade Munich

On the 14.08.2019, the second interview was conducted at the main Fire Brigade in Munich with Andreas Sirtl. He deals among other things with questions about the digitalization of the fire department. The conversation took place in his office.

Core statements of the interview at the fire brigade Munich (App. 4):

➢ Used map types mostly *analogue* and *on paper* (Process of digitalization is ongoing: maps are being digitized for the use on tablets; headquarters already with GIS)

➢ Biggest problem area of used maps: *topicality*

➢ *No interaction* with used maps (except drawing on blackboard)

➢ DiMAN *evaluation positive*, two main application areas were defined: for the *education of firefighters* and in *crisis rooms*

➢ Benefits especially visible for *large area situations* with multiple fire sources

The interview was concluded with a presentation of the crisis room (Fig. 40). In the middle of the U-shaped tables exists convenient room for the Tabletop-MR application.



*Figure 40: Crisis Room of Fire Brigade Munich*

[Own photograph]

### 4.3.3 THW – Technisches Hilfswerk München-Mitte

As a well-known institution, the THW is a German technical disaster relief agency operating all over the world. 99% of the THW members work on an honorary basis (THW, 2019). The final interview was executed on the 26.08.2019 with Max Berthold from the THW local branch "München-Mitte". He has a big amount of leadership experience inside of disaster management and operations of the THW.

Core statements of the interview at the THW "München-Mitte":

➢ Used map types: *mixed (incl. 3D)*

➢ Biggest problem area of used maps: *homogeneity*

➢ Interaction level with maps: *small* (creating own layers on Google Earth)

- DiMAN *evaluation positive*, 3D perception of space enhances perception and situational awareness
- Many potential benefits of a *standardized disaster application*, but in reality → too many variables for an accurate calculation
- Not all emergency cases require a very detailed modelling

# 5. Discussion

Subsequently, the results of the case study are being discussed in combination with the found literature. At the same time, the theoretical and practical implications of this thesis research will be described as well as the limitations of the created disaster management application. This discussion critically reviews the findings of this paper.

The user requirement's survey developed general insight into the disaster management community. In the section of current problems and biggest challenges, the results have a high similarity with the preliminary gap analysis of the SAYSO project (chap. 2.2.2). Maps at first seem to be a secondary issue for most practitioners. Concerning the map types used, it was surprising that against the initial assumption of this thesis, almost 60% of the participants named 3D visualizations as the most common map type in EM. This result might be subject to change with a bigger sample size. Mobile devices and reality technologies as cartographic mediums have not really found their way yet into the field of EM which goes along with the slow innovation lifecycle stated multiple times. The strongly negative assessment of the quality of the maps and the received information quality boosts this research's significance as it points to a real backlog and improvement necessity. Another clear outcome of the survey was the demand of real-time information and the requested integration of this data into maps. The lack of human resources in EM was one more dominant theme of the survey. It also became obvious that due to the complex structure of EM, it is difficult to identify one problem area for the whole domain.

For the practical development of the disaster application, the technical problems (chap. 4.2.6) underline the sensitivity of the model. Especially in the field of EM where life hangs in

the balance, it is essential to remove any errors before the technology can be deployed safely. Another limitation of the model is the big demand of data coming from various sources which might not be possible to obtain due to availability, financial or legal reasons. Moreover, the application is dependent on a platform which is capable of its realization.

Nevertheless, the disaster model was able to show the potential of cartographic 3D and MR applications which was confirmed by the interviewed experts from the field (chap. 4.3.3). The benefits of reality technologies for disaster management was not only indicated in the survey but also re-affirmed by the experts. Due to independent factors like a lack of political engagement and investments into the disaster infrastructure, it cannot be predicted when the new technologies will finally be put into practice, regardless of their benefits.

## 6. Conclusion & Outlook

Disaster Management is a complex, interdisciplinary and multi-actor process. Most of the current mapping products used don't really support situational awareness. Therefore, improvements are necessary and requested. Whereas plenty of tools and cartographic solutions are already on the market and able to facilitate a better situational awareness during emergency situations, they seldom play a role in active disaster response planning. Mixed Reality and 3D approaches can be a useful visualization tool for disaster management as they simplify and enhance the perception of reality as well as allow for the dynamic integration of data coming from multiple sources. Limitations exist in the form of technicalities, areas of application and hardware dependency. Another aspect to consider is the degree of detail inside the maps which depend on the type and severity of the disaster. For some emergency events it might not be necessary to create digital twins to their full extent. In conclusion, the assumed hypotheses (chap. 1.2.3) have been proven true and therefore the research objective has been fulfilled. Future research should be directed at specific disaster types and the further development of the Tabletop-MR approach.

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| Employed by | Profession |
|---|---|
| GAF AG | *Senior Expert Remote Sensing and GIS* |
| THW | *Bürosachbearbeiter (BsB)* |
| Help.NGO | *Technology Specialist* |
| Ministerium des Innern und für Kommunales Land Brandenburg | *Polizistin* |
| Freistaat Bayern | *Verwaltungsbeamter* |
| Bayerisches Staatsministerium des Innern, für Sport und Integration | *Dipl. Verwaltungswirt* |
| Freistaat Bayern | *Beamter* |
| Berufsfeuerwehr München | *Brandoberinspektor* |
| Wasserwirtschaftsamt | *Hydrologin* |
| WWA München | *Bauingenieur* |
| Freistaat Bayern (WWA) | *Bauingenieur* |
| Branddirektion Frankfurt am Main | *Feuerwehrbeamter* |
| Freie und Hansestadt Hamburg | *Feuerwehrbeamter* |
| Bundesamt für Bevölkerungsschutz und Katastrophenhilfe | *Referent* |
| Bundesamt für Bevölkerungsschutz und Katastrophenhilfe | *Sachbearbeiter* |
| Bundesamt für Bevölkerungsschutz und Katastrophenhilfe | *Dipl. Geograph* |
| Behörde | *Ingenieur* |
| Bundesamt für Bevölkerungsschutz und Katastrophenhilfe | *Referatsleiter* |
| Land Rheinland-Pfalz | *Polizeibeamter, derzeit beim BBK* |
| Wasserwirtschaftsamt | *Fachbereichsleitung Monitoring, Hydrologie, Warndienste* |
| DRK | *Einsatzleiter* |
| öffentlicher Dienst | *Sachbearbeiter* |
| Landkreis | *Beamtin* |
| Stadt Dessau-Roßlau | *Sachbearbeiter Katastrophenschutz* |
| Landkreis Stendal | *Angestellter* |
| Landkreis Anhalt-Bitterfeld | *Sachgebietsleiter Brand- und Katastrophenschutz* |
| Bundesamt für Bevölkerungsschutz und Katastrophenhilfe | *Dozent* |
| BBK | *Referentin* |
| THW | *Einsatzleiter* |
| BBK | *Referent* |

**soSci**
oFb - der onlineFragebogen



**English**



Deutsch

M.Sc. Kevin Helzel, Technical University of Munich, Cartography – 2019

# EMERGENCY MANAGEMENT QUESTIONNAIRE

**WELCOME!**

Thank you very much for participating in this survey.

You have been contacted because you work in one of the following parts of the emergency/disaster management chain:
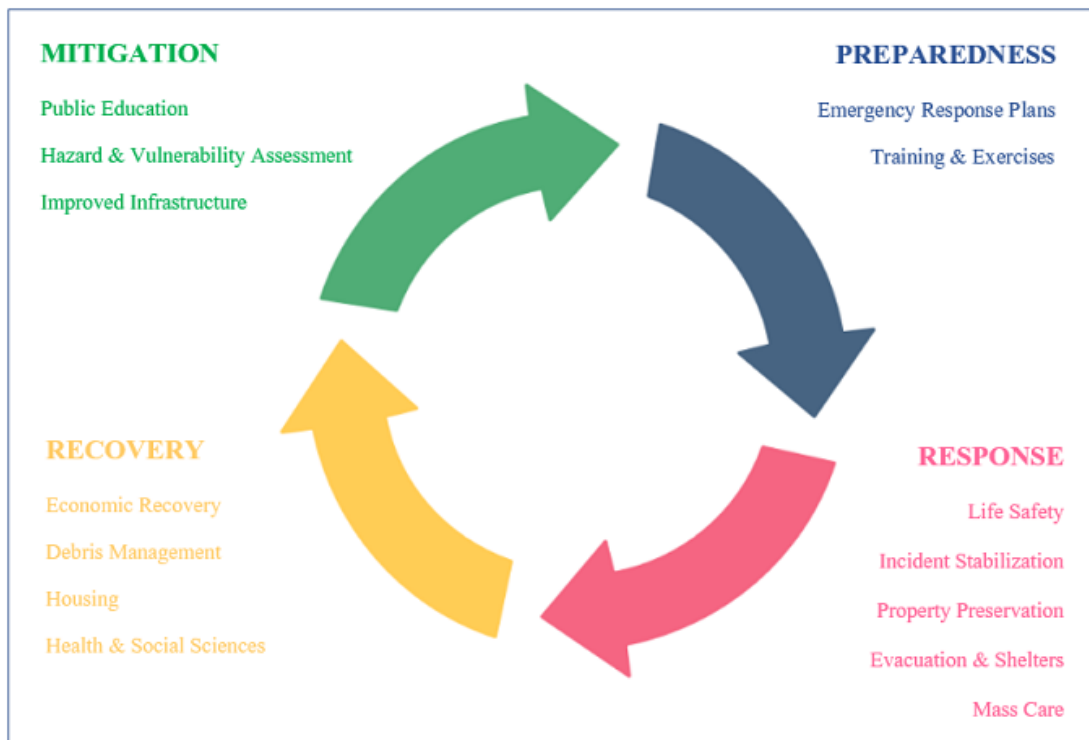


SOURCE: Onslow County, NC (2019) [modified]

Every answer will be a great support for my master thesis and a valuable contribution to the future of emergency/disaster management!

Your data is going to stay 100% anonymous and encrypted. It will not be stored longer than 6 month.

LET'S GO!

Next

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### 1. Please enter your age.

[Please choose] ▼

---

### 2. Who is your employer and what is the title of your profession?

| Employer | |
|---|---|
| Profession | |

---

### 3. How long have you been working at your current job/position?

[Please choose] ▼

---

### 4. Would you describe yourself as experienced in your domain?

| ○ | ○ | ○ | ○ | ○ |
|---|---|---|---|---|
| Absolute Beginner | Beginner | Intermediate | Experienced | Very Experienced |

**Next**

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**5. Please describe 1-3 of your recent activations/missions which paint a representative picture of your job (in note form, short but precise).**

**6. Were the described activations/missions carried out successfully in an optimal way (from your perspective)?**

○          ○          ○          ○          ○

**7. In case of problems, please name the main causes/obstacles that interfered with the correct execution of the mission.**

☐ Internal communication

☐ Digital devices (e.g. computer screens, tablets)

☐ Missing human resources

☐ Lack of significant decision-making information (e.g. satellite images)

☐ Inefficient leadership structure

☐ Cartographic products/maps

☐ Individual mistakes

☐ Unthorough execution

☐ Independent circumstances

☐ Other

**8. Where do you see – from your personal point of view – the biggest challenges in your domain at the moment?**

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40% completed

**9. Which kind of maps are you using during operations as well as for mission planning and/or post-analysis purposes?**

- ☐ 2-D analogue maps
- ☐ 3-D physical landscape/terrain/city models
- ☐ 2-D web/digital maps
- ☐ 3-D visualizations using computer software
- ☐ Maps using Virtual Reality/Mixed Reality/Augmented Reality technologies
- ☐ Other

**10. How or on which kind of devices are these maps being viewed?**

- ☐ Analogue (e.g. printed maps)
- ☐ Digital screen (e.g. desktop computer)
- ☐ Advanced digital screen I (e.g. digital situation wall)
- ☐ Advanced digital screen II (e.g. multi-touch/tangible tables)
- ☐ Digital mobile screen (e.g. smartphone, handheld-device)
- ☐ Hologram (e.g. tablet using Virtual Reality/MixedReality/Augmented Reality technologies)
- ☐ Other

**11. In case you have already worked with either 3D, Virtual Reality, Mixed Reality or Augmented Reality technologies at your job, please explain your experiences shortly (incl. the device you were using).**

**12. Which sort of information is displayed on/shared through maps?**

- ☐ Topographic information (natural, man-made structures of the environment)
- ☐ Thematic information (mission-specific)
- ☐ Updated information (e.g. situation updates)
- ☐ Real-time information (e.g. position of first responders)
- ☐ Customizable information (interactive, dynamic)
- ☐ Georeferenced video-livestreams
- ☐ Other

**13. How would you rate the quality of the maps you are working with in general?**

○     ○     ○     ○     ○     ○     ○

**14. How satisfied are you with the quality of the information you receive from maps?**

○     ○     ○     ○     ○     ○     ○

**15. Is there any type of lacking information during current missions that you currently don't have access to but would improve the quality of your work? If yes, what kind of information?**

Next

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60% completed

**16. Please rank the following aspects according to their necessity/importance of being improved in the near future.**

| | | | |
|---|---|---|---|
| Internal/external communication | Cartographic products/maps | Real-time information sharing | Combination of cartographic visualizations and real-time information sharing |
| Combination of cartographic visualizations and internal/external communication | Technical equipment | Human resources | Digital devices |

1

2

3

4

5

6

7

8

**17. Do you see benefits in using new state-of-the-art Virtual Reality/Mixed Reality/Augmented Reality technologies (e.g. holographic overlays providing additional information on top of a 2-D map) in the field of emergency management?**

**18. How big would you rate the benefits/potential of Virtual Reality/Mixed reality/Augmented Reality technologies in the field of emergency management/disaster response?**

○　　　○　　　○　　　○　　　○　　　○　　　○

**19. Is there anything else you want to contribute to this study which was not covered in this questionnaire? Feedback?**

Next

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# Thank you for completing this questionnaire!

We would like to thank you very much for helping us. Have a good, disaster-free day :D

Your answers were transmitted, you may close the browser window or tab now.

M.Sc. Kevin Helzel, Technical University of Munich, Cartography – 2019

████████████

Gemeinsames Melde- und Lagezentrum von Bund und Ländern (GMLZ)
Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK)
Provinzialstraße 93
53127 Bonn

REMARKS: translated into English, vernacular language has been corrected
I = Interviewer
E = Expert

I: Hello! Thank you for showing me the GMLZ from inside. It was very interesting. Can you tell me again for the record a little bit about yourself and your job here in the GMLZ?

E: Yes, sure! My name is ███████████ and since 2017 I'm working as an assistant and shift foreman at the GMLZ inside the BBK. I have previously been part of the voluntary firefighters and the emergency service where I gained leadership experience. The BBK is the federal agency for civil protection and disaster help with a 24/7 availability. As such it is the intersection between the European Union and the German individual states and keeps the information exchange ongoing. Here in the GMLZ we have 3 major tasks: observation of the current situation, being the national contact point for emergency requests and management of resources. Of course our main focus is about German interests. Principally we are a service provider for other institutions and offices. No small stuff

I: Which kind of maps and cartographic visualizations do you currently use in the GMLZ for disaster management and response?

E: Most of the maps we are dealing with are 2D maps as PDF or web maps. It is important to know that we don't create the maps ourselves. Our job is more about the collection and bundling of information which include maps from our rich list of partners (e.g. DWD). Afterwards we create situation reports where we integrate those maps and keep an eye on the developments of the event.

I: In a pre-survey for my master thesis many of active professionals rated the quality of their maps and the quality of information they receive from them "bad" or "very bad". Do you agree with that? Are the current visualization techniques adequate and capable of facilitating an effective management of disasters?

E: This is definitely the case. To be honest the maps we receive seldom show what we want. In this respect we are at least 2-3 technology steps behind what would be possible.

I: What reasons can you imagine for this state?

E: The innovation management is generally very slow in German federal offices. Another problem is that disasters usually only happen sporadically, so no money is invested to change anything in the long-term prospect. The same counts for human resources, there are too few people consistently employed in disaster management. Inside the BBK geographical competence is missing at the moment. Furthermore, the responsibility and leadership for disaster management in Germany is in the hands of the individual states. We are more a national information center which assists.

I: How and from where do you receive up-to-date information and data about a disaster?

E: We receive all the data from our partners. In the GMLZ there is a digital situation wall which consists of TV news monitors and monitors with different purposes like displaying various types of maps and information. Then we are an authorized user of the Copernicus programme which means we can request satellite imagery for certain areas of interests. We also advise our clients if it makes sense to activate Copernicus or not.

I: In what way is it possible to interact with your maps?

E: As we are only collecting and providing information, there is no real interaction with the maps.

*[ The self-developed application is being presented to the user.]*

I: What is your first impression of the model itself and its features?

E: It looks very interesting but for us this is still too much of science-fiction. Before we go into Augmented Reality, we first need to improve our simple 2D maps. Between university and the BBK there are at least 2-3 technology steps. That is why at the moment your model looks like Star Wars.

I: How useful would you consider technologies like 3D and AR in disaster management?

E: There is potential use for your application on all hierarchy levels. It would be good for collaborated and synchronised work environments with access to comprehensive data sources. But the availability of the data will be a big problem. Also in a decentralised system like in Germany usually different actors have different information needs. The integration of every dataset to a standardized model is a big challenge and the question is how it would be realized.

I: Thank you very much for this conversation!

E: It was a pleasure having you here. Thank you for coming to Bonn.

Andreas Sirtl

Hauptfeuerwache IV – Branddirektion/Katastrophenschutz/Zivilschutz
Heßstrasse 120
80797 München

REMARKS: translated into English, vernacular language has been corrected
I = Interviewer
E = Expert

I: Hello! Thank you for the invitation. To begin with, please introduce yourself and your work!

E: Hello, my name is Andreas Sirtl and I am working in the IT section of the main fire department no. 4 in Munich. In my everyday job I am dealing with questions about the digitalization of the fire department.

I: Which kind of maps and cartographic visualizations do you currently use in your department for disaster management and response?

E: Most of our maps still work analogue. These paper maps are now increasingly being digitalized to view them on tablets. These are essentially the same static maps in a PDF format. Additionally, we are using official basic Geo Data from the city and also layout plans with the footprint of houses up to a scale of 1:5000. The digitalization still has a long way to go. But the headquarters and control rooms have their own GIS.

I: In a pre-survey for my master thesis many of active professionals rated the quality of their maps and the quality of information they receive from them "bad" or "very bad". Do you agree with that? Are the current visualization techniques adequate and capable of facilitating an effective management of disasters?

E: The main flaws of the maps we are using is the up-to-dateness of them. Fire safety plans of houses can be very old and are not updated regularly. More interactivity and more user-friendliness would be beneficial. Also a current situation map or live images from the spot would be good.


*[ The self-developed application is being presented to the user.]*


I: What is your first impression of the model itself and its features?

E: Thank you for the presentation. The model looks good.

I: From your perspective, does it make sense to incorporate additional dimensions beyond 2D like 3D or Augmented Reality into the maps you are using for disaster management?

E: Two areas of application come to my mind. One use case would be to use in the training and education of firefighters. Augmented Reality can create a very vivid and descriptive model of reality. Moreover, there is a big potential to use it inside of crisis rooms as kind of a interactive, collective disaster model to work out on response plans.

I: Thank you very much for this conversation!

E: I have to thank you. Looking forward to reading your thesis!

Max Berthold

THW Ortsverband München-Mitte

Schleißheimerstr. 387

80935 München

REMARKS: translated into English, vernacular language has been corrected

I = Interviewer

E = Expert

I:  Hello! Thank you for taking your time. For a start, can you please introduce yourself and your profession?

E: Good evening! My name is Max Berthold and I have been part of the THW for 44 years. I am occupying a leading position for the district of München-Mitte since around 25 years. All the work we do here functions on an honorary basis.

I:  Which kind of maps and cartographic visualizations do you currently use in your department for disaster management and response?

E:  We are using a mix of different products. First, there would be the topographic maps with a scale of 1:50.000, the former NATO maps. But we also have them in other scales like 1:25.000 or 1:10.000. These maps are paper maps but are increasingly being digitalized. Then we are using geodata provided by the city of Munich in the form of a city plan and other official products like the Bayern Atlas from the Bavarian state authorities in PDF/JPEG format or as a web map. Moreover, we make use of publicly available mapping software like Open Street Map, Google Maps or Google Earth.

I:  In a pre-survey for my master thesis many of active professionals rated the quality of their maps and the quality of information they receive from them "bad" or "very bad". Do you agree with that? Are the current visualization techniques adequate and capable of facilitating an effective management of disasters?

E: On the one hand this is surprising to me, on the other hand not. Two things come to my mind at first. Primarily, people are ignorant about how to use the existing maps in a correct way, there is no explicit training for that. Also, people might be angry because they are not allowed to use certain maps, or they do not get equipped with the right tools and would have to use their private devices. But I have to say that the satellite imagery we receive, or Open Street Map are of a high quality already. The biggest problem with the maps is that there is no homogeneity between them. For example, plans of water pipes or electricity networks exist in different scales and different level of detail. There is no GIS system which integrates all the relevant maps into one platform. GeoKAT is a GIS system for disaster management from the Bavarian state. It is about the organization of resources, but it is not area-wide available yet. Other points for improvement are the possible zoom-level, user-friendliness, the data bandwidth required for viewing the maps or the dependence of certain maps to be connected to the Internet. Of course, a big potential for improvements exists.

I:  How and from where do you receive up-to-date information and data about a disaster?

E: The activation of the THW can be requested by several institutions or eligible members like town courthouses, fire department headquarters or on a higher state-level [Bavaria]. Usually many actors are working to get the situation under control depending on the severity of the disaster and the disaster type. So, if for example satellite imagery, video-livestreams from a police helicopter or drone imagery was requested, this information will also be shared with us. We as well own sensors and devices that can be used to monitor disasters like thermographic infrared cameras for urban fires. Some data (e.g. real-

time GPS positions of vehicles, first responders) are theoretically possible to obtain but data protection rights are called from unions. It depends on the agreement of your staff they give permission to be tracked.

I:  In what way is it possible to interact with your maps?

E: The level of interaction is still very small. Now and then we create a few layers of geodata on our own. Here Google Earth Pro is a good, free software. When for example a 2$^{nd}$ world war bomb was detected, we draw an explosion radius around and in combination with data from local registration offices we can approximately calculate how many people would be affected.

*[ The self-developed application is being presented to the user.]*

I:  What is your first impression of the model itself and its features?

E: It's a really cool application that you have created. I like the features and the idea very much. The capability to zoom and showing information in an alternative way can help a lot. Thank you for showing!

I:  From your perspective, does it make sense to incorporate additional dimensions beyond 2D like 3D or Augmented Reality into the maps you are using for disaster management?

E: Very much. These technologies sound promising. Having a 3D perception of the disaster scene creates a much better and more graspable impression of what is going on. The overview of the situation would also become faster. We are naturally lagging a bit behind in what happens in current research. Augmented Reality seems to be very flexible and there is a big potential for numerous features. It's a great idea. One drawback of your model I would see in the heavy reliance on data provided via the Internet.

I:  How do you consider an application which integrates many layers of geoinformation into to make them comparable?

E: This is of course great in theory. It would be the dream of every disaster manager to have something like that. Nevertheless, you must work with what is available. Some legal issues like data protection rights and restricted use of datasets stand in the way of the development of a kind of standardized application. To this comes the fact that in a disaster situation in real life too many variables are present, and any forecast would be subject to all of this. One variable is changing slightly and the whole situation changes. A single model can hardly predict all the environmental influences. Moreover, not always do you need so much information. It always depends on the severity of the disaster as well.

I:  How useful would you consider technologies like 3D and AR in disaster management?

E: I see many possible and beneficial fields of applications for both. Maybe it is a bit comparable to Augmented Reality DTMs for pilots so they can "see" when the weather is foggy and cloudy. It is a great technology but not yet used by airlines because it is not stable yet, errors must be minimized when lifes are at stake. These technologies will all become integrated at some point in the future, but they must be resistant to error.

I: Thank you very much for this conversation!

E: I have to thank you. Looking forward to reading your thesis!