Exploring Augmented Reality Design Recommendations to Create a Safe and Efficient Leak Detection for the Surveyor

Master's thesis in Computer science and engineering

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Abstract

The user of a surveying system has to be safe and efficient when performing tasks out on the field. There are many hazards such as oil fields, gas leakages and rough terrain that can harm the user if no safety is present. Research suggests that there are many benefits with augmented reality being used for engineers and similar professions. Through an exploratory research approach, this specific project aimed to discover the advantages with interaction design and user experience to design a new augmented reality interface that can contribute with safety and efficiency for the surveyor. The new design solutions will provide a new perspective on how creative ideas can be created to make an augmented environment crucial for the surveying activities. During the process, two unique solutions were constructed that touch upon both the safety and efficiency aspects. The first soultion is a wind direction compass that highlights the orientation of the wind as well as providing location awareness. The second solution is a self-inspection checklist that has to be completed by the surveying user in order to increase the safety awareness. The solutions were created using digital tools in order to make simple and effective final prototypes that can be verified and tested. The project concluded with evaluation on these prototypes and the feedback and results gathered from that phase helped with the development of essential design guidelines as well as a crucial comprehension of the problem and solution space.

Keywords: prototyping, interaction design, user experience, augmented reality, design methodology, design recommendations, safety, efficiency, surveying, land surveying, augmented surveying, construction, engineering safety, creative thinking, creative solutions, digital tools, surveyor.

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Thomas Jinton, Gothenburg, August 2023

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1
Introduction

Surveying engineers are people who work out on the field and they have multiple equipment and cartography tools with them when doing their job. Land surveying is a profession where safety is of paramount importance and in addition the surveyor has to be efficient when performing the necessary steps of the job. Many of the tools and equipment are traditional and conventional and with the rise of new technology, other more advanced devices can be used by the surveyors out on the field. One of the new emerging technologies is Augmented Reality and it has the potential to assist the surveyor in their task and primarily increase safety and efficiency for the user of the augmented reality system. When working with land surveying there are multiple factors that can affect the safety aspects, both the terrain around the user and the actual surveying augmented reality equipment can contribute with some risks. Understanding the actions and performance of the augmented reality system is significant in order to improve the safety as well as the efficiency for the surveyor. Furthermore, the new system should be effective and precise when it comes to visualizing information to the user about leaks and hazards when performing the surveying actions.

Land surveying can be a mental and demanding process depending on the environment around the user. Gas fields and underground pipelines can be located in any type of terrain, where conditions can be both rough and dangerous. With this perspective in mind, the augmented technologies can be used to increase and improve surveyor's safety and efficiency. Understanding what safety is for the surveying user is significant and additionally understanding the tasks and actions the surveyor performs is crucial in order to reflect on how to establish efficiency and safety when using the augmented technologies. The process of grading leaks is something that requires the surveyor to have boots on the ground [41] and therefore the user will be in close proximity to potential hazardous elements. From the perspective of the company it is essential to guarantee that the surveying user is safe from harm when performing the required tasks. Several aspects regarding the augmented reality equipment and system needs to be considered in terms of safety as well as efficiency, especially since many studies have shown that people are overly optimistic with regard to their own personal risks [8]. Therefore, the actions and movements of the surveyor are of key interest to explore from both a safety aspect and an efficiency aspect.

This Thesis project will aim to gain understanding about how efficiency and safety can be improved when a surveyor is performing certain significant tasks; while also exploring what aspects of the augmented reality user experience that can contribute to the safety and efficiency perspectives. In essence, through the absoluteness of this Thesis, the following unique and definitive research questions will be answered:

- ***When performing the surveying tasks, what actions can influence an augmented surveyor system in relation to the safety and efficiency of the user?***
- ***What are the essential design recommendations to establish a safe and an efficient augmented surveyor system?***

The Thesis project will conclude with a presentation of the results as well as the recommended guidelines that are crucial for the comprehension of the design solutions. The results can be viewed from multiple perspectives and going back to previous chapters the essence of the Thesis will be transparent.

2
Background

The augmented technologies have been used in many different areas as a tool to enhance certain experiences or help users with completing tasks or to increase the learning aspect. Within the construction and engineering industry, safety and efficiency are terms that are taken seriously and users out on the field must have guarantees that they can work safely and free from harm. This section will provide the sufficient background necessary to establish why safety and efficiency are key areas for the augmented tools and the section will also give a strong foundation for the importance of the research questions.

The context the project has with ABB is that augmented technologies are believed by the company to be vital to the new future of land surveying. ABB has a strong focus on manufacturing robotics, automations, transportations and surveying technologies. All of the current manufactured items are in need of new technologies and this is where augmented reality comes into the picture. Especially for the surveying profession there is need for creative solutions with how to make the surveying activity safe and efficient and this is where the connection between the project and ABB lies.

2.1 What is Surveying?

Current solutions exist at ABB where gas leak detection services are provided to the market. Surveying is a term that can be seen as similar to leak detection and the surveyor is the person who performs the actions to find and mark for example gas leaks or other hazard emissions. Surveying can be referred to as Land Surveying, because often the detection of gas leakages occur in the outside environment. The essence of surveying is that the responsible surveyor scans an area for potential leakage locations and determines certain attributes like concentrations and distributions of the gas. When using the term surveying the focus is on the actions and movements that the surveyor performs when scanning the terrain and land. Unique equipment is used for this profession as the gas has to be studied with instruments in order to determine the many attributes of the gas.

2.2 Safety for Surveying Engineers

The aspect of safety and efficiency are two keywords that exist for many different types of professions and techniques. Especially for the construction industry the two terms prove to be essential for the people who are working for the large industries. Ming-Kuan Tsai explains that for construction engineers out on the field, protecting their safety and health is of paramount importance [2]. The author suggests that researchers believe in safety training as a key solution for achieving safety improvements. The author continues by revealing the growth of information technology(IT) in the world and highlights that the new information technology applications and techniques can be good solutions for helping with safety [2].

The aspect of safety is critical when it comes to the aspect of failure as well. Verma et al. explains that it is important and essential to understand *"why"* and *"how"* families occur in order to achieve safety for engineering systems [3]. The authors underline certain factors that highlight the need for better and higher safety, for example Safety considerations with undesirable consequences, Accelerated growth of technology and Increased product complexity. Verma et al suggests that by using good components and quality control practices safety can be improved [3]. Furthermore the authors highlight some aspects that can lead to failures and errors, which in turn affect the safety for engineers. For example, poor maintenance and design errors are some of the elements to consider when it comes to safety concerns [3].

Parker et al. explains that for the mining profession the area and air can be very dangerous and the hazardous work environments can lead to health issues if there is no proper focus on safety [5]. Health problems such as musculoskeletal disorders, respiratory illness, noise induced hearing loss, and traumatic injuries are consequences. The authors emphasize the difference on how supervisors and employees view safety aspects at the workplace [5]. Employees in a workgroup have contrasting views on safety compared with the supervisors and management.

According to Ben Ale the term safety is associated with things like incidents and accidents [6]. This means that safety is used for specific instances, for example when a threat is an unwanted side effect of something else that the developing engineers want. The author highlights that safety along with health and the environment are often considered as essential things to protect [6] and they are worth the protection as well. Anthony Bainbridge suggests that at the start of a product's journey the safety of that product has a cost, a price and a value [7]. Furthermore the author underlines the terms that can be connected to the state of being safe. For example being safe is considered being protected against physical, psychological, occupational, spiritual and social types of consequences [7]. In addition, other types of undesirable consequences can include for example failure, damage, errors, accidents and harms.

Hinze et al. explains that the safety performance is the result of the safety process and if the process is weak or insufficient then more injuries can occur [22]. The authors highlight that in order to increase safety the construction process for sustainable production should involve setting safety as well as health and the environment as production design parameters. The authors also point out that construction workers are arguably the most valuable resource for construction and their well-being is of paramount importance [22]. In addition, Cheng et al. explains that construction activities include physically demanding tasks and actions [26]. Things like heavy lifting and carrying, forceful exertions, pushing and pulling, sudden loadings, repetitive motions, vibrations, and awkward work postures are examples presented by the authors. Furthermore Cheng et al. reveals that the physically demanding tasks are often performed in harsh environments and that there is still need to improve work site conditions [26].

2.3 The Usage of Augmented Reality

Hafsa and Majid point out that augmented reality has become an emerging platform in the field of education as well as in the industry field [23]. The authors highlight that augmented reality systems are available on the market, for example smartphones, smart glasses, head-mounted displays and other augmented reality devices [23]. Ghazwani and Smith also suggests that augmented reality is an emerging technology but that the consumer product status of augmented reality technologies is not widespread or mainstream yet [24]. One of the factors behind this is that the user experience needs to be enhanced according to the authors. However, Koelle et al. points out that augmented reality applications have become increasingly popular in recent times with the help and spread of portable and cheap high-fidelity mobile devices such as smartphones, tablets and dataglasses [25].

The emerging wave for augmented reality has led to a rising trend of utilizing augmented reality technologies in practical applications. Examples of application areas include education, design, construction, manufacturing and entertainment [28] according to Chi et al. The authors suggest that for these areas there is a potential with augmented reality to improve existing technologies and also a better quality of life can be provided. In addition, the authors highlight that augmented reality applications are becoming more variable and popular [28], and that the augmented reality technologies are becoming more well-established. It is described that several research studies have been conducted on the application of augmented reality in the field of engineering and additionally the establishment of augmented reality has become easier in the fields of engineering and construction. Chi et al. presents that this is because of the improvements done to the tracking methods used for augmented reality [28]. The authors conclude by stating that the future utilization of augmented reality will be extensive based on the current state of existing augmented reality applications.

Substantial and unique research have been performed with focus on using augmented reality for different areas of engineering. The usage of augmented reality within engineering has rotated from extensive technical environments to smaller conventional technical environments. For instance, augmented reality has been used for emergency procedures surrounding fire suppression and evacuation training [4]. Kang et al. reveals that there are strengths with augmented reality as well as virtual reality to visualize a realistic environment for fire drills training. In addition to the augmented reality visualizations the authors constructed a fire-extinguisher prototype to be used for the simulations when wearing a head-mounted display that envisions the environment [4]. Further smaller areas of augmented reality implementations have been used for museums. For example, an augmented reality system for an Ultra mobile PC was implemented to guide museum visitors around the exhibitions and arts [15]. Wang and Schnabel highlight that an enhanced guidance system has been used as well for the museum setting, focusing on giving the visitor additional location and object-aware multimedia content with the help of camera-equipped mobile phones [15].

An example of a more extensive technical implementation of augmented reality has been used for military maintenance. Henderson and Feiner constructed an augmented reality application prototype that serves as a maintenance tool for military mechanics [29]. The authors explain that the prototype supports a specific vehicle, named LAV-25A1, an armored personnel carrier and light-wheeled military vehicle. The mechanic for this vehicle operates inside the turret of the LAV-25A1. The authors highlight that the process of maintenance in this case is time consuming and physical, especially for the neck and head [29]. In addition to the augmented reality system, Henderson and Feiner present another tool for the maintenance process, a wrist-worn controller to assist the mechanic with the maintenance and repair of the vehicle. The authors underline the importance of augmented reality for their application and that it helps to enhance several things, for example localization, attention-directing, context-setting 2D and 3D graphics and animated sequences [29].

3

Theory

This section presents the relevant theoretical concepts and significant frameworks that surround the Master's Thesis research and study. In order to understand the overall ambition and goals of the Thesis it is important to see the concepts and relevant areas in a model that represents the structure and orientation of the essential theory. The concepts and how they are connected are presented in Figure 3.1. In the following sections of the Theory chapter the theoretical concepts and academic material will be introduced. By viewing and gaining comprehension of the extensive theory, the core goals and essence of the Thesis project will be made clear and understandable. In principle, the theory part of the Thesis can be seen as the crucial foundation that strengthens the credibility of the research and study.

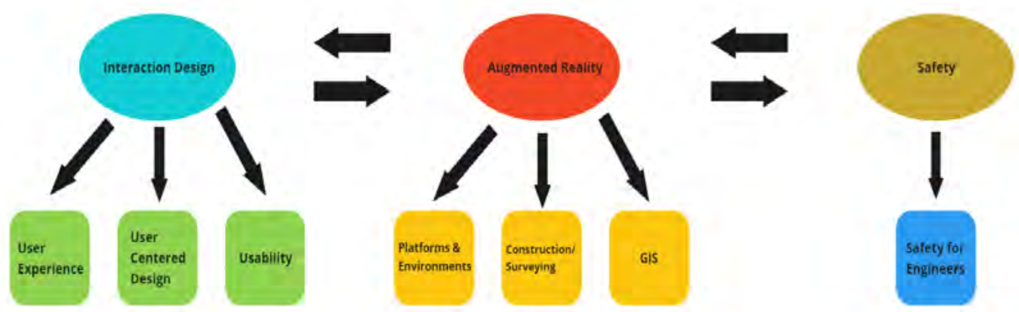


Figure 3.1: Connections between theoretical concepts and important areas surrounding the Thesis' research.

3.1 The Interaction Design process

The authors of *Interaction Design: beyond human-computer interaction* explains that there are many fields of design [9]. When designing an interactive product the creator can do it in many different ways and the essential steps do not have to be similar for every creation. However, the authors highlight that there are four phases that a designer should approach when starting the development of a product [9]. These four phases are the following:

- Discover
- Define
- Develop
- Deliver

The four phases can, according to Sharp et al., be viewed and captured in the double diamond of design [9], as shown in Figure 3.2. One of the unique characteristics with the double diamond model is that it can be adaptable and that it illustrates a simple visualization of the design process [17].

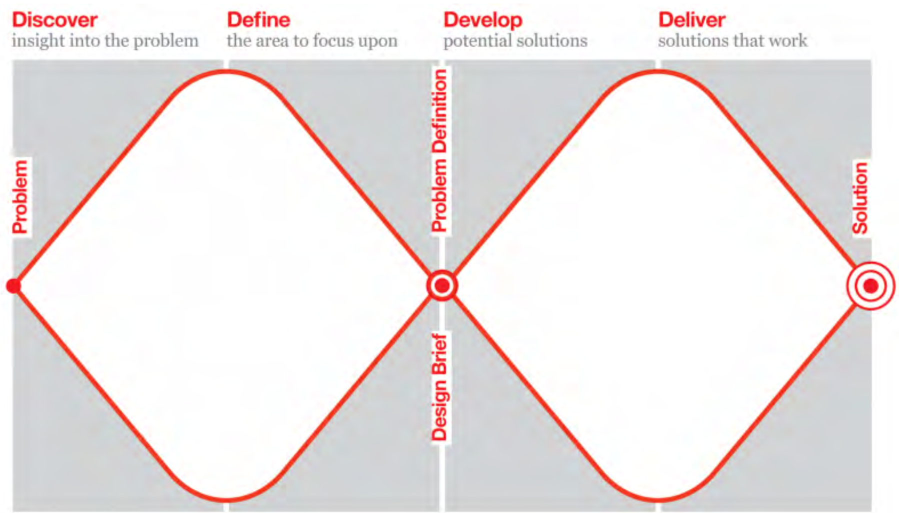


Figure 3.2: The Double Diamond of Design, as presented by Sharp et al. [9].

Raposo et al. specify that the phases of the double diamond represent a combination of thinking styles for the designer [17]. They continue by explaining that the thinking process of design can be divergent and convergent. When thinking from a divergent perspective the designer can receive a good understanding of the design context and find out where potential solutions are. From the convergent perspective it is good for removing uncertainties which in turn leads to finding optimal solutions. The editors also highlight that analysis and synthesis are crucial characteristics of the design and that the four phases show the generic structure of every design process [17]. Another benefit with the phases of the double diamond is that it allows designers to work efficiently with non-designers and that there is room for flexibility in the overall process.

Sharp et al. emphasizes that attention on users and their goals is a major focus area for interaction design [9]. Within interaction design there are essential activities that should be followed in the life cycle process. The authors explain that the four activities are:

- Discovering Requirements
- Designing Alternatives

- Prototyping
- Evaluating

The four activities are described as the following in full detail:

Discovering Requirements: This activity is described as iterative and that it is about discovering something new and defining the thing that is going to be developed [9]. By discovering and comprehending requirements a designer can understand a user's goals and motivations. The authors explain that a requirement is a specification of what is expected of a product and how it should perform. Cooper et al. suggests that requirements can consist of objects, actions and contexts [16]. Furthermore they explain that requirements can have many different types. For example there are business requirements, technical requirements and functional requirements [16].

Designing Alternatives: This activity is defined as a key and central principle of interaction design [9]. Furthermore they suggest that generating a set of multiple ideas is not a difficult task. The authors explain that the activity can be viewed in two parts, conceptual design and concrete design [9]. The conceptual design describes the skeleton of a product, what users can do with a product and what concepts they need to understand the purpose of it and how to interact directly with the product. The concrete design is more focused on the details of the product. This includes things like colors, sounds and images. Alternatives for a concrete design can be many.

Prototyping: Hanington and Martin characterize prototyping as a physical realization of a product that is a crucial part of the design process [10]. In addition, the prototypes constructed can be seen as checkpoints for the designer. Sharp et al. emphasize the importance of prototyping when potential solutions need to be communicated with the user. The design has to be reviewed, revised and improved, which means that a limited version of the final product is key to show the user the imitation of a real product [9]. The authors suggest that building prototypes is an extremely powerful approach and that there are many different prototyping techniques, some of which are cheap. The authors also explain that prototypes support designers in choosing alternatives and that prototyping can be classified as either low-fidelity prototyping and high-fidelity prototyping [9].

Evaluating: Performing evaluation is an essential part of the design process [9]. The authors describe the evaluation as being focused on both the usability of the system or product and the experience that the user has when interacting with it. They highlight that for the evaluation process it is significant that the user is participating in the overall process. In addition, the authors explain that the evaluation activity has a strong focus on collecting and analyzing data about users' experiences with the prototype or other systems [9].

The activities are related to each other and that the interaction design lifecycle model captures the essence of the process [9], as shown in Figure 3.3. The authors suggest that there are many different interaction design lifecycle models that all have the same four activities but with different emphases on certain aspects [9].

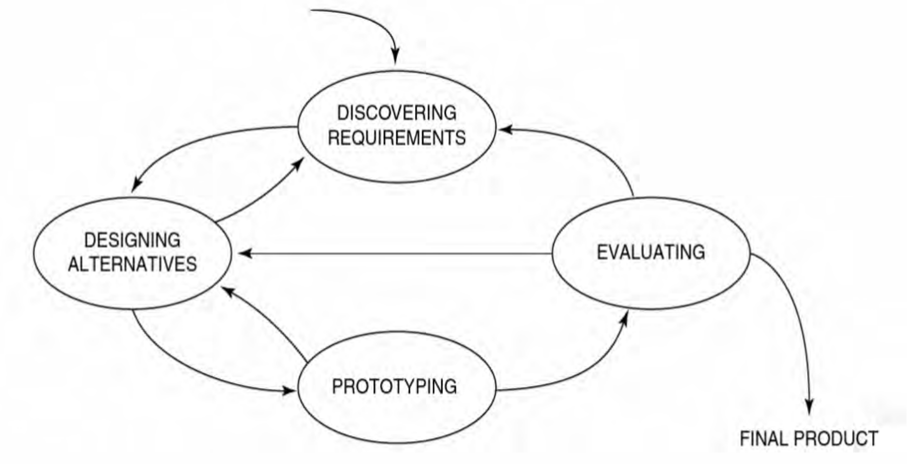


Figure 3.3: Interaction Design Lifecycle Model, as presented by Sharp et al. [9].

3.2 User Experience

User Experience, or simply UX, is a key area for many designers and for this Thesis project the essential characteristics of the user experience are significant in order to achieve the desired goal and ambition of the research. Allam et al. explains that the definition of the term *user experience* has many unique definitions from both the industrial perspective and the academic perspective, for example user experience can be defined as a “person’s perceptions and responses that result from the use and/or anticipated use of a product, system or service” [69]. Another definition is as follows: “A term that describes user’s feelings towards a specific product, system, or object during and after interacting with it. Various aspects influence the feelings, such as user’s expectations, the conditions in which the interaction takes place and the system’s ability to serve user’s current needs” [69].

According to Sharp et al. there is an important principle to remember when discussing user experience and design and that is that a person can not design a user experience but only design for a user experience [9]. In addition, user experience is a person’s involvement with any technology, product, or service [18]. From another perspective the shortened term of user experience, UX, can sometimes by designers be referred to as UXD in order to put focus on the quality of the process [9]. User experience can also be seen as the overall experience, including many touch points over different devices and platforms [18]. For example, some types of interaction, according to Elizabeth Rosenzweig, include the physical, mental and mechanical aspects [18].

User experience can also be associated with many unique and different concepts, such as emotional, affective, experiential, hedonic, and aesthetic variables [70]. The emotional aspect is especially interesting to consider since users' moods and feelings constantly change and understanding how the emotions work for the users will provide ways of designing specific user experiences [9]. Furthermore, Hassenzahl and Tractinsky explain that the user experience is a consequence of a user's internal state and in combination with that it is also the characteristics of the designed system and the context within which the interaction occurs [71]. The user experience is part of the interaction design and the human-computer interaction areas and therefore it is significant to consider the many perspectives of the phenomenon known as user experience in order to improve the products and designs. In conclusion, the user experience refers to how a product behaves and how the product is used by users in the real world [9].

3.3 User-Centered Design

Miaskiewicz and Kozar explains that user-centered design(UCD) can be more commonly referred to as human-centered design or customer-centered design and that the popularization of user-centered design has led to the improvement of many products [32]. The authors point out that user-centered design can be seen as a principal philosophy toward design that brings the users or consumers into the essential design process [32]. Sharp et al. highlights that the crucial driving force behind the product development are the real users and their goals [9]. The authors explain that for the user-centered approach it is recommended and advantageous to consider three main principles. The principles are the following: Early focus on users and tasks, Empirical measurement and iterative design [9].

According to Tidwell et al. there is a motto in the field of interaction design, and it is the following: "You are not the user." [1]
Understanding the meaning of this quote can be essential when thinking about the users and their needs. Tidwell et al. underlines the importance of understanding human contexts when it comes to the design intentions of the designer [1]. In addition, there is a spectrum of ways in which users are involved in the user-centered design but the important concept is that users are involved one way or another in the design process and how the users influence the shape of the designs [39].

One of the essential things with User-centered design is that the approach can be applied to the design of any project, although the main areas of interest are computer technology as well as information technology [14]. Furthermore, companies benefit greatly from integrated User-centered design and the concept can be used for developing products efficiently and with a high level of customer satisfaction [14]. Vredenburg et al. suggests that some activities are crucial for User-centered design, for example understanding users and evaluating design.

3.4 Usability

There are objectives when it comes to understanding the users and designing an interactive product for them [9]. The authors explain that a beneficial approach for a designer is to break down the objectives into terms of usability goals as well as user experience goals. The authors suggest that following the goals are crucial in order to achieve a good process and outcomes [9]. Sharp et al. presents the six goals that establishes the overall Usability term as the following:

- Effectiveness - Effective to use
- Efficiency - Efficient to use
- Safety - Safe to use
- Utility - Having good utility
- Learnability - Easy to learn
- Memorability - Easy to remember how to use

It is important for the designers to pay attention to the evaluation process in order to capture the usability criterias and Abras et al. highlights that the six criterias are difficult for the designers to know by heart or to imagine [39]. The usability of a product can only be determined by an interactive iterative process that leads to the product being refined [39]. Furthermore, a key aspect with usability is that the research surrounding it can be useful when comparing specific design variants, especially when an optimal and effective solution needs to be chosen [16]. The usability of a product can be seen as the capability it has to be used by humans easily and effectively, and additionally accessibility may be more closely related to usability than to user experience according to Sauer et al. [38]. Although there are many different usability definitions the most common shared versions include objective outcome measures related to performance and in addition subjective outcome measures at the same time [38].

3.5 Augmented Reality

Wallergård et al. explains that Augmented Reality is a term closely related to Virtual Reality but with a definitive characteristic that defines how they are not the same [12]. This characteristic is that augmented reality is a combination of virtual and real aspects. The authors continue by describing the three fundamental attributes that surround augmented reality. The first characteristic is that augmented reality is a combination of the real environment with the virtual environment [12]. The second characteristic is that the augmented technology is interactive in real time [12] [11] and the third characteristic is that the augmented reality is registered in the Three-dimensional(3D) space[12] and that the augmented reality operates and is used in a 3D environment [11]. According to Wallergård et al. the third attribute implies that a virtual object should be experienced as if it was locked to a specific position in the real world [12]. Conclusively, the authors highlights that for the Reality-Virtuality continuum there exists something called augmented virtuality as well as augmented reality. Ghazwani and Smith explains that augmented reality is located within the mixed reality space and this specific space can be seen as the connection of the real world and the virtual world [24], as seen in Figure 3.4.

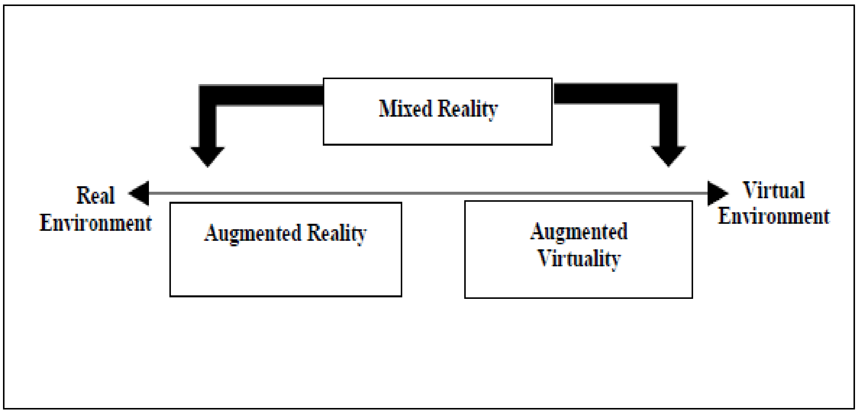


Figure 3.4: Reality-Virtuality Continuum Model, as presented by Ghazwani and Smith [24].

Augmented reality can be viewed as something that gives us the ability to bring usable information into the visual spectrum in real time wherever we are and in addition augmented reality can technically enhance the five senses[11]. Kipper and Rampolla present five unique categories that are relevant to understanding what augmented reality is to the humans who are perceiving it.

- A technology
- A field of research
- A vision of future computing
- An emerging commercial industry
- A new medium for creative expression

Hafsa and Majid explains that augmented reality is a phenomenon that has emerged out of science-fiction to become a reality for the industry [23]. The authors describe augmented reality to be an insight of the real physical world and the things around us are improved and more specifically augmented. This with the help of computer generated material and feedback where some of things can be described as audio, videos and GPS graphics [23]. Ghazwani and Smith emphasizes that augmented reality is a significant emerging technology that is important for users [24]. The authors explain that augmented reality supports users to view virtual objects in real time while viewing a real-world environment. The authors continue by pointing out that augmented reality systems have a good capacity to authorize physical objects in real-world environments to interact with virtual objects [24]. They acknowledge the concrete definition of augmented reality to be a system where the real environment is augmented by virtual content.

Wang and Schnabel clarifies that augmented reality adds virtual elements to the perceived reality and authorizes an interaction in a real world environment, while the user of this augmented reality system receives supplementary visual computer generated information to support the specific task or challenge that the user will need to face with the help of augmented reality [15]. The editors reveal that in recent years the augmented reality environments have been explored for educational purposes as well as for collaboration within design interactions. Previously the augmented reality environments were used and practiced generally for scientific visualizations and in gaming entertainment [15]. Wang and Schnabel concludes with highlighting the leading advantages of augmented reality. Examples of advantages include ease of collaboration, mobile computing, integration of digital information and intuitive interaction [15]. In addition, the editors claim that augmented reality allows several users to interact with it, since it is a collaborative tool.

Ghazwani and Smith explains that augmented reality is not a widespread consumer product yet, even though the augmented reality technology has been used across a range of diversified fields [24]. The authors reveal that the various fields where augmented reality has been used extensively includes areas such as medicine and education. For both the medicine and education environment the primary focus of augmented reality has been on teaching as well as training. For the augmented reality interactions there are three principal elements that contribute to the enhancement of the user experience(UX). These elements include the user, the user interface and the virtual content [24]. In addition, the authors suggest that when an augmented reality system is being used, the usage can either occur in a collaborative environment or in a single-user environment. This definitely depends on the number of individuals who are interacting with the given system.

3.5.1 Augmented Reality Platforms

Wang and Schnabel points out that augmented reality technologies are being migrated to mobile phones and devices [15]. The editors suggest that it is essential to investigate how these certain technologies can be used to support both architectural and constructional applications. Mobile devices with cameras equipped to them can be useful and significant augmented reality applications. For example, the editors explain that mobile augmented reality systems have been used in museums [15]. The purpose of augmented reality devices at museums is to provide guidance and additional object-aware multimedia content. The key benefits with mobile smartphones and tablets is that they utilize the cameras attached to them [11] but the major benefit is the Global Positioning System(GPS) that strengthens these platforms. Kipper and Rampolla suggest that the GPS functionality is a crucial factor for augmented reality [11] in especially portable handheld devices such as smartphones.

In addition, less well-known platforms utilize augmented reality as well for different purposes. For example, kiosks, digital signage, and window displays [11] are some alternatives that are used today around the world.Another platform that is seeing the advantages of augmented reality are the Virtual Fitting Rooms(VFRs) [36]. Pachoulakis and Kapetanakis explains that the Virtual Fitting Rooms rely heavily on augmented reality since the technology merges the digital worlds as well as the physical worlds. The positive aspects can be seen from different perspectives, for example with the help of augmented reality there is a fun factor to the Virtual Fitting Rooms [36]. The authors point out that the modern technologies allow the system to provide robust body recognition functionality and successfully address the fit and suit aspects of shopping. Other unique platforms for augmented reality include safety suits for motor racers and smart jewelry as well as smart footwear [37]. These augmented reality platforms have one thing in common with the conventional augmented reality glasses and headsets and that is that they are wearable technologies.

3.5.2 Augmented Reality in Construction

Wang and Schnabel highlights that there is a primary benefit with augmented reality and that is the enablement of delivering computer-mediated contextual information to the user. This information would otherwise not be properly accessible for the user, augmented reality helps to solve this problem [15]. The editors explain that the augmented reality systems would be significant when it comes to calculating the wide ranges of space at the construction sites. Shakil Ahmed highlights that augmented reality is used in various phases and departments of construction projects and that augmented reality has a great contribution to change the culture of the construction industry to a fully automated sector in near future [35].

The editors of *Mixed Reality in Architecture, Design and Construction* describe augmented reality as an extremely potential tool for the construction phases and suggest some examples. For instance, an augmented reality prototype was created to guide assembling of a space-frame structure. In addition, augmented reality systems were used to superimpose a virtual representation of underground pipes and cables. The editors highlight that this example of augmented reality could be crucial for avoiding accidental damage to the underground systems, in the case of excavation work [15]. Furthermore, Wang and Schnabel present the potential applications areas of augmented reality as the following:

- Building and inspecting
- Coordination
- Interpretation and communication

Angelia et al. clarifies that construction sites are one of the most unsafe areas for workers and that there are many potential risks that affect the safety for the workers [33]. The authors suggest that personal protective equipment(PPE) should be used when working in a construction environment. Furthermore, the benefits of augmented reality are crucial when it comes to decreasing the use of conventional printed construction drawings [34]. A positive outcome of this is that the quality of the construction workers will be improved and the augmented reality will serve as a guide for the user [34]. Augmented reality technologies are also beneficial for the communication between workers, as it can be less time-consuming and more effective [35]. Shakil Ahmed suggests that the augmented reality platforms are useful for sharing and exchanging significant information with each other within seconds and without having to think about physical limitations [35].

3.5.3 Augmented Reality Environments

Wang and Schnabel explains that augmented virtual worlds can be constructed in an automatic way with the help of textures that are generated from real world images and pictures [15]. The significance of this approach is that objects can be manipulated and contrived in unique ways that the real world does not allow. For instance, the physical laws of the real world do not have to be followed and the objects can behave and change according to what needs and demands the user has. The authors highlight that the manipulation perspective of the augmented virtual world is crucial for the user when it comes to making the environment more comprehensible [15]. For example, any irrelevant and insignificant parts of the real world can be omitted in order to give the user an environment that is easy to understand and that within the environment there is no unneeded and confusing information [15].

The authors describe that there are five core techniques to consider when the focus lies on a realistic augmented reality environment [15]. These five categories of techniques are the following: a modeling technique that visualizes physical forms, a tracking technique that visually integrates real environments with virtual objects, a rendering technique that realistically generates geometry, an authoring technique that generates a final output based on a database of construction information models, and an interaction technique that focuses on detecting users' gestures and movements where focus on a user-oriented interaction model is key [15].

3.5.4 Augmented Reality and GIS

GIS is an important technology and the shortened term stands for geographic information systems [73]. GIS is a process of organizing spatial data in order to exhibit and analyze its value using computerized technology [72]. It allows strata of collected data from a survey to be superimposed onto a digital map and interrelationships assessed [72]. Wang and Schnabel present an idea of an ultimate system of construction management where GIS can be linked together with augmented reality and put focus on both the interior design and the urban design as well as the infrastructure design [15]. The benefits of augmented reality are not only prevalent in construction but for viticulturists as well according to King et al. For their research it was proven that GIS data can be visualized effectively on an outdoor augmented reality system and this is important in understanding the parameters that affect viticulturists' yields and the quality of grapes from different vineyards [73]. Outdoor augmented reality systems can be employed at key points in the construction process, for example in the team collaboration, determining the proper placement of the building and visualizing construction and engineering data on site [15]. Schall et al. highlights the importance of augmented reality and how it can visualize network planning and inspection of underground infrastructure [74]. For this specific area of engineering it is essential to rely and understand the data from the GIS. The augmented technologies can be used to full effect with the help of GIS. For instance, Schall et al. explains that in their evaluation the field workers appreciated the 3D visualizations over the conventional 2D GIS visualizations [74].

3.6 Safety

The aspect of safety can be viewed through many different perspectives. From a user experience perspective, Grundgeiger et al. suggests that the aspect of user experience is significant for safety-critical domains and that interaction with technology always has an associated user experience [40]. In addition, user experience helps with the design of better tools and the support of contemporary safety management [40]. From an Augmented reality perspective, the technology can be used to support different areas such as education and training. Kang et al. explains that both augmented reality technologies as well as virtual reality technologies can be applied to many unique fields and especially for safety directed fields [4], for instance training of emergency procedures. In the article the authors worked with augmented reality to create a fire-drill application with an immersive and effective training environment with focus on safety [4].

The role of the designer is crucial for establishing safety for especially construction workers. Gambatese et al. explains that the mindset of the designer has to be changed in order to understand the concept of safety [20]. Additionally the designer should have more knowledge about the concept of safety and construction safety knowledge should be considered in the design phase. When developing an augmented reality system there are considerations to examine as a designer of the system [20]. According to Hinze and Wiegand, the designers have a strong and essential position to play in decreasing the occurrences of injuries and fatalities among construction workers [21]. The authors suggest that the designer has a key responsibility in every design aspect to commit to a safer workplace for the workers. A consequence of fatalities at the workplace is that the owners face a higher cost of construction. The authors also strengthen the function that the designer has in the construction safety and that they have a direct impact on the construction workers' safety [21]. Therefore, their presence in the discussion of safety is significant. For instance, Hinze and Wiegand suggests that an education process can assist the designers and give them the correct perspective on the safety aspect that surrounds the workers out on the field [21].

4
Methodology

This chapter will be a thorough display of the methodological approaches used for the Thesis project. The first parts that will be presented are the methods connected to the Interaction Design Methodology and how they contribute to the crucial structure of the project. Later, there will be detailed presentations of the methodology for comprehending and exploring the problem space as well as significant methods for comprehending and exploring the solution space. In Figure 4.1, a visual representation of the iterative nature of the project is displayed. The model will serve as an overview for how critical models can be used to execute the project.

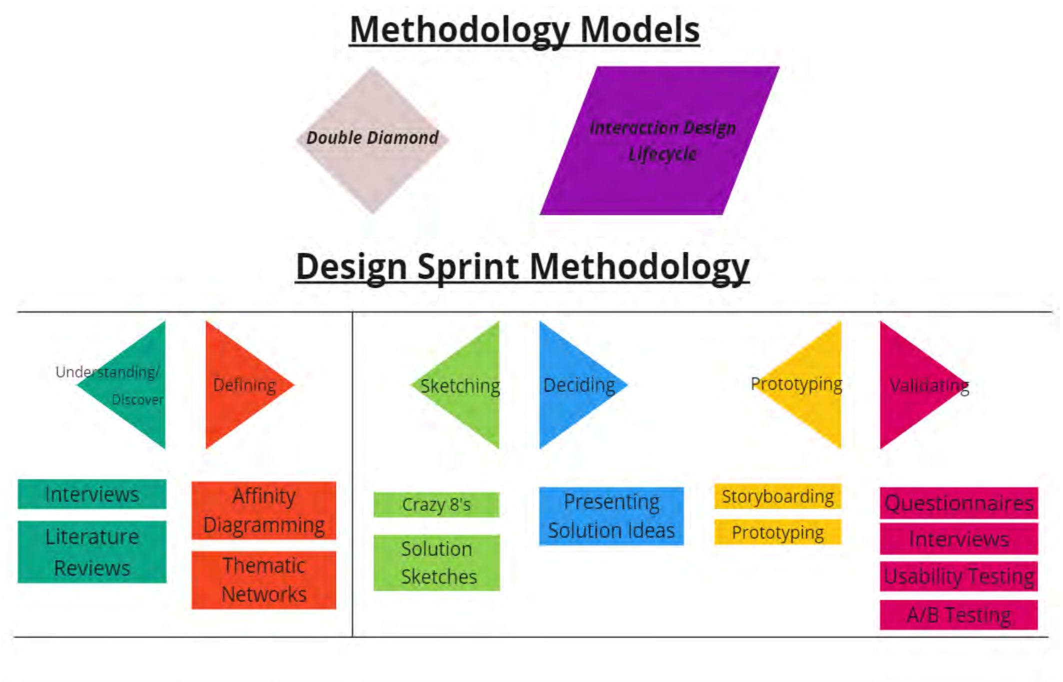


Figure 4.1: The methodology models are presented as being a significant part of the project. The Design sprint methodology is presented in its entire structure and essence. The methods either belong to the problem space or the solution space.

4.1 The Design Process

For the Thesis project the iterative design process will follow the interaction design methodology to explore solutions. However, since there are many unique phases with different names as well as different types of models for the design methodology, the overall design process will take many of these aspects in mind when approaching the essential exploration of the research. The sections below will provide more details and structure to the methodology being used for the entire process of the project.

4.1.1 The Interaction Design Methodology

As explained in Section 3.1 the interaction design process has several parts and phases involved in the entire development of a design product. The double diamond of design model and the interaction design lifecycle model serves as useful tools for the Thesis to assist and guide the designer through the process, as seen in Figure 4.3 where the models are on independent sides of the black border. The models are beneficial since it is best practice, especially for the interaction design part, to develop a design system that follows a flexible development methodology [45] and in addition the double diamond of design is a crucial design research methodology that is also increasingly adapted and tailored to include other methodologies [44]. Furthermore, the interaction design process is iterative and can require multiple iterations to pinpoint solutions [46]. A similar model of the interaction design process can be viewed in Figure 4.2, where the iterative process, similarly to the lifecycle model, can be observed horizontally between the unique stages [46].

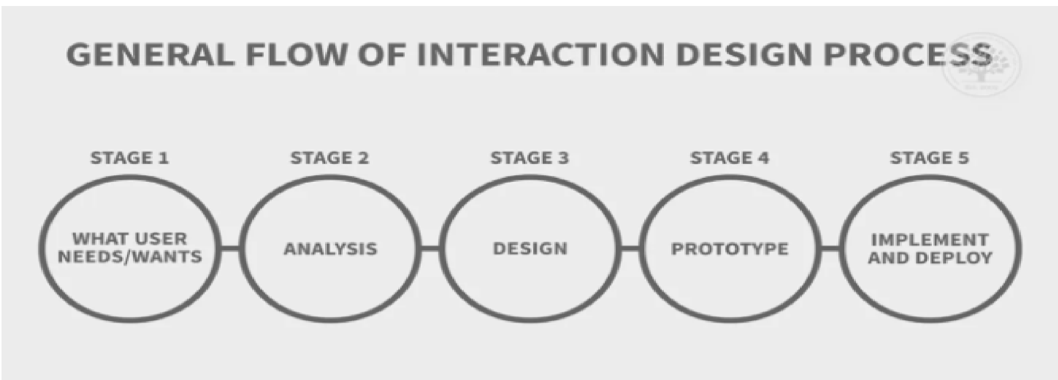


Figure 4.2: The 5 Stages of the Interaction Design Process, as described by the Interaction Design Foundation [46].

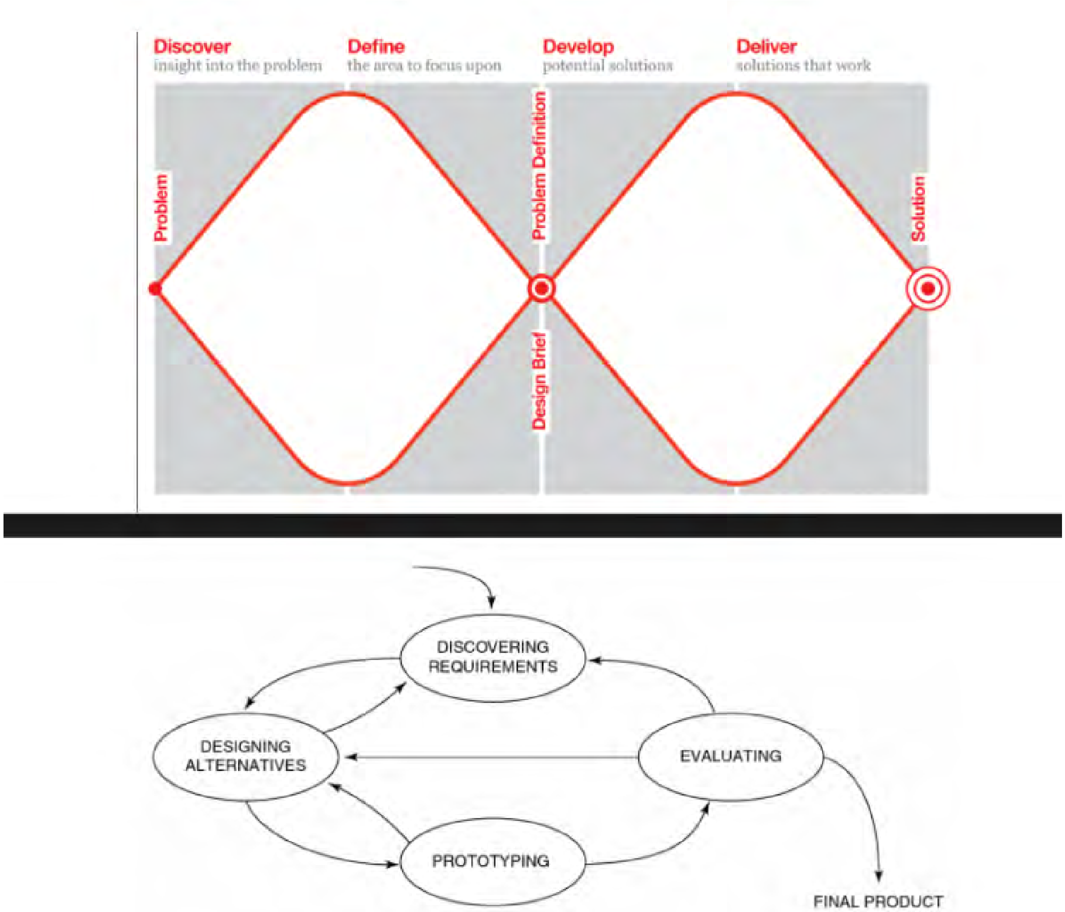


Figure 4.3: The main Methodology models, as presented by Sharp et al. [9]: The Double Diamond of Design and the Interaction Design lifecycle Model.

4.1.1.1 Design Thinking

A significant part of the methodology aspect of this Thesis will be to solve problems and find proper solutions, and therefore it is good to have the concept of Design Thinking in mind when exploring the vast perspectives of interaction design. Considering the Design Thinking methodology can be beneficial, especially since the term has gained popularity over the past few years [53]. Furthermore, the Design Thinking approach is crucial when both a breakthrough idea or concept is needed and in addition when a problem is not that well defined [13]. The term Design Thinking can also be described as productive synthesis [54]. A key characteristic of Design Thinking is that it can be seen as a systematic and collaborative approach for identifying and creatively solving problems [13], where the creative part is of course of interest for this Thesis. In essence, the five stages of Design Thinking can be described as the following [52]:

- **Stage 1: Empathize** — Research Your Users' Needs
- **Stage 2: Define** — State Your Users' Needs and Problems
- **Stage 3: Ideate** — Challenge Assumptions and Create Ideas

- **Stage 4: Prototype** — Start to Create Solutions
- **Stage 5: Test** — Try Your Solutions Out

In addition, the Design Thinking process includes two essential phases. These are identifying problems and solving problems [13], as seen in Figure 4.4. For the success and positive outcome of the Thesis project the ambition will be to not see problems but only see the problem solutions.

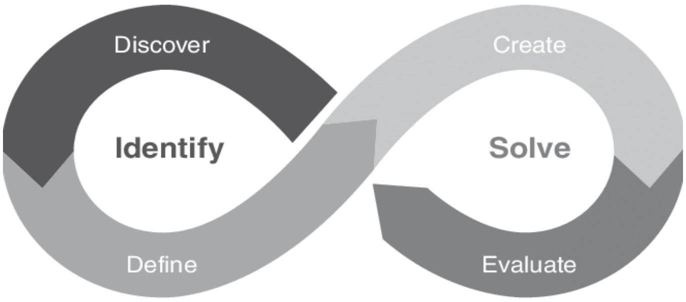


Figure 4.4: A framework for Design Thinking, as presented by Luchs et al. [13].

4.1.1.2 Design Sprint

Similarly to the Design Thinking model there is the Design Sprint methodology to consider as well. The Design Sprint can be described as a rapid technique that also supports fast and adaptive design development [57] and in addition the method can be used to solve critical issues through prototypes and brainstorming with customers [58]. There are many advantages with this model, for example shorter time required during the process, making designs based on user needs and satisfaction, and the cost can be lower than other methods [55]. Furthermore, the Design Sprint process can in fact be completed within five days [58] [57]. The unique aspect of the Design Sprint method is that the number of phases can vary depending on who is implementing it and also where the different models originate from. For instance, the research model presented by Bachtiar et al. [59] only consists of five phases, see Figure 4.5, where some of the names of the stages differ from other models.

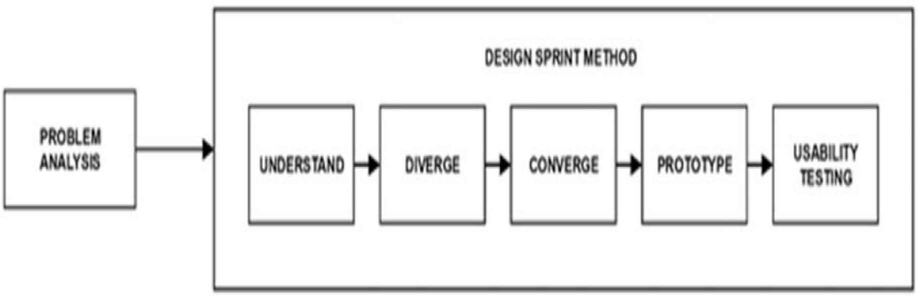


Figure 4.5: A design sprint model presented by Bachtiar et al. [59].

However, for the Thesis project the phases that are going to be of interest and studied are originating from the Design Sprint model presented by Google, as seen in Figure 4.6.The ambition is not to finish the design in five days as several previous sources discussed, instead the aim will be to follow the fundamental principles that each phase represent and to execute them properly in order to develop a good result for the Thesis. The six phases of the Google Design Sprint model are the following: Understand, Define, Sketch, Decide, Prototype, and Validate [56].

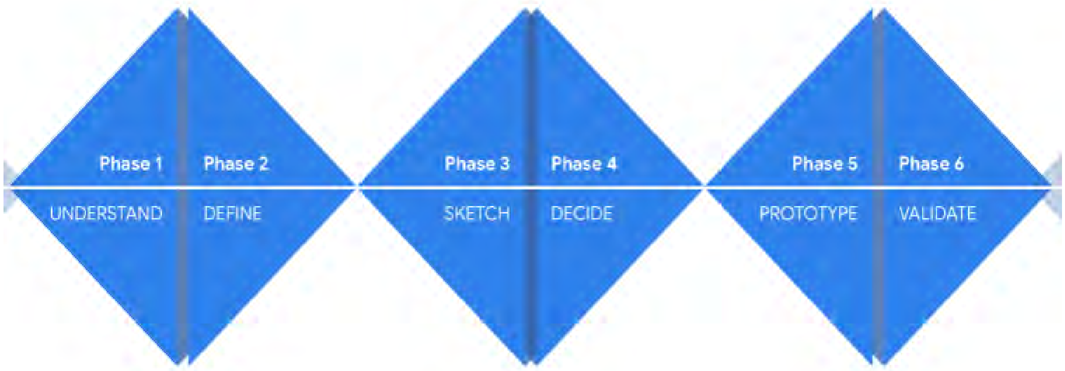


Figure 4.6: The Design Sprint Methodology model by Google [56].

4.1.2 The Methodology for Comprehending and Exploring the Problem Space

A leading and patient attitude will have to be used for approaching the problem space, since comprehending the problem is vital in order to conclude the future solutions. The first two phases of the Google design sprint are extremely relevant for this part, see Figure 4.6. In addition, the discover and define aspects of the Double Diamond of Design model will be considered as well as the discovering requirements aspect of the Interaction Design lifecycle model. The models and the chosen methodology to each phase will be of key importance.

4.1.2.1 Understanding and Discover

This phase will aim to receive an insight into the problem and to discover requirements and to discover something new about the situation [9]. The methods for this part are the following:

- **Interviews**
  Interviews can be summarized as a research method that is substantial with multiple defining attributes and benefits, such as being qualitative, exploratory, generative and evaluative [9]. Hanington and Martin explains that Interviews are a fundamental research method [10] for the design phase and interviewing both current and potential users is of key significance [16]. Interviews can be split into four main types where the three most common types are unstructured interviews, structured interviews and semi-structured interviews

[9]. Hanington and Martin highlights that a structured interview can follow a script of questions while an unstructured interview is more flexible during the conversation with users [10]. For the structured interviews it is useful to use that approach when the goals are clearly understood and specific questions can be identified [9]. Structured interviews have an advantage and that is that they can be controlled efficiently and are easy to analyze [10]. With the unstructured interview the setting is exploratory and the conversation can go into considerable depth [9] and the advantage is that the participants can feel more comfortable with this conversational environment [10]. By interviewing users we can learn insights such as users goals and motivations when using a product and also tasks and activities connected to the product [16].

- **Literature Reviews**
According to Hanington and Martin, Literature Reviews can be an exploratory research method that proves to be a useful and significant method for the design process and especially projects where design is the core element [10]. A literature review can be structured in specific ways and the four most common approaches to use are chronological, thematic, methodological and theoretical[60]. The crucial literature review does not need to summarize every single detail and the gathered material is always good to organize by research categories [10]. For instance, in the article by Katherine K. Fu et al. regarding design principles the authors reviewed 66 references and they included diverse material such as monographs, books, anthologies, journal publications, and conference publications [61]. Selecting literature that is of relevance to the specific project is also important for this research method [10].

4.1.2.2 Defining

This phase will be crucial for establishing a sufficient and precise focus on how to approach data for the problem. The aim will be to take a large part of the problem and break it down to smaller items. The methods that are going to be considered for this part are the following:

- **Affinity Diagramming**
Affinity Diagramming, also known as affinity mapping [42], is a significant method for the design process as well as a synthesis and analysis technique [10]. The data gathered from interviews can be difficult to break down and observe straight on but with the help of the affinity diagramming method the research data can be clustered on a wall [10]. Hanington and Martin strengthen that the method is crucial for designers as it helps them to capture research-backed insights, observations as well as requirements [10]. The research gathered is placed on individual sticky notes [10] which can be done physically or on the online visual collaboration platform Miro [43]. When performing the categorization of the sticky notes it is important to remember that if some notes handle identical information then they should be stacked on top of one another with the most descriptive one showing [47].

- **Thematic Networks**
  The analysis technique known as Thematic Networks is a useful method that helps the designers to identify and collect significant data and then organize the data and finally connect the data to common themes [10]. Thematic Networks analysis is an important visual tool when the grouping of categories is created and the method can be performed collaboratively with multiple people or a team [68]. Furthermore, the design method has three classes of themes: Basic themes, Organizing themes and Global themes [10] [66]. Thematic Networks is a qualitative method used for qualitative research and some advantages are that summarizing key features of a large data set is made easy and the method offers a more accessible form of analysis [67]. In addition, Jennifer Attride-Stirling argues that there is exploratory and explanatory power in the thematic networks qualitative research [66]. One of the significant aspects of this method is that text, especially, can be systematically broken down into simpler and manageable clusters of patterns and themes [10].

4.1.3 The Methodology for Comprehending and Exploring the Solution Space

Approaching the solution space with a good focus and a strong motivation will be an advantage. This part of the project will be the most significant since the solution is the key feature of the Thesis. The right side of the Double Diamond of Design will be of focus for this part and a large part of the activities of the Interaction Design lifecycle model will be useful, see Figure 4.3. In addition, phase 3-6 of the Google design sprint, as seen in Figure 4.6, will be explored as well and following this model will be a beneficial and favorable approach.

4.1.3.1 Sketching

The sketching process will result in simple designs on paper that have an essential purpose for the future implementation of the solutions. A lot of ideas in this phase will end up being potential solutions. The sketching phase will focus on creative and innovative results. The methods in this phase include:

- **Crazy 8's**
  The Crazy 8's is an ideation method [65] [62] that can be used by a designer to spawn ideas fast, often by sketching. A sheet of paper is used and it is folded into eight squares where the ideas are sketched during a limited time period. One aim is to draw the idea in as many ways as possible, namely into the eight squares on the paper sheet [63]. The method is a great exercise tool for when a designer has "sketching block" [63] and the most important thing will be to be creative and make sure that at least something is drawn into the squares, for example icons or shapes. The method can be described as a rapid manual sketching approach [65] and this is a crucial feature for making sure that design solutions can be established early on in the process.

- **Solution Sketches**
  With the help of the ideation method Crazy 8's some solutions will be in place to be chosen, mostly the ones that gain the most support. The final chosen idea will be considered for the development phase as the design solution can be viewed as being a definitive result.

4.1.3.2 Deciding

This phase will be short but essential for the result of the project. The sketches will be reviewed and then chosen for prototyping. The method for this phase is:

- **Presenting the Solution Ideas and Sketches**
  The student will collect all the designed ideas and sketches into a shared presentation portfolio and then bring this forward to ABB for feedback and confirmation that the solutions can move forward to the significant prototyping phase.

4.1.3.3 Prototyping

The prototyping phase will be an extensive but important journey for the design. The design will go from being simple and changeless, to being an acceptable product and an interactable tool that is ready for validation by a set of users. The prototypes do not have to be definitive in their functionality and performance. However, they need to be sufficient enough to be experienced in order for feedback and data to be collected from their performance with users during a test. The purpose of the prototype is of paramount importance since it will give a believableness to the design solution and how it engages users in the overall experience. The methods that will be used are:

- **Storyboarding**
  Storyboarding is a form of low-fidelity prototyping and in essence it is a series of sketches of the user in different scenarios and how that user progresses through a task or an experience [9]. The Storyboarding method is a research deliverable and it helps with visually capturing the essential social, environmental and technical factors that shape the heart of a product [10]. The keywords connected with Storyboarding are why, how and where [10]. By looking at the series of sketches the designer can understand for example why a user is using an application in a certain location and how the user interacts with it. For some of the sketches designers can determine if the situation of the product is realistic and meaningful [10] and for the high-fidelity prototyping the storyboards created can be reviewed in order to assist with the development of the final solution.

- **Prototyping**
  Prototyping is a useful method when the designers have the users in mind, for instance when the users receive a prototype object from the designers they can soon realize what they want as a final product compared to what they thought

about when they did not interact with a prototype [9]. Hanington and Martin explains that the Prototyping method is part of the design process as well as the research deliverable phase [10]. The term prototyping is referred to the tangible creation of artifacts at various levels and it is a physical realization of a product or interface concepts [10]. Sharp et al. presents that there are two levels of fidelity for prototyping and these different levels can be of either low-fidelity or high-fidelity rank [9]. The characteristics of low-fidelity prototyping is that the visualization of design ideas begin at very early stages of the design process and in addition, the prototypes are often developed using paper and other "low-fidelity-materials" according to Sefelin et al. in their article [48]. The complexity of the prototype can be reduced and for low-fidelity prototypes they can be horizontal or vertical and most importantly the low-fidelity prototypes are practical [49].

High-fidelity prototypes are characterized by being more identical to the final product and the functionality is also more prevalent and extensively active [9]. For the prototypes the visual and interactive details that look and behave like a real product can be implemented to the design at this stage [50]. Functional interactive high-fidelity prototypes are often built at the later stages of the design process [51]. For high-fidelity prototyping there are many digital tools that can be used to create click-through prototypes to demonstrate minimum interaction, for instance Adobe XD [50] is an example of a digital platform used for high-fidelity prototyping.

4.1.3.4 Validating

For the validating phase the key focus will be to underline the believableness as well as the creditableness of the prototype design. The evaluation of the prototypes will be an integral part to the design process [9]. The main objective is to gather data from users when they are interacting with the prototypes. Later in the process, it is crucial to structure the collected data and analyze every single part of the users' experience with the product [9]. The methodology considered for this phase are the following:

- **Questionnaires**
  Questionnaires are a simple technique and they are seen as the primary tools for collecting survey information [10]. The unique factor with Questionnaires is that they can be distributed to a large number of participants [9]. Questionnaires are often constructed using online tools and they are digital forms that hold questions that the participant can answer and then send the form to the designer. From the Questionnaires the designer can capture good information about users such as characteristics, thoughts, feelings, perceptions, behaviors, attitudes etc [10].

  The structure of the Questionnaires can vary. For some forms the basic demographic information can be good to collect and other background information is essential too [9]. The format of the Questionnaires can vary as well since the method includes both closed-ended or open-ended questions [9]. The most common formats include check boxes and ranges, rating scales, likert scales and semantic differential scales [9]. Hanington and Martin recommend the likert scale questions for gaining a strength of response for the research [10]. The likert scale is interesting since it can be used with a set of numbers, for example rank something from 1(weakest) to 5(strongest), and it can also be used with a set of keywords instead of numbers [9]. An example from Hanington and Martin includes a scale of very useful-useful-useless [10]. For the semantic differential scales the user can mark on the scale which adjective something feels closer to. An example from Sharp et al. includes different adjectives that are in contrast to each other, such as attractive and ugly [9]. The user marks where the design is closer to, either closer to attractive or closer to ugly. The data gathered from this method can be analyzed and compared with distinction. In addition, there are special cases of a closed-ended question called contingency questions and they can be used to obtain detailed data from a specific subgroup of the population [83].

- **Evaluation Interviews**
  The method used here will follow the same theory as explained in Section 4.1.2.1. The main difference here will be that the focus will be on evaluating the users' experience with the prototpes. Evaluations often involve observing participants and measuring their performance as well as exploring users' behaviors and analytics [9].

- **Usability Testing**
  Usability testing is performed to explore the interface and to evaluate the interface and its functionality. Observing the users when they interact with the product can help developers understand usability issues [9]. Usability testing helps with revealing the problem with the interface and the developers can see what parts of the interface that frustrate and confuse users [10].

- **A/B Testing**
  This research method is used for comparing two versions of the same design to see which one performs statistically better [10]. The method is a quantitative approach and therefore qualitative methods should be considered if a deeper understanding of the design is desired [10]. For the method there can also be two groups of people that test the two different versions of the same design [9]. The A/B Testing is a more analytical approach and the collected data can be explored and analyzed with the help of utilizing certain visualization tools.

5
Planning the Project

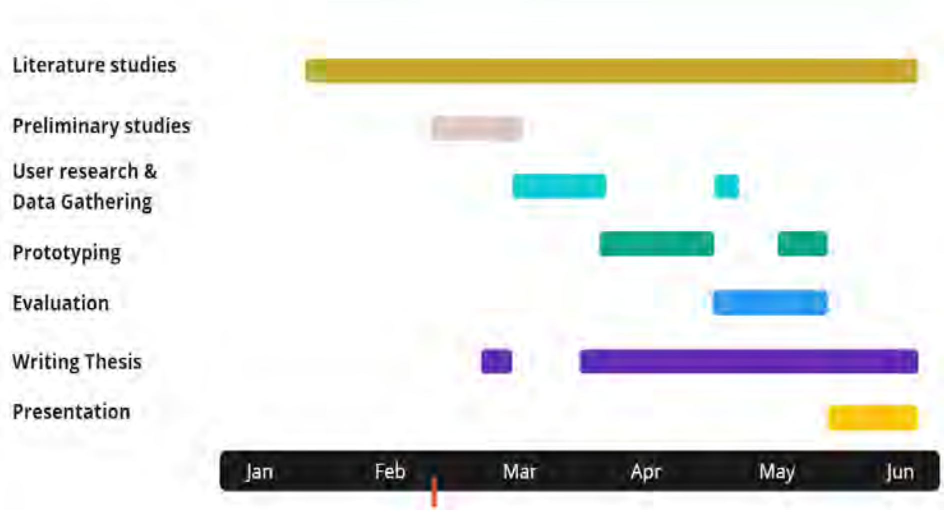


Figure 5.1: A simple and understandable model of the preliminary timeplan. The red marker represents where in time the Thesis progress can be active.

The preliminary plan for the execution and structure of the Thesis project can be seen in Figure 5.1, where the months are located on the black bar and the bars with colors represent the estimated time for each activity. The most important and crucial detail of this timeplan is that it is first of all a preliminary structure and it can be seen as a template for the whole process. A keyword that characterizes the timeplan in Figure 5.1 is that it is extremely flexible. In addition, the planned events and tasks of the timeplan can be adaptable and changed according to the circumstances that can happen throughout this project. Of course the major parts of the timeplan will be executed, however there can be some adjustments depending on unexpected situations or limited resources etc. If unanticipated things happen then the structure of the time will have to be reorganized in order to make the Thesis progress the best it can possibly be and of course the end goals must be reached.

The ambition will be to do many of the planned things iteratively. A significant part of the process is backed by the essential methodology that will serve as a guide for the Thesis project. The important phases of the project will be directed by the Google Design Sprint Methodology as well as the Double Diamond of Design and the Interaction Design lifecycle Model. All of these models, as explained in Section

4.1, are crucial items that are needed for the design process and the final outcome of the project. Following the methods will guarantee a good result for the project and the models will be beneficial for the Thesis as well. The Sprint Methodology will especially be a great asset since it will help with solving the surface of the problem and Knapp et al. explains that a sprint will help with moving fast and answering big questions before commiting to the execution [19].

Furthermore, in combination with the planned events in the timeplan there will also be several pockets of time reserved for meetings and supervision with the people involved in the team activities surrounding the Thesis. It is important to remember that these meetings can change the planning and future outcome of certain stages for the project. Approaching the preliminary planning and the desired planning with the right mindset will be a favorable and beneficial procedure. The flexibility aspect will be viewed as a positive perspective for the Thesis project.

5.1 Planning: Comprehending and Exploring the Problem Space

The beginning of the project will be crucial in order to approach the problem in the proper way. At this stage there will be a lot of aspirations and visual ideas of how the project will end up looking like for the final stages. However, even though many of the ambitions at the start of the project feel like they can be tackled with immediate solutions this will not be ideal and instead the approach should focus on the theoretical material and definitive methodology. Specifically the first two phases of the Google design sprint and the discover and define aspects of the Double Diamond of Design model will be adapted to ensure good outcomes, see Figures 4.3 and 4.6.

5.1.1 Understanding and Discover

The first steps can be viewed as the most significant part of the Thesis project since understanding the problem is essential for subsequently solving the problem. The understanding and discover phase will begin with a strong focus on the literature reviews as well as studies on different academic sources. For this part of the project reading and reviewing the relevant and significant literature will be performed extensively and continuously. Reading the literature and other academic sources will prove to be a great tool for collecting the crucial information and material that will help with the entire Thesis process. Literature will especially be advantageous when reaching the stages of the project where methodology is key in finding solutions and therefore understanding the material beforehand will be beneficial. Since the student will work together with the user experience team at ABB the literature findings will have to be shared with the team members in order to achieve a good collaboration and discussion. The collaboration with ABB will have to be compliant with their digital working tools and therefore the plan is to utilize the collaboration platform Mural.

Later in the process, interviews with expert users will be performed for the data gathering part of the project. Since the augmented surveyor project is a confidential part of ABB the participants that are going to be asked will be ABB employees. The plan will be to ask employees with experience with the surveying technique and profession. Sharp et al. explains that people who fit the profile are called the study population [9] and the employees with experience will be the expert users for the data gathering. The Interviews method is a qualitative method [10] and this is significant for understanding the problem space for this specific project. A quantitative method on the other hand, would not prove to be beneficial for this specific project and instead the qualitative interviews will be conducted. The plan will be to prepare all the interviews with the expert users with care and precision in order to gather proper data for the Thesis project as well as running the interviews smoothly and professionally.

Furthermore, the initial step of the augmented surveyor project will be to understand the actual surveying system as well as the user. With the help of ABB the student plans to view the system and users in operation in order to comprehend what kind of actions are used for the augmented surveying and in addition how the equipment and tools behave with the user. Reviewing existing technologies for augmented reality at ABB could also be significant in order to receive additional comprehension of the systems. The plan will be to do this process in line with the literature reviews and meetings with the UX team at ABB.

5.1.2 Defining

Once the interviews with the study population have been completed the next part of the process will be to organize and interpret the numerous findings. Results will have to be analyzed in order to decide where and how the project can continue with the purpose of exploring the many possible solutions to the research problem. After the interviews, the first steps will focus on interpreting the various written notes, transcripts and recordings of the interview sessions. By doing this essential step, many common themes and information, from the qualitative data, can be identified and established. It is logical to presume that the interviews will cover many unique aspects of the surveying activity and augmented reality. Therefore, going through the transcripts and recordings and then writing personalized notes will be a good strategy in order to dissect the relevant data that will be of paramount importance for the safety and efficiency parts.

In order to perform the data analysis successfully the many themes will have to be identified using a thematic analysis. The identified themes can relate to several different aspects, for example behaviors, events and situations [9]. As a part of thematic analysis, Sharp et al. suggests that a more systematic analysis is good for identifying themes throughout multiple perspectives [9]. The student will focus on using qualitative methods for the categorization and organization of the data. Hanington and Martin explain that for the method Affinity Diagramming, sticky notes are used to store the collected data [10]. The student will work with the team at ABB to create an affinity diagram where all the identified themes and keywords can be explored. This will be done using the collaboration tool Mural, where digital sticky notes can be created. In addition, an affinity diagram with categories connected to the research questions of this Thesis will be constructed as well.

Once the data analysis and interpretation is done, the aim will be to discuss this with the team at ABB. The categories that are relevant and crucial for the safety and efficiency aspects of surveying will be remembered and considered when the project approaches the next phase where solutions to the problem are explored and understood.

5.2 Planning: Comprehending and Exploring the Solution Space

The next steps will surround the right hand side of the Double Diamond of Design and phases 3-6 of the Google design sprint methodology. Develop will be a key characteristic of this phase since the project has moved from understanding the problem to developing solutions. For instance, Prototype development will be a significant area for the exploration of solutions. Several parts of the Interaction Design lifecycle model will be relevant and essential for the exploration of solutions, mainly Designing Alternatives.

5.2.1 Sketching

When the common themes related to the safety and efficiency aspects have been identified, the time for designing solutions will begin and sketching will be a great tool for this phase. Sharp et al. explains that sketching is not about drawing, it is about design [9]. This will be the mindset when exploring possible solutions, and getting ideas on paper is more important than getting specific shapes and colors specified for this phase.

With the data gathered in mind, new solutions can be sketched. In order to spawn beneficial ideas the ambition is to use an ideation method, for instance Crazy 8's(Crazy Eights) [65] [62]. With this as the main method for this phase, ideas can be created quickly and it will be an inspiration for generating new designs. The eight ideas will be sketched on a piece of paper and it is important to push oneself in order to put something in each of the eight areas [64]. It is important to always get something down on the page and keep writing as well as drawing [63] during the limited time. A couple of ideas that are relevant for the research will be chosen and further sketched upon to give the ideas a more expanded vision. The student will then show the ideas to the advisor at ABB.

5.2.2 Deciding

The deciding phase will be a short but crucial phase for the Thesis because the ideas that are the most relevant and beneficial for the research will have to be established. The plan will be to approach the advisor at ABB with some good descriptions of the ideas that the student has constructed. Together with the advisor and with the perspective of the safety and efficiency aspects in mind, two ideas will be chosen to develop further in the later phases.

By receiving feedback and input from the expert opinion of the advisor the optimal sketches can be chosen. Prioritizing ideas that the student has ambitions for will also be a deciding factor for this phase. Time will have to be spent on correct decision-making for this phase as decisions shape important outcomes for individuals as well as businesses [75] and this will be significant for the final phases of the project. Especially the research questions will have to be answered and then choosing good design ideas will be relevant for answering the questions.

5.2.3 Prototyping

As explained in Section 4.1.3.3 of the Methodology chapter, prototyping comes with a lot of advantages and it is definitely a beneficial tool. The sketched ideas from the previous phase will now be expanded upon with the help of the digital tool Figma. In addition, since ABB will offer computer software and applications for the development of prototypes then those tools will be considered as well for this phase, for instance Adobe XD. The use of low-fidelity prototyping and high-fidelity prototyping will be utilized for the project.

However, the ambition will be to work iteratively and therefore starting with completing the low-fidelity prototyping stage will be essential for being more efficient in the high-fidelity prototyping stage. Sketching is a part of the low-fidelity prototyping [9] and the plan will be to finalize design solutions on paper before implementing the ideas into a digital tool. Storyboarding is also a part of the low-fidelity prototyping phase [9] and using this method can be helpful for the exploration of solutions.

For the end of this phase, the solutions will be implemented using high-fidelity prototyping and the key focus will be to create an imitation that looks like the final product and behaves sufficiently with some functionality [9]. Both Figma and Adobe XD have prototyping modes that support connections from one design to another design and multiple interactions can be added as well. Utilizing this technique from the digital tool will be crucial for the evaluation part of the project, where users can interact and give feedback on the design solutions.

Before delving into the grand high-fidelity prototyping, the plan is to perform the low-fidelity prototyping technique called Storyboarding [9] as a tool to assist with the precise construction and development of the final prototypes. The storyboards will be sketched on paper and will include both icons, shapes and text. The ambition with the series of storyboards is to give a strong believableness to the purpose of the design and how it could actually work in a situation where augmented reality is needed for engineering.

5.2.4 Validating

The validation and evaluation of the prototypes and solutions will be significant for the Thesis. As the evaluation helps with collecting and analyzing data from the users' experience with the product it can be concluded that the evaluation is an integral part of the design process. The validation can also be a quality assurance process of establishing evidence that provides a high degree of assurance that for example a product accomplishes its intended use requirements. The plan is to use effective methodology for this phase of the project.

Since the ambition and purpose of the Thesis is to explore the design recommendations that help with establishing a safe and efficient surveying, the methods for the evaluation do not have to be that extensive. If on the other hand the aspiration focused on completing a highly functional prototype and exploring themes as user experience and usability then more extensive methods would be optimal. However, learning about how the user perceives safety and efficiency aspects will require effective methods that can gather both qualitative data as well as quantitative data. The method Usability testing is considered from the perspective of the usability of the design solution. However, the main objective at the end will be to see if the prototypes helps with strengthening the safety and efficiency aspects. Of course some usability aspects can be explored as well but the major questions in the evaluation interviews will aim to gain information about the safety and efficiency perspectives. If participants mention and discuss the overall user experience then that data can be collected and reviewed from a usability angle. Any interesting usability results can of course be presented in the conclusion and how it relates to the theme of the project.

The Interview method will be considered for the evaluation, as the method is in fact an evaluative and exploratory approach [10]. The ambition will be the same as for the data gathering procedure during the understanding phase, to receive good and rich qualitative data. However, the difference for this part is that the qualitative data collected will be analyzed extensively and conclusions will be drawn from them. The research questions about safety and efficiency have to be answered and with the help of the data collected from the interview during this evaluation, a conclusive result can be established. Presenting the interview participants with the design and then listening to their experience and opinions will be essential in understanding if the design solutions actually contribute with safety aspects as well as efficiency aspects. Most importantly the data gathered from the users will have crucial value to ABB for the continuation of the surveyor project. The plan will be to do the interviews either via Microsoft Teams or at the ABB office location. For both alternatives the interviews will be recorded in order for the student to go back and analyze the material and also create transcripts and notes of the data. In addition, the recordings can be shared with the rest of the team for their future work with the project.

In order to establish a definitive result the qualitative data from the interviews will not be enough to draw conclusions. An additional method is needed to help with validating the design and confirm that the solutions have credibility for some specific attributes and aspects. Using the Questionnaires method will be a great tool for the validation of the design solution as it is both an evaluative and exploratory approach [10]. The structure of the Questionnaire consists most of the times of check boxes and ranges [9], and this is the structure that will be used for the validation of the design solutions for this project, in order to capture quantitative data from the participants. The interviews can be quite long depending on the interviewee and the setting, therefore not all the relevant questions can be asked and answered within the time of the interview. Utilizing the Questionnaires method the additional questions about the design and how it relates to the safety and efficiency aspects can be asked in the Questionnaires where the user can give an answer in the shape of a number. For instance, one planned thing to do in the Questionnaires is to have pictures in the form that the user can view and then ask a question related to that image. Naturally the plan is to have a set of interviewees that first take part in the interview and then answer the Questionnaire after the interview is completed, as the Questionnaires method is seen as a complementary method to Interviews [10]. As they will perform a user test on the design they will have experienced it and then they can grasp the pictures they see in the Questionnaire and answer the questions that touch upon the design solutions.

Some parts of this final phase will be significant and will have to be done properly and with precision. For example, for the participants the plan will be to inform them about their rights and that the data collected from them will only be used for the project and their names will not be shared externally. Sharp et al. highlights the importance of protecting the privacy of the participants and ensuring them that they will not be endangered physically or emotionally. The aim for the validation is to receive a consent from the participants that it is okay that they are being recorded and to also verify that they are okay with the procedure. The option to drop out of the interview will be given and they can talk freely about what they like or what they do not like, there will be no right or wrong answers.

The final part of the validation will focus on the significant analysis of the qualitative and quantitative data. The recording will have to be explored in detail and the two scenarios for either the safety aspect or the efficiency aspect will have to be analyzed and dissected in a precise manner. From these findings the student can draw conclusions and also present comparisons between what one participant thinks versus what another participant thinks. One major crucial part will be to establish a good result that can then help with answering the research questions. The ambition will be to prove the credibility of the design solutions and present the data that confirms that one of the scenarios is preferred more than the other scenario or perhaps both are equally respected. For the qualitative data the goal will be to use some design method that can help with the grouping of different themes that are discovered from the evaluation. For example A/B testing can be relevant for researching different versions of the same design and the method Thematic Networks can be considered for the organizing of the essential comments that are captured when going through the interview transcripts.

For the quantitative data from the questionnaires the goal will be to present the result with a number and interpret the total score for all the questions. If one question receives top marks then a definitive conclusion can be drawn. If the question receives mixed opinions then another form of conclusion will have to be drawn and discussed. Depending on how many participants join the validation the student can present anomalies in the results and showcase that for some questions the opinions are deviating but that could still be a positive if some of the participants give top marks for that specific question. The ambition will be to use a mathematical formula that can help with finding the average of the final result in the questionnaires. In addition, the median and mode could be beneficial as well even though they do not represent the possible rogue participant who ranks everything with low scores when all the other rank questions with high scores.

6

Execution and Process

This chapter will focus on the execution of the project and more specifically the execution of the research and explorations of the project. In this chapter some of the phases as well as methods will be different compared to the material presented in the Planning chapter. The reasoning for the changes are that the scope and comprehension of certain parts of the project have changed or that new approaches are needed to solve the unexpected problems that occur naturally during the project process. A model shows a rough representation of how the project is executed for the problem space and the solution space, see Figure 6.1.

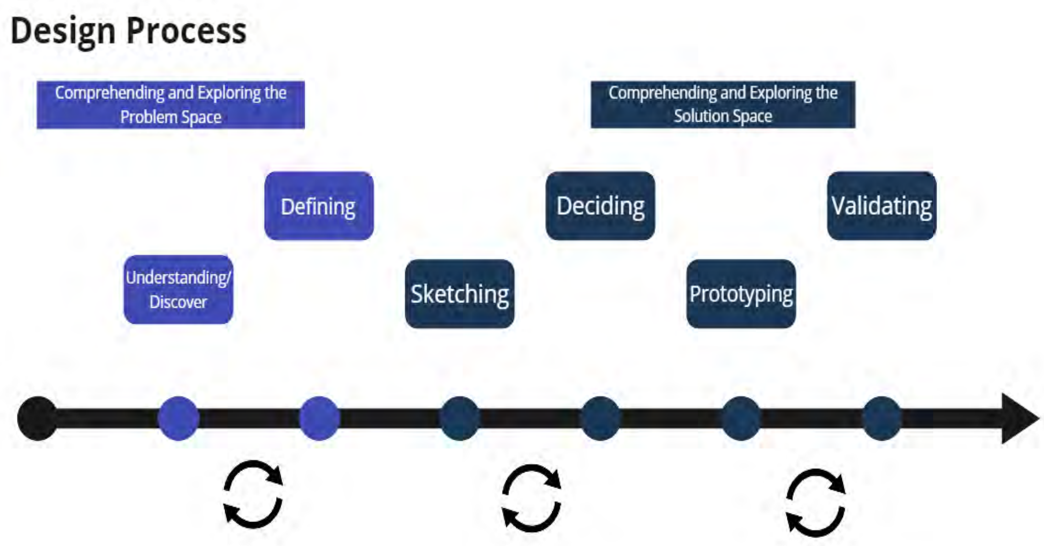


Figure 6.1: Model of the execution of the Thesis project. The circle arrows represent the iterative nature of the phases of the design process.

In the chapter there will be many pictures and images that highlights the execution of the project as well as the overall progress. The images will serve as essential material to show that problems were solved and that creative thinking was used to explore design alternatives.

6.1 Executing: Comprehending and Exploring the Problem Space

The key focus for this crucial section is to understand the overall situation and all the different pieces that will build up the project. Understanding the problem is the first and important step in order to delve into the solutions. The initial phases of the design models will be of paramount importance for this specific stage, namely the understanding and defining phases.

6.1.1 Understanding and Discover

This phase will be crucial for the Thesis as the entire essence of the project needs to be comprehended. The Discover part of the Double Diamond of Design will be followed as well as the first phase of the Google design sprint methodology. The aim with understanding the problem is to give a theoretical foundation and an overall awareness of the challenges. For this stage two main methods were used efficiently, Literature Reviews and Interviews with an esteemed set of expert users. In addition, a preliminary study was carried out in order to comprehend the extensive and fascinating area of surveying. The following items presents the flow of the first significant part of the project:

6.1.1.1 Literature Reviews

Working with the literature reviews proved to be challenging since the searching aspect of the activity was demanding. The student began the project by searching extensively on specifically Google Scholar for literature and other academic sources. Other online platforms like ACM Digital Library and Chalmers Library were sources of information as well. The main focus was to find credible sources [10], which is a significant thing for the credibility of the Thesis. Some physical books for the literature research as well as for the theory of the project were acquired. For the online material the focus was on finding articles specifically from conferences as they would be credible.

For literature reviews it is useful to organize the material by research categories [10] and this is something that the student structured with precision. Since the focus of the project is regarding augmented reality and leak surveying, the student used specific keywords to find material connected to the themes of the project. Of course this process was the most challenging since finding something that qualifies for all of those keywords is difficult. However, by using categories the items collected could be more easily identified when it came to analyzing the entire collection.

As stated before, the student worked with the ABB online tool Mural and this is where the literature findings were organized and also presented to the UX team. Figure 6.2 displays a set of summaries of different literature material. When the student found good and relevant literature the entire piece was read through and a short summary was crafted both as an aid for the student as well as for the team members. Since the summaries were shared on Mural the other members of ABB could study the material and use it for their own research if needed.

Figure 6.2: Some of the summaries for the collected literature.

Mural was an essential tool for the literature review activity as the platform held many advantageous functions that could build up the entire literature collection in a clear and understandable way. In addition, the design tools in the platform were beneficial as well and the categorization icons used for the literature material, as seen in Figure 6.3, were created directly in Mural. The whole digital tool helped a lot with this specific activity.

Furthermore, the literature review activity was conducted iteratively. After collecting a number of academic material and presenting it to the rest of the team at ABB, the student was tasked with continuing searching for material connected to the different themes. Especially the research questions were considered when searching for relevant material. Many unique and different augmented reality articles were found by searching for specific keywords. The new material that the student found was inserted into the Mural work area. New findings were communicated with the rest of the UX team.

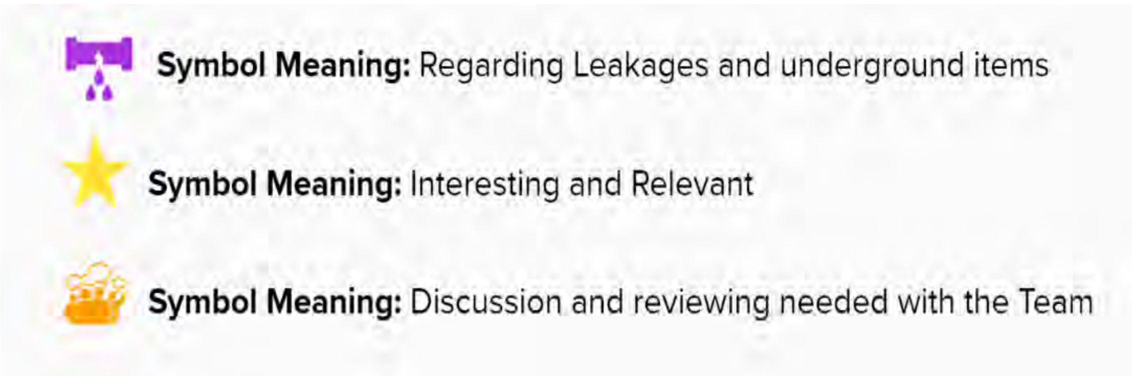


Figure 6.3: Icons used to categorize the collected literature.

6.1.1.2 Preliminary Study: Surveying wand prototype

One planned activity for the Understanding and Discover phase was to do a preliminary study about the augmented reality surveying systems, tools and users as explained in Section 5.1.1. However, the student was not aware at the time of the planning that the ABB Swedish Corporate Research Center did not actually have the surveying equipment and systems. The items needed for the preliminary study were located in America across the ocean. With this new information in mind, the student spawned a replacement idea of the planned activity that would still give the student a good understanding of the surveying area.

The new activity for understanding the surveying equipment can be described in a simple and effective way: prototype the ABB MicroGuard surveying sample wand. Since the equipment could not be reached at the current location, the new aim was to bring the surveying equipment to the project somehow. By developing a low-fidelity prototype of the sample wand the student could then use this prototype to imitate the movements and actions that a surveyor performs out on the field. This is significant because in order to answer the research question related to the actions of a surveyor and how it affects safety and efficiency.

For the development of the prototype the aim was to capture the shape and approximate size of the sample wand. The decision to make the tool into a low-fidelity prototype was based on significant academic literature. For example, characteristics of a low-fidelity prototype include things like it being simple, cheap and fast to produce [9]. This in return means that the produced prototype will also be simple, cheap and quick to modify [9]. With this perspective in mind, the ambition will be to use the prototype for testing certain actions in outdoor terrain. And since the prototype is of simple and inexpensive material the tool can be used in a more casual and rough manner compared to if the actual equipment was used for testing. If something is damaged on the low-fidelity prototype then it can be changed and updated quickly without any consequences in terms of cost or time. In addition, low-fidelity prototypes are characterized by being portable and useful for communication [78] which will be helpful when discussing things with the team at ABB.

The first step of constructing the low-fidelity prototype focused on observing the images of the current sample wand being used by ABB. After receiving good observations of how it relatively looks in shape and size the student searched the interaction design Studio, at Chalmers University of Technology, for the optimal material and resources. The majority of the sample wand's length consists of a cylinder tube item and luckily there were some plastic hollow tubes in the Studio that could be used to represent this part of the sample wand. For the handle that holds the mobile device the student found some bendable and flexible metal sheets that could be shaped in the desired vision, see Figure 6.4. An inspiration for this activity was the usage of a rapid prototyping process, as presented by Deneke et al. where the team created a social robotic agent that is used to dispense medical pills [77]. Creating the prototype of the sample wand fast was crucial since the understanding phase was primarily focused on the literature studies and they required significant attention.

The student understands the importance of documentation and capturing the thinking process. A lot of images and pictures below will highlight the decisions and techniques used to create the prototype in a quick and effective way.

Figure 6.4: The tools used to bend the metallic sheet.

Many decisive and perceptive solutions were implemented for the creation of the sample wand prototype. For example, there were no optimal tools in the Studio that could pierce the hollow plastic tube without making the entire item crack. Using the large saw for wood actually proved beneficial as it could make linear cuts in the plastic without cracks. Multiple linear cuts were made and later the spaces between them were cut and a hole had been made for the metallic handle, see Figure 6.5 for precise details.

Many of the tools seen in Figure 6.4 were used in some form for the metals. Getting the right bend on the handle was a challenge but with the help of the big pressing tool the problem could be solved. The smaller tools helped a lot with the edges and corners.

Figure 6.5: The plastic tube being placed on the working area for the saw. At the end of the tube cuts are visible where the hole later was formed.

For the merge of the plastic tube and the metallic handle many unique solutions were approached in theory. For example, metallic strings and super glue were some of the options that the student considered. However, by thinking from a practical and flexible perspective it was decided to use duct tape instead for the integration of the two items. Especially since the tape can be cut and taken away if an update were to be needed to the low-fidelity prototype. Super glue on the other hand would be far more complicated to remove and then the plastic tube and metallic handle could be damaged if they were to be separated. Conclusively, a support stick was crafted and inserted into the handle in order to give it a more stable position, see Figure 6.6. Extensive duct tape was used to merge the two items together, but since the duct tape is effective and strong the end result proved to be satisfactory.

a) b)

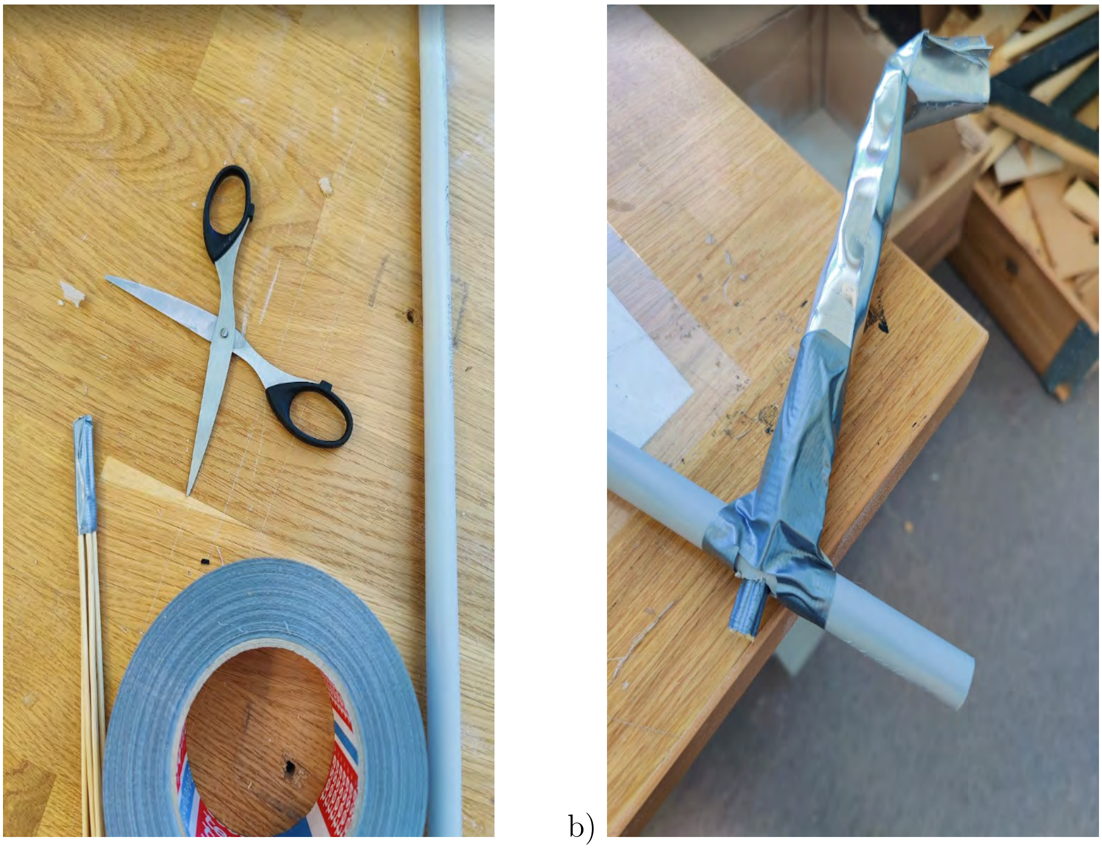


Figure 6.6: Figure a) shows the support stick on the left hand side. The duct tape was used extensively for the prototype. Figure b) shows the duct tape being used effectively to connect the two items together.

A lot of cutting was needed with the scissor in order to get the duct tape to go around the metallic handle and also to hold the support stick in its place. As many of the figures demonstrate, extensive duct tape was used and of course it looks odd but it was crucial for the entire prototype to hold together.

A lot of potential surrounded the prototyping of the mobile device that should be placed on top of the metallic handle. The student knew that if possible users wanted to try the prototype for testing then the screen could be adaptable depending on the situation. For instance, if a participant wants to know about potential interactive elements on the screen then that could be added by drawing an example interface. The mobile's foundation was therefore constructed using layers of thick cardboard with the screen being regular paper that was attached with duct tape. By doing this precise solution the "screen" can be changed depending on what interface the mobile device could show in a specific scenario, the image in Figure 6.7 shows the structure of the mobile's foundation.

Figure 6.7: The mobile's foundation, merged together using duct tape. Paper used to create an imitation of the actual screen.

The finished prototype can be viewed in Figure 6.8, where a more detailed vision of how the grip on the handle looks like. Some additional squeezing on the metallic handle was used in order to get a better ergonomic handle on the item. The screen for the final prototype is a simplistic mockup interface since the focus is not on adding any elements there, instead the prototype's weight and shape will be used for some field trials.

The purpose with the prototype was to help with understanding the surveying activity and to gain insights in how to answer the research questions. Although these are relevant things for the success of the Thesis, the student knew that the surveying wand prototype could be a beneficial asset for the rest of the team at ABB. Therefore the surveying wand prototype was brought to the office in order for the team members to share the experience as well. The product can be used as a significant tool for the later stages of the project and the whole team can benefit from this.

a) 

b) 

Figure 6.8: The final result is shown from two perspectives. Figure a) shows the prototype being held above ground. Figure b) shows the prototype in full without being touched.

6.1.1.3 Preliminary Study: Surveying Field Study

In order to understand the surveying activity better the student used the prototype outdoors and captured the experience of using certain actions and movements. Of course it was transparent that the real experience could not be achieved with a simple non-technical prototype, however the activity would be beneficial for understanding the general feeling of surveying. In addition, future user experience solutions can be spawned from this activity thanks to the documentation of the trials.

The student performed reconnaissance around Campus Lindholmen, Chalmers University of Technology, and found some good terrain for field testing. The muddy and marshy grass area proved to be especially intriguing since it could represent the rough and hazardous terrain that real surveyors could be tasked with exploring. For instance, when the student performed the surveying sweeping actions and kept only focus on the screen the outcome was a deep footprint in the mud, see Figure 6.9 a). From a safety perspective it was interesting to explore the attention users could have on the screen versus their surroundings. In this terrain it was flat but what if the terrain had rocks and the user stumbles when the foot goes into the mud without paying attention? Those were some of the observations that the student thought of when performing the field test. In Figure 6.9 b) the sample wand prototype is held in a conventional way and the camera captures the approximate point of view for the user. That experience was also intriguing since it explores how augmented reality could be placed in the field of view for the user.

a) 

b) 

Figure 6.9: Field study on a muddy and marshy terrain. Figure a) shows a footprint that was made when not having focus on the surroundings. Figure b) shows the conventional position that the user holds the sample wand.

As the images in Figure 6.9 demonstrate, the prototype could be used in both a careless and playful manner. For some situations the tip of the prototype's tube was pushed into the mud to give the student an experience of how that action could be like. Since the prototype is cheap and expendable the exploration of odd movements was good to do for the sake of understanding the profession better. Imagining how the test would have been with the real equipment would of course be less playful as the student would not want to damage the tip of the sample wand or drop it by accident.

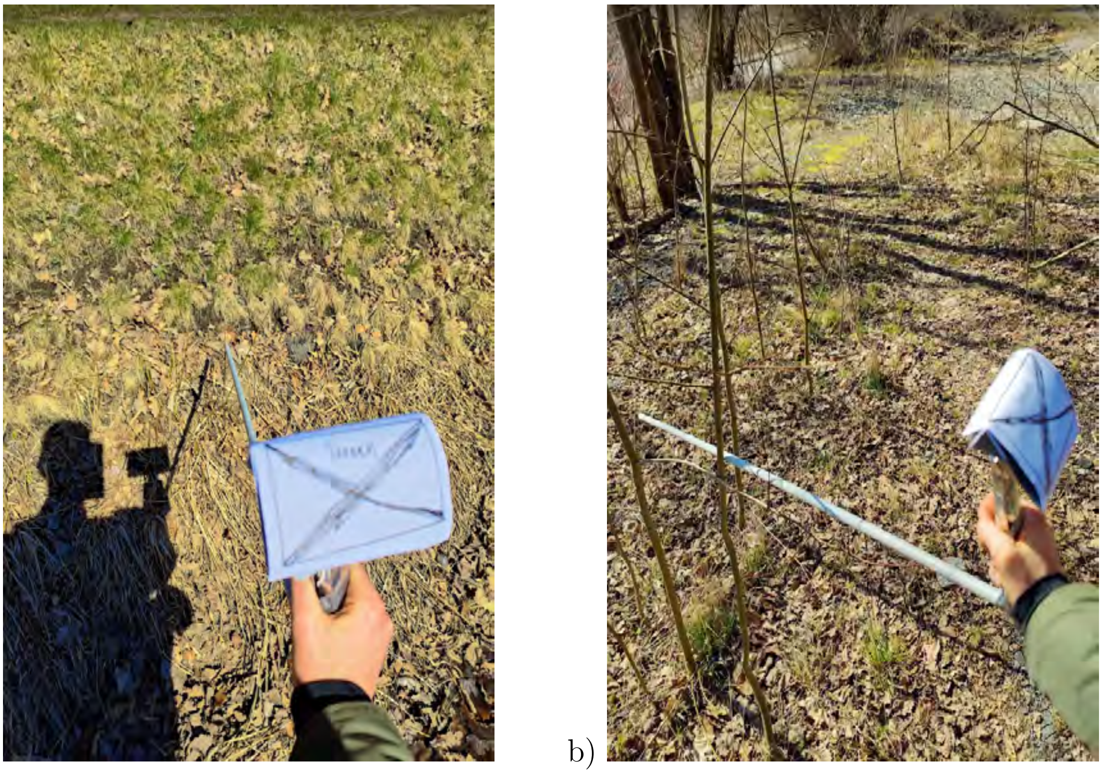
An interesting observation from the field test was that some of the environment could be explored with perhaps an already damaged sample wand or an outdated unit. By having the real equipment and a muddy terrain it would be interesting to see how the real weight can affect the user depending on how a surveyor slips in the rough terrain.

Further observations were made on how the attention on only the screen of the sample wand affects safety. In Figure 6.10, the screen is held extremely close to the user and the ground underneath the screen is difficult to see. Thinking from a perspective that a user could get lost in the screen and only focus on that could be a risk if the terrain is dangerous. Some interesting observations from this included questions like: "Should the users take responsibility for their own field of vision or should the augmented reality system display a warning?" and "Should users receive recommended guidelines about what their eyes should focus on?". Many good observations were made thanks to this test of the prototype.

Figure 6.10: A close perspective of the screen of the prototype.

The muddy and marshy area was beneficial for some aspects but there were other areas as well around Campus Lindholmen that gave the student new insights about the actions and movements of the sample wand. For example, in Figure 6.11 a) the user is standing on the ground but at a different elevation compared to the green ground on the top of the image. In order to get up on the high ground the student would have to push in speed and if the wand is facing forward it would go directly into the high ground. Some parts of the sample wand could be potentially damaged during this event or the impact could make the user lose balance. In addition, moving in compact terrain with a lot of trees, bushes and other things sticking up from the ground proved to be difficult to navigate through. Figure 6.11

b) shows the sample wand striking the small sticks in the environment when the user performs a 360 degree turn. Depending on how fast a user turns, those actions and movements can definitely affect both safety for the surveyor and other people around the surveyor.



a) b)

Figure 6.11: The environment affecting the sample wand. Figure a) shows the wand tip striking the high ground. Figure b) shows the sample wand being used in a compact forest environment.

In Figure 6.12, a hill is tested and how it affects movements. Moving fast up the hill requires the user to lift the sample wand in order to not strike the ground, see Figure 6.12 b). Perhaps a hill would not be a reasonable place to perform surveying on and doing a surveying activity in a rush does not feel logical. However, it was interesting to test regardless in order to understand if that could actually happen.

Another good observation made during this activity surrounded the weight of the prototype. For some areas the student walked back and forth with the sample wand prototype in a stable position above ground. Although not a heavy object, the positioning of certain arm movements made the weight irritating for the muscles of the arms.

a) b)

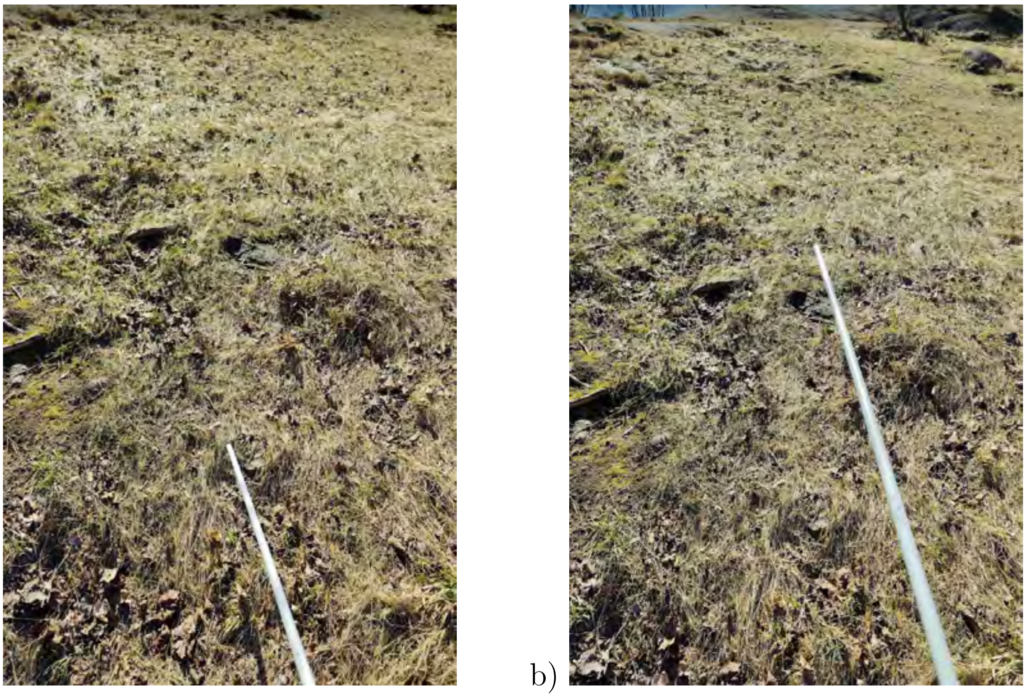


Figure 6.12: The prototype being used up a hill. Figure a) shows when the tip is nearing the ground. Figure b) shows the movement made in order to avoid impact.

In conclusion, the unconventional field study was a success in regards to learning about the actions and movements and how the environment can affect surveying. The weight of the prototype also felt slightly bothersome which was a good thing for the testing experience. Reflecting on the information learned from the interviews with the expert users also helped when performing the actions and movements. The activity was also good for thinking about potential solutions to some of the problems. The fact that the sample wand prototype could be used in a careless manner was a good thing since many insights could be discovered from doing different testing scenarios, without having to worry about costs and damages.

6.1.1.4 Preparations for the Interviews

The upcoming interviews with expert users would be a joint collaboration with the UX team. The student's aim with the interviews was to ask definitive questions about the safety and efficiency aspects and their relations to surveying and augmented reality. However, since the augmented surveyor project is of interest to the UX team at ABB this meant that the entire interviews could not solely focus on the safety and efficiency aspects but other crucial perspectives as well. Therefore detailed planning and preparations for the interviews had to be made within the team.

With good communication and productive meetings the team could together finish the main interview document with items like the introduction and preliminary surveying questions. The student would later on his own structure and complete questions regarding safety and efficiency. The focus was on making the questions precise in order for them to fit the qualitative data that is going to be needed to answer the research questions. The student also structured the questions with the subject matter experts(expert users) in mind because they can provide valuable perspectives on a product [16] and this was crucial for the Thesis.

The confidentiality behind the project meant that the expert users would have to be ABB employees. Furthermore, since many of the expert users were not on location at the Swedish Corporate Research Center the aim became to conduct all the interviews via Microsoft Teams. This will be beneficial because the interview sessions can be recorded directly and then they can be returned to at a later time and be analyzed in a more thorough manner.

6.1.1.5 Interviews with Expert Users

When all the documents were ready the team moved forward with conducting the interviews on Microsoft Teams. The expert users had different backgrounds as well as different experiences with surveying and their expertise can be summarized as the following:

- **User 1** - Man, expert user. Extensive experience with the surveying systems and the surveying activities. Experience with surveying logistics.
- **User 2** - Woman, expert user. Good experience with the surveying systems and the surveying activities.
- **User 3** - Man, expert user. Sufficient experience with the surveying systems and the surveying activities. Experience with safety for surveying.
- **User 4** - Man, expert user. Extensive experience with the surveying systems and the surveying activities. Experience with how wind affects surveying.

The interviews were expected to run for around 90 minutes each and most of them lasted for 90 minutes with one exceeding 120 minutes. For one interview, a follow up session had to be made in order to capture more qualitative data. Finding the right balance between the student's questions and the questions from the other observers proved to be difficult. Respecting ABB's interest in the project was important and not only thinking about personal motivations. For the later interviews the student received the chance to start with his questions and this reduced the stress of the timing. Significant information that concerned unique safety and efficiency aspects were written down on personal notes. A set of introductory and conventional interview questions can be seen in Figure 6.13.

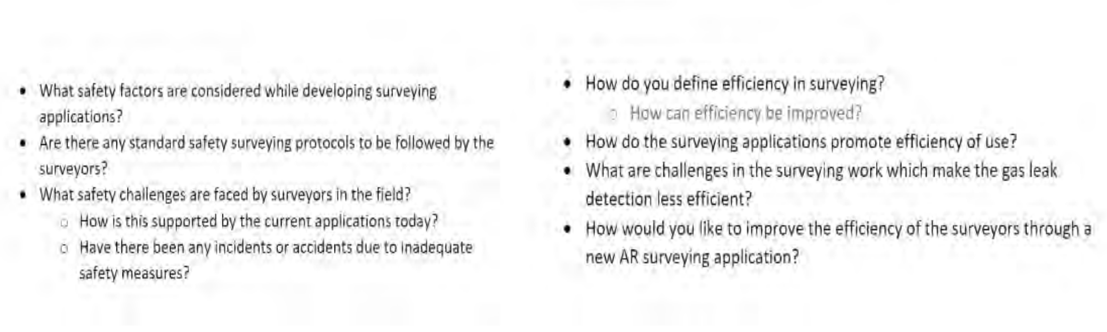
- Can you please describe your background and experience?
  - For how long have you been working in this position?
- What are your responsibilities/ tasks?
- How much time do you spend on each responsibility?
- Do you require any training/ certification to be a surveyor?
- What is the toughest/ challenging aspect about being a surveyor?
- Do you have any experience of using AR technology or glasses?

Figure 6.13: A set of introductory and conventional interview questions.

One challenging aspect with the interview procedure is that timing and scheduling is crucial for the effectiveness of the process. For instance, since some of the expert users are working in a different time zone the team had to adapt to make it work for both parties. Finding participants and then setting a date took longer than expected in regards to the planning of the Thesis. The actual number of participants required for an interview varies, for example a rule of thumb for interaction design is 12 [9]. Guest et al. explains that depending on the study the number of participants can range from 5-25 and specifically for a homogenous sample only six to eight participants would be needed [79]. However, since the participants for this part of the project are expert users it was discussed that five would be a sufficient number. For instance, Dumas et al. highlighted in their article that five usability specialists were enough for their study on the user interface to a phone-based, interactive voice response system [80]. The usability experts all had at least eight years of experience designing and evaluating user interfaces [80], an intriguing aspect on why using experts is good.

Based on literature and previous work, the ambition was to have five experts for this phase. Although five expert users were contacted, only four participants were a part of the final interviews with the UX team. Because many of the employees at ABB have other tasks and duties to attend to it was difficult to find a time that worked for everyone. In addition, some people were contacted but did not return with a reply. As time was needed for the data analysis of the interview it was decided that the student could move forward with only four expert users since the information gathered from them was sufficient and of good quality.

In conclusion, the interview phase was beneficial and useful for the Thesis. New insights about the surveying profession were made and the understanding for the concept grew as well. Learning about how to perform an interview via Microsoft Teams was certainly a good experience for the student. A lot of relevant data for the research questions were gathered and observed. In addition, technical concepts about for example concentration of gas and the names for the equipment were observed as well. A set of questions regarding safety and efficiency from the interviews can be viewed in Figure 6.14.



- What safety factors are considered while developing surveying applications?
- Are there any standard safety surveying protocols to be followed by the surveyors?
- What safety challenges are faced by surveyors in the field?
  - How is this supported by the current applications today?
  - Have there been any incidents or accidents due to inadequate safety measures?
- How do you define efficiency in surveying?
  - How can efficiency be improved?
- How do the surveying applications promote efficiency of use?
- What are challenges in the surveying work which make the gas leak detection less efficient?
- How would you like to improve the efficiency of the surveyors through a new AR surveying application?

Figure 6.14: Safety and Efficiency related questions for the interviews.

6.1.2 Defining

The following section will present the activities that established many important aspects of the project. The data analysis is a key part of this section and in addition many collaboration events with the team at ABB were crucial for putting a strong focus on the current progress. Focusing on defining the problem is significant for this specific section.

6.1.2.1 Workshop with the UX team

As the augmented surveyor project is a significant part for the UX team at ABB, many meetings had to be held in order to plan the future steps. Although the student did not have any hand in the future events after the Thesis it was good to join the workshop meetings and discuss the current steps and of course the data analysis of the interviews. The workshop meetings were organized online with Mural, where all the ideas and concepts were being saved on the many workspaces and then the team discussed them together. The expertise of the workshop participants can be viewed in the list below:

- **Participant 1** - ABB employee, woman. Researcher and Designer. Part of the UX team. Good experience.
- **Participant 2** - ABB employee, man. Research Team Manager. Part of the UX team. Extensive experience.
- **Participant 3** - ABB employee, man. Tech-ethnographer, Senior UX Researcher. Part of the UX team. Good experience.
- **Participant 4** - ABB Thesis Student, woman. UX Consultant and University student. Sufficient experience.

For the Thesis this activity was very beneficial and positive, since the student could receive feedback from the team about what methods to use for the defining phase. In addition, since many different approaches were discussed this proved to be useful if something would go wrong and the student would have to change a method. Then the backup methods from this workshop activity could be used as they had been approved by the team. In addition, the workshop gave the student good experiences with working with the overall development process and how it works at a company level.

For example, the quantitative research method Ergonomic Analysis [10] was being discussed during the workshop as the student thought it could be helpful for exploring the research question connected to the actions and movements and if the method could be used in any stage of the Thesis. Figure 6.15 is an example of a discussion area for the encouraged method Ergonomic Analysis. The qualitative analysis technique method [10] Personas was also discussed as a potential tool for the upcoming prototyping phase as Personas help with making a decision for designers [9] and they remind the design team that real people will be using the product [9]. Thematic networks as a possible method for the later phases was discussed as well since the concept of organizing data in different themes, such as basic, organizing and global [10], felt like it could give a good structure for the qualitative data.

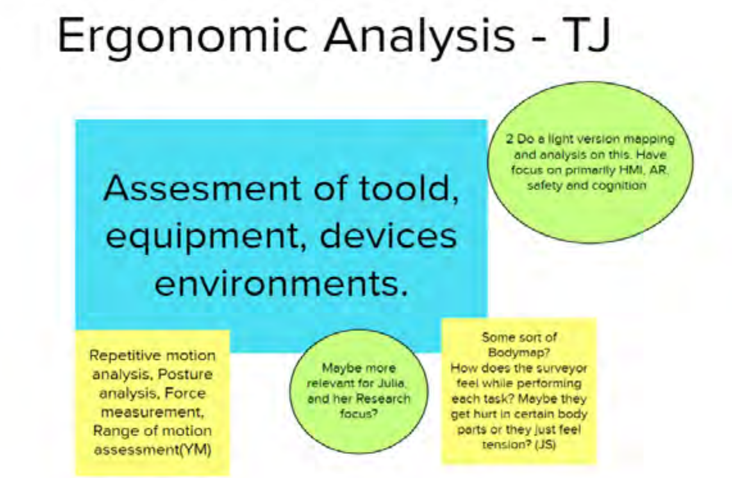


Figure 6.15: Discussion regarding design methods for the project.

Many of the methods that were discussed during this workshop were preliminary planned as being potential solutions to the entire process. Since the student had already planned to use Affinity Diagramming due to its simplicity and effective structure and the fact that it was approved by the other team members, the need for other methods did not feel relevant. However, things that are planned might not always go into full effect and the workshop was useful and beneficial as a backup solution if something unexpected were to happen later in the process. Then it is better to have learned and touched upon design methods instead of trying to explore unknown methods. In order to be flexible a quick change to the process could then be made with good knowledge of previously discussed methodology.

6.1.2.2 Data Analysis - Affinity Diagramming

For the data analysis phase of the Thesis the main method used was the Affinity Diagramming. The design method was chosen mainly because it is a qualitative and generative method [10]. During the workshop discussions the method was approved by many individuals as being an effective tool for the defining phase. In addition, since almost all work is done via the online tool Mural it felt optimal to utilize that tool and build up the categories of data using digital sticky notes.

In order to be effective with the method, the student decided to listen to the recordings of the interviews and write specific notes for the data that connect to the safety and efficiency aspects. Instead of listening and writing directly onto the digital sticky notes, the interpretations were written down on paper as that would be faster and more effective than switching between windows. When the notes were completed they were converted into their respective sticky note color, where each interviewee had their own unique color, see Figure 6.16 for the complete sticky note board. The data analysis was done using Miro, which is identical to Mural, and the final analysis was pasted over to Mural for the team to interpret as well. The reason Miro was being used was because the student's home screen was bigger and more effective than the small ABB laptop.

Figure 6.16: The notes and keywords from the recordings pasted onto sticky notes. On the left side there is a guide for mapping the user to a color.

When all the notes were on the board the actual analysis began in order to identify and categorize the data into structured groups. Reading through the insights and feedback from the interviewees was the first step performed and after that some categories could be established based on themes captured from the overall data. For instance, since the interviewees were expert users they mentioned the term GIS and this was captured from the analysis and made into a category. After analyzing all the data further, new categories could be created and specified, as presented in Figure 6.17, where all the major common themes had been identified for the safety and efficiency perspective.

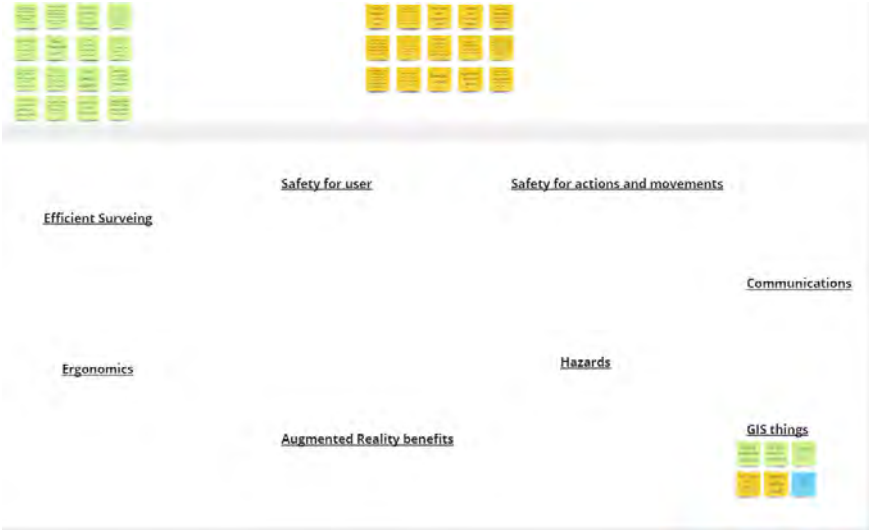


Figure 6.17: The categories and common themes that were concluded to represent an approximate grouping of the overall data.

Once the categories had been established, the next step was to sort and group the sticky notes into columns close to the keyword themes. This process was easier said than done, mainly because some of the items could be identified as being part of two themes. Therefore, the student went through the most clear connections first instead of finishing one interviewee's insights first and this made the board a little more cluttered with colors. Although this process took some time, it was significant and important for defining the future solutions as the student could identify the current problems and other opinions on the surveying activity. A lot of comments and insights from the expert users gave the student a greater understanding of the surveying profession and challenges, and when the data was grouped into categories that understanding grew. For example, the group called Forces of Nature focused specifically on how non-human actions can affect both safety and efficiency. The fact that wind direction is such a definitive factor for surveyors was unknown to the student and then this analysis and grouping made the situation more clear and comprehensive.

Although not all of the categories included the keywords “safety” and “efficiency” they still held a crucial purpose for the analysis of the engineering challenges for surveying. The different themes helped with spawning interesting design ideations and thoughts for the student when thinking about the later stages of the project. For instance, the group called Current Surveyor Tasks was a good source to both analyze and consider when thinking about how a more optimal and strong design could look like for surveyors using augmented reality. The final Affinity Diagram with all the themes and categorizations can be viewed in Figure 6.18

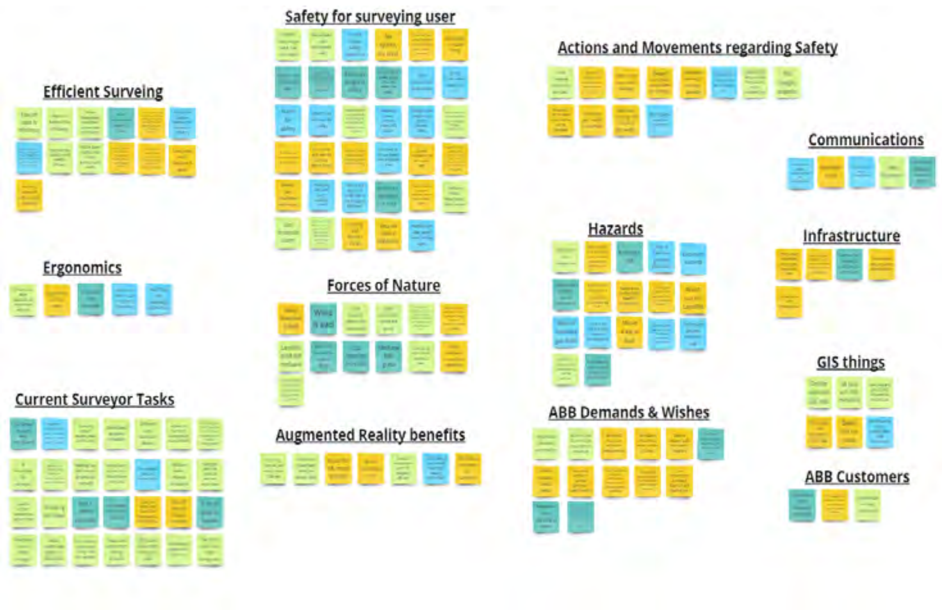


Figure 6.18: The final Affinity Diagram from the data gathering phase.

The finished affinity diagram was shared with the team by transferring the digital sticky notes from Miro into Mural. Although the finished data gathering did not reach the desired five expert users the final result proved to be beneficial and significant for the solutions to be explored. The student studied the final data closer for some time when everything was shared with the team and when a basic understanding of the situation had been established it was decided to move on from the problem space and move into the solution space.

6.2 Executing: Comprehending and Exploring the Solution Space

For this extensive and crucial section, many unique phases are explored. The phases all have a common purpose and that is to create a solution. As this final stage will be iterative and conclude in a delivery of a solution and a discussion connect to it, the approaches to many of the challenges have to be precise. Consulting the conceptual and academic models is a key strategy for this section. The Interaction Design lifecycle model is the most beneficial and relevant model for these last phases and in addition the right hand side of the Double Diamond of Design is an important area to consider when approaching the solutions. However, since there are many different and critical areas to explore the Google design sprint methodology is the main model to follow in order to structure the results. The phases of Sketching, Deciding, Prototyping and Validating are explored in full detail in this section and their connection to the project.

6.2.1 Sketching

The sketching phase provided the Thesis with some good examples of ideation as well as creative thinking. Although the plan was to start with the method Crazy 8's, the student started with some ideas that felt especially intriguing based on the data collected from the expert users. As some of the experts expressed deep wishes for future improvements, the student had visions of how to please the users. However, the student went back to perform the Crazy 8's method in order to achieve the correct ideation progress and to also see the bigger picture and additional solution perspectives. As the sketching activity was individual it was a challenge to approach the design ideation method, especially since the method is mainly a team activity [62] [64]. Although doing this phase alone proved to be a challenge, the benefit was that the choosing of ideas to move on with for the prototyping was easy, as no votes or discussions were required.

The sketching phase also helped with some good planning for the eventual high-fidelity prototyping. As getting solutions down on paper was easy, the student could analyze possible complexities and from the sketches see what is actually feasible in the digital tools and what solutions that might be too extensive as well as time-consuming. The sketching phase is of course a very beneficial and significant part of the project. The solutions presented in this section benefited greatly from this ideation activity and conclusively the sketching phase can be viewed as the most paramount part of the entire design process.

The images in this section can be compared with the final images of the high-fidelity prototypes in order to see how the thinking process has been changing for some parts of the design and how it has stayed the same for other ideas.

6.2.1.1 Crazy 8's

The Crazy 8's method was performed with a good structure. By having the affinity diagram in front of the student the ideas could come quicker to mind when doing the time-limited design method. The student placed a piece of paper on the desk and created eight boxes on one sheet. Then for two minutes an idea was created inside the box, the next two minutes another idea was created into another box and so on. The sketching activity was important as it helps designers think through as well as talk through ideas [65]. Even though the activity was individual the student discussed out loud some of the possible solutions and approaches.

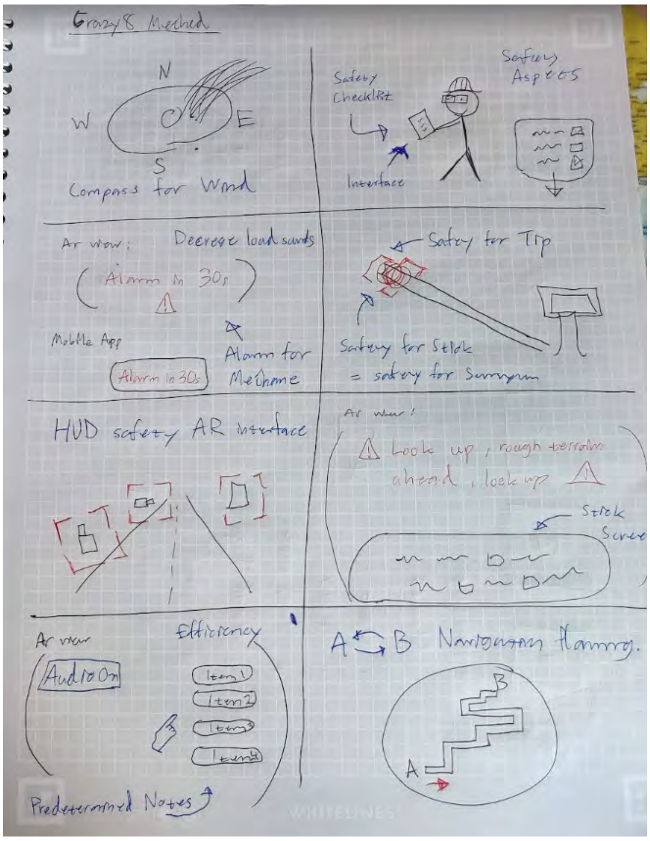


Figure 6.19: Crazy 8's result from the ideation session.

Figure 6.19 shows the final result of the Crazy 8's ideation method. As some things were difficult to doodle during the limited time, words were used to describe the thinking process in order to get a positive ideation result and to have something to work with. Inspired by the principle of "keep writing and keep drawing"[63] the student managed to get the ideas on paper and think about the solutions. As with many ideas, some are favored more than others and when it came to choosing some ideas to sketch further the choice was simple as the opinions from the expert users were always considered as a key factor.

6.2.1.2 Solution sketches

Favored ideas were refined and developed further on paper. By having both the data from the expert users and the research questions in mind, the problem could be tackled more precisely. The student analyzed the problem from multiple perspectives and put an emphasis on the keywords "safety" and "efficiency". By doing this many of the designs received a greater purpose than just being interfaces, they had a connection to making the surveying activity safe or making the surveying activity more efficient. By also focusing on the perspective of augmented reality the sketches could be created with an effective touch. For example, the point of view(POV) for the augmented reality headset was taken into account for many of the sketches and it makes the ideas easy to understand as well as communicate further with other people.

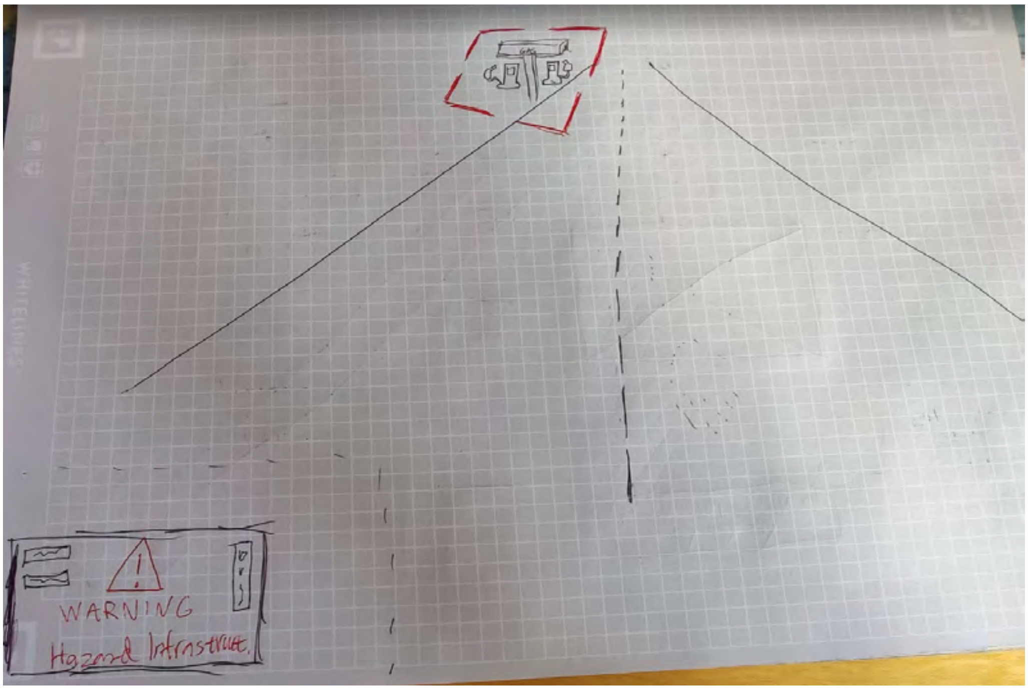


Figure 6.20: A safety lock-on design element that is viewed in augmented reality.

One major fascinating idea with implementing safety aspects into the augmented reality environment is that colors and shapes could be used to a great extent. In Figure 6.20, one of the generated ideas is presented in a fairly simple sketch where the safety perspective is explored. As the expert users concluded that methane gas can be an explosive risk and that structures with high concentration of that substance should be avoided it would be beneficial to have an effective visualization to show these areas. The idea to have a heads up display lock-on type of visualization felt that it could be a key design for warning users of risks. Making it red and styling the shape as a lock-on visual element felt advantageous.

A theoretical inspiration for the safety lock-on design came from the in-vehicle AR-HUD system [82] created by Hye Sun Park et al. In their article the authors suggest that augmented reality technologies can be used to provide the driver with a large amount of information within the vehicle [82], and the HUD(heads-up display) is a key tool in that solution. Although the lock-on target indicator in efficiency solution is not a heads-up display, it is a part of the augmented environment and the designed elements works as a heads-up recommendation item. The design for the technology developed by Hye Sun Park et al. features squares to highlight pedestrians and other cars, and red colors are used to highlight obstacles in front of the driver [82]. With the lock-on target indicator the choice to use a square lock-on felt like a natural approach as it is common for other HUD technologies and then it can be recognizable for the user.

In addition, placing oneself in the shoes of the surveyor and viewing the design from a POV perspective proved to be beneficial for the ideation process. Especially thinking about the outdoor experience was significant for understanding certain positions that can occur during the navigation.

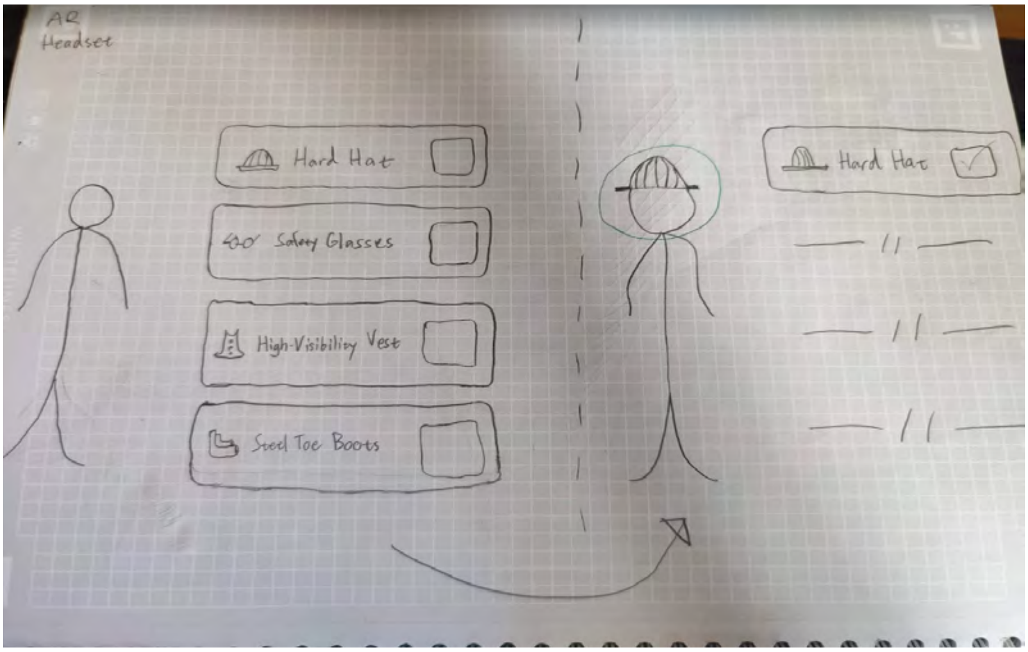


Figure 6.21: A safety checklist for the surveyor to complete. The left side is the first view of the screen. The right side shows the result from an interaction with the previous screen.

An additional safety design solution surrounded the required safety equipment and gear that a surveyor needs for the surveying activity. By utilizing the augmented reality environment and the gestures that can be used for completing certain simple tasks the idea felt reasonable. The idea to have a checklist in the augmented reality environment was conceived and the rough interface idea can be viewed in Figure 6.21. For the design idea both the user experience perspective as well as the safety perspective was considered in order to capture the whole purpose of the solution.

For the efficiency aspect of the Thesis the aim landed on the navigation of the surveying user. Many of the experts concluded that knowing wind direction versus knowing the walking direction is a key part in making the surveying activity efficient. As the two directions can interrupt the navigation through many different ways, a new solution is needed to make sure that the user can identify the direction of the wind with the augmented reality and at the same time identify the path for surveying. By taking inspiration from the scientific wind rose diagram the student sketched a solution where the diagram visualization is fused together with a compass in order to increase the navigation efficiency. Figure 6.22 shows a close up of the wind direction compass and where the compass can be located when the user has an entire environment to survey. The red pipe on the sketch represents the underground pipeline that the user has to investigate for possible leaks. The other representation in Figure 6.23 highlights how a mini map can be used in combination with the wind direction compass. In addition the path that the surveyor takes, the blue arrows, is more extensive compared to the previous image.

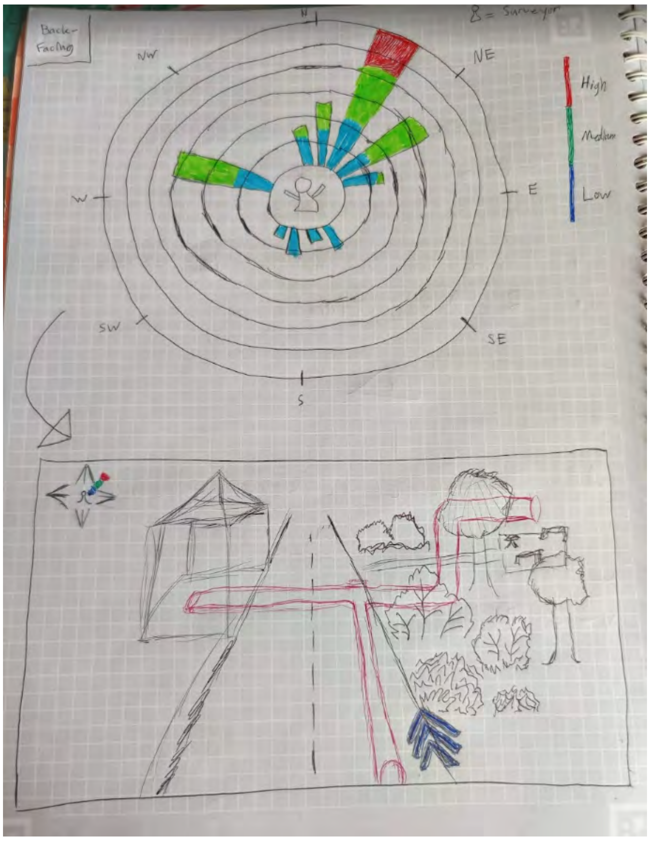


Figure 6.22: The wind rose diagram and the environment where it can be used.

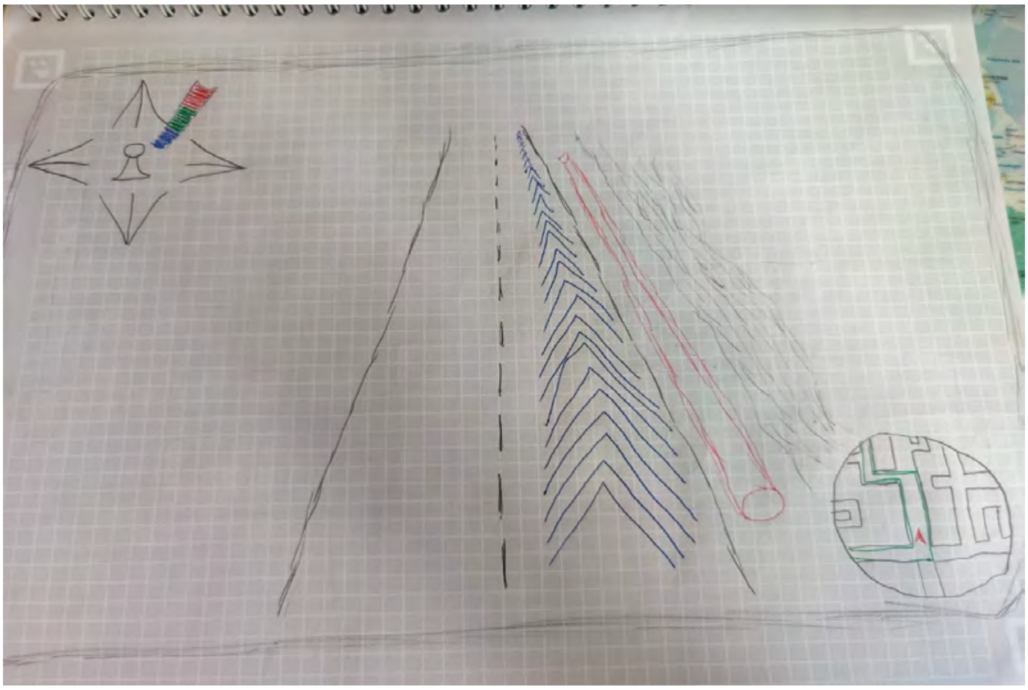


Figure 6.23: A mini map and the wind rose compass in an environment where the user looks to the horizon.

6.2.2 Deciding

The following phase is an essential part of the Thesis, however it is a fairly sufficient and short part of the process since many of the decisions are made individually. The Google design sprint highlights many different deciding techniques that can be used by a team, for example Dot Vote and Decision Matrix [62]. The methods are relevant for a team working together on design solutions and therefore not optimal for a single student choosing a design solution. For this phase personal selections were made based on feedback from the advisor as well as the supervisor.

6.2.2.1 Presenting the Solution Ideas and Sketches

The sketched design on paper and the connected concepts and visions to each of the ideas were presented to the supervisor first and the feedback was taken into account. The presentation for the advisor at ABB was more crucial and the process of presenting the sketches and ideas had to be made in a correct manner while connecting the design to the research questions. Once all the potential solutions had been presented the feedback was taken into account. The presentation of the solution ideas gave the student additional insights into what items could be made into prototypes. With the presentation phase done the next phase would be to prototype the solutions using computer programs.

6.2.3 Prototyping

The deciding phase provided a lot of good insights and perspectives on how to take a simple sketch and develop it into something definitive and significant. With a good grip and perception of how to continue with the solution development, major steps were taken into the realm of prototyping. This section will showcase the entire prototyping phase, from the storyboarding of scenarios of the solution ideas to the actual high-fidelity items that will be used for the important validation of the solutions. In this section, selected images from the prototypes will be presented and their connection to the safety and efficiency aspects.

The solutions presented in this section will be referred to as belonging to scenario 1 or scenario 2 or either the safety aspect or the efficiency aspect. Based on feedback from the advisor it was decided that having two scenarios both for the safety and efficiency perspectives would prove to be crucial for the validation as well as the analysis of the design solutions. Therefore some designs can be very similar but the purpose is different and this will be shown in the following section.

The design of the prototypes can be compared with the initial ideas from the sketching ideation in order to see how the solutions essence have changed from a simple idea to a more extensive final version.

6.2.3.1 Storyboarding

Before taking the chosen ideas from the sketching phase and transforming them into the high-fidelity prototypes, the first step began with the creation of low-fidelity storyboards of the design solutions. Although many of the sketches had a sufficient amount of designed information on them, the additional storyboarding treatment of their themes created new visions previously not implemented in the sketching phase. Especially, the safety aspect, the self-inspection checklist, benefited from the series of storyboards that gave the solution more context. In addition, storyboarding is important and good for imagining the finished prototype, in order to spot problems and points of confusion [19] before any prototype development is generated.

The images in this section will showcase the set of storyboard series for both the safety solution and the efficiency solution. The storyboards are simple in their design as the objective is to get a better understanding of the experience and how the surveyor can use these tools in a real life context. Although the essence of the safety checklist, created in the sketching phase, is still the same and the purpose of doing the checklist task is true to the intended version is the sketch the storyboarding present a new design compared to the original idea, as seen in Figure 6.21. The new definitive design for the checklist, as seen in the series of Figure 6.24, is inspired by a theoretical design pattern.

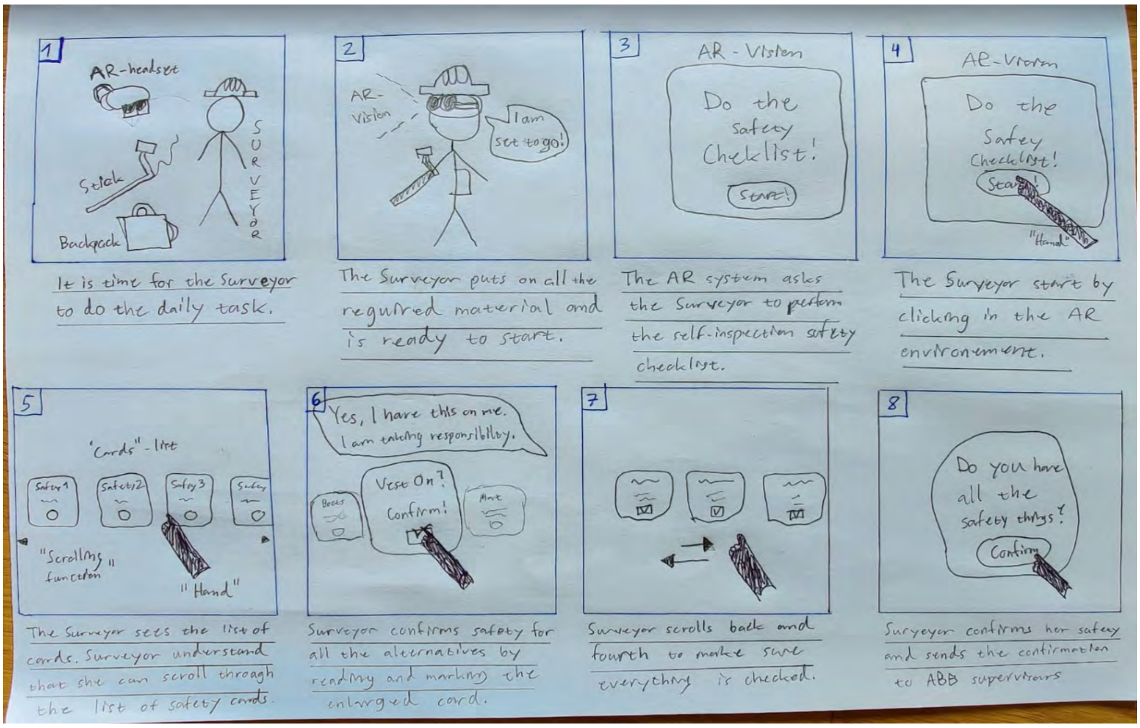


Figure 6.24: Storyboard scenes for the augmented self-inspection checklist, part of the safety aspect.

The inspiration to make the items of the checklist into cards came from the design pattern Cards. The main reason to use this approach is because a list of heterogeneous items that have the same behaviours associated with them will benefit from this method [1]. Tidwell et al. explains that the pattern is one of the most popular and flexible user interface components [1] and this means that using it in a design scenario will make it recognizable and apparent. Another perspective gained during the storyboard prototyping was the realization that the augmented reality visual elements would exist in a 360 degree environment and therefore using the Carousel design pattern would be an advantage and a crucial user experience solution. The Carousel pattern is a great tool for making the interface more engaging for the users and to allow them to browse through visual items in a horizontal manner [1]. Combining the Cards pattern with the Carousel pattern is a significant design solution for the checklist. It makes the interface feel more engaging and clear, and the visual elements adapt well to the augmented reality environment. Figure 6.24 showcases some of the Carousel functionality and how it relates to the task of completing the self-inspection.

As the intended final version of the efficiency prototype is expected to be light in interaction the set of series in Figure 6.25 present the envisioned user scenario in a good and precise way. The storyboard for the wind direction compass and the lock-on target indicator shows a fraction of how the surveying task could look like in real life. Of course there are many different things that can happen out on the field that affects both the wind direction but the effectiveness of the surveyor. For example, if a major storm would strike the surveying area then the system would have to inform the user in a definitive way that there is no point in performing the tasks in that kind of weather.

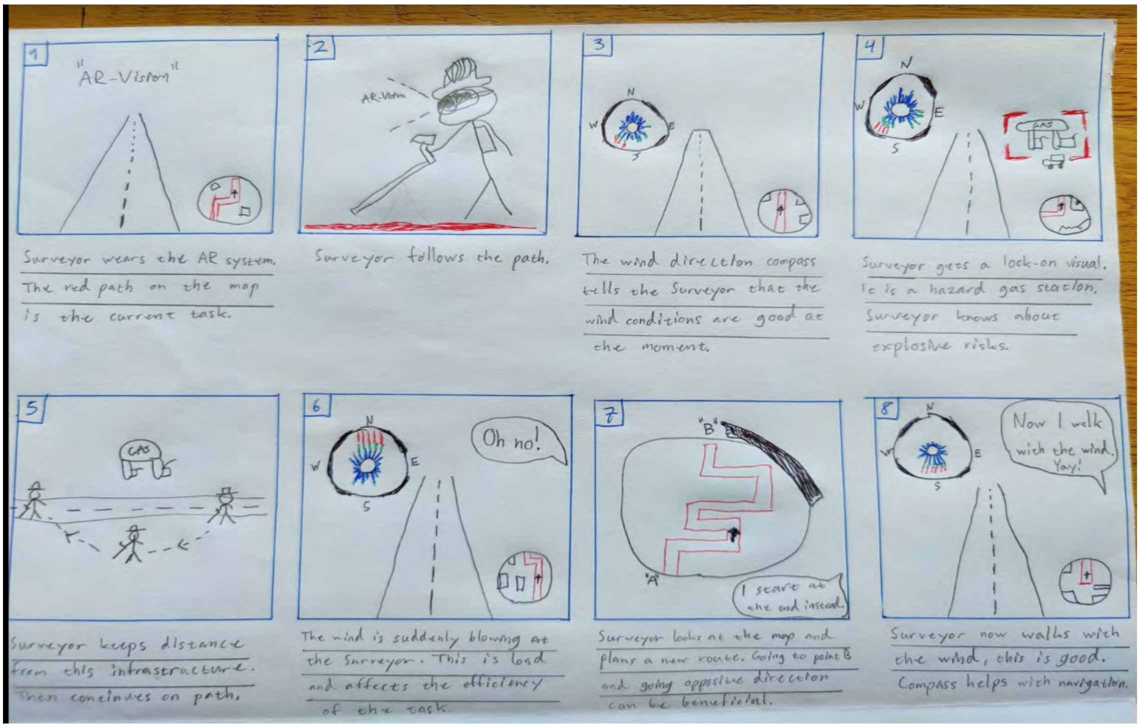


Figure 6.25: Storyboard scenes for the augmented wind direction compass and the lock-on target indicator, part of the efficiency aspect.

6.2.3.2 Gathering of real life images

In combination with the high-fidelity prototyping procedure one of the ambitions was to acquire real life pictures that fit into the vision of the storyboarding, for example a petrol or gas station environment. For the entire prototyping process the aim with the design is to make it as original and distinctive as possible. Therefore a lot of the design is developed in the digital tools and existing shapes and forms are a substitute resource. The same motivation is used towards the usage of real life images. Of course there are many free stock photos that can be used for this project but since the student wants to create a distinctive feeling and avoid any potential copyright the task to find real locations began.

Some photos from Section 6.1.1.3 could be reused for this part of the project. As the student scouted many areas for the Surveying field study, the location of a potential gas station was known as well as some construction sites. The student went to these locations and took photos around the infrastructure area with the storyboarding and the prototypes under development in mind. By doing this task instead of searching for free images online where the right angle would have to be found the student could now take the photos from the desired spot and also imagine being a surveyor in that location. A work bench area was found as well and this spot could be photographed from the desired angles as well. The photos taken would later be used for the prototypes to build up the real life setting and environment.

6.2.3.3 High-Fidelity Prototypes

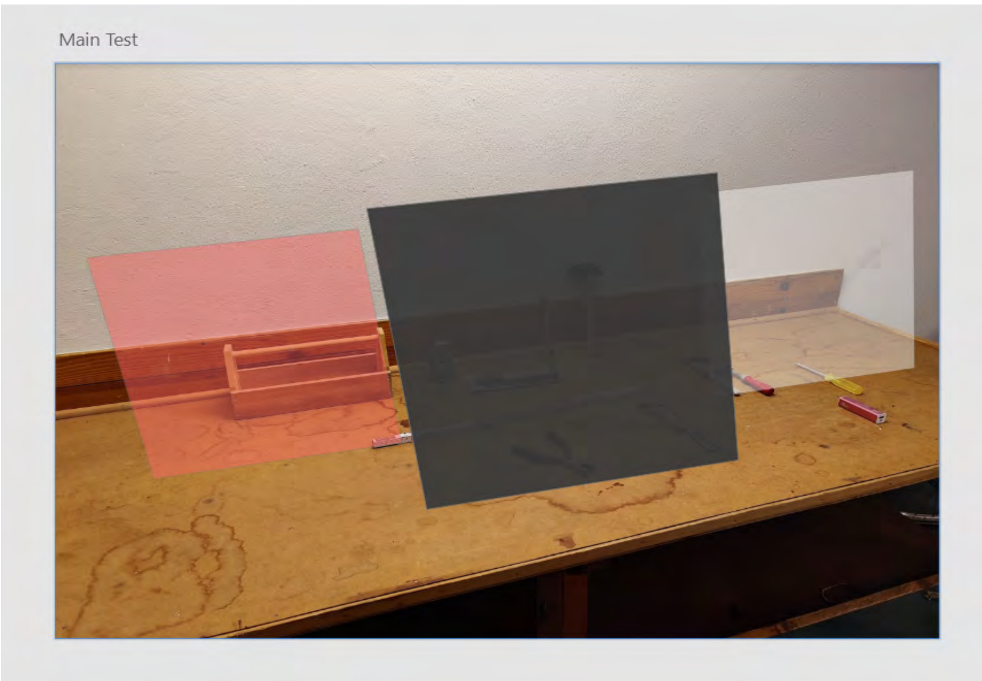


Figure 6.26: Test for the Safety scenario: 3D functionality being explored and calculated.

Many different high-fidelity procedures were considered for this part of the Thesis, for instance the Unity real-time development platform was explored at the beginning of the project. However, with the limited time available for the continuation of the Thesis the digital tools Figma and Adobe XD were used instead in order for the prototypes to become closer to the vision of the final product. The two platforms have one thing in common and that is that they have a prototyping functionality that can connect digital items together and make the whole design interactive. Furthermore, Adobe XD has third dimension functions that enables graphic content to be moved into and around the images. This functionality was especially adopted for the construction of the self-inspection checklist design.

Using the paper sketches from Section 6.2.1.2 together with the storyboard series from Section 6.2.3.1, the initial parts of the prototype phase could begin. In order to achieve the look and feel of the envisioned product the significant prototyping instruments of the digital tools were explored. Although the student had good knowledge about the digital tools, the specific third dimension functionality of Adobe XD had to be explored and tested upon before the actual design could be implemented. In Figure 6.26, the colored cards in the images have been aligned along the position of the table in order to imitate how the elements could be visualized through an augmented reality system. Furthermore, the decision to have a shot of the table with a slight angle was made to highlight the imitation of the augmented reality world being in balance with the real world. In the image the black card could be moved in the z-direction with the help of the Adobe XD functionality. The black card represent the selected item that the user wants to take a closer look at. By having the test being completed the actual task of making the real design could begin.

Due to the limited time the student began working with the efficiency scenario in Figma as that platform was set to go while Adobe XD needed an account activation. Several iterations of designs were completed and compared to each other. For example in Figure 6.27 many of the unique designed elements can be viewed. Many of the items were created outside of the black working area but then brought back to this place where the 3D atmosphere could be explored in more detail. The grey shape in the middle of the screen represents a road that the user of the system views through the augmented reality headset. The grey area is more difficult to see in the distance and this is the point since it represents the viewer looking to the horizon and perceiving certain objects from different distances. The 3D cylinders in the image represent infrastructure that could be positioned at different distances and the perspective of that was explored in this test. The size of the compass and the minimap were put into perspective as well. Although the test for this specific scenario is somewhat unorganized, the purpose was good and clear. Having the essential designs in a common and united area was good for the thinking process as they could be compared with each other and how they relate to each other in a real life context.

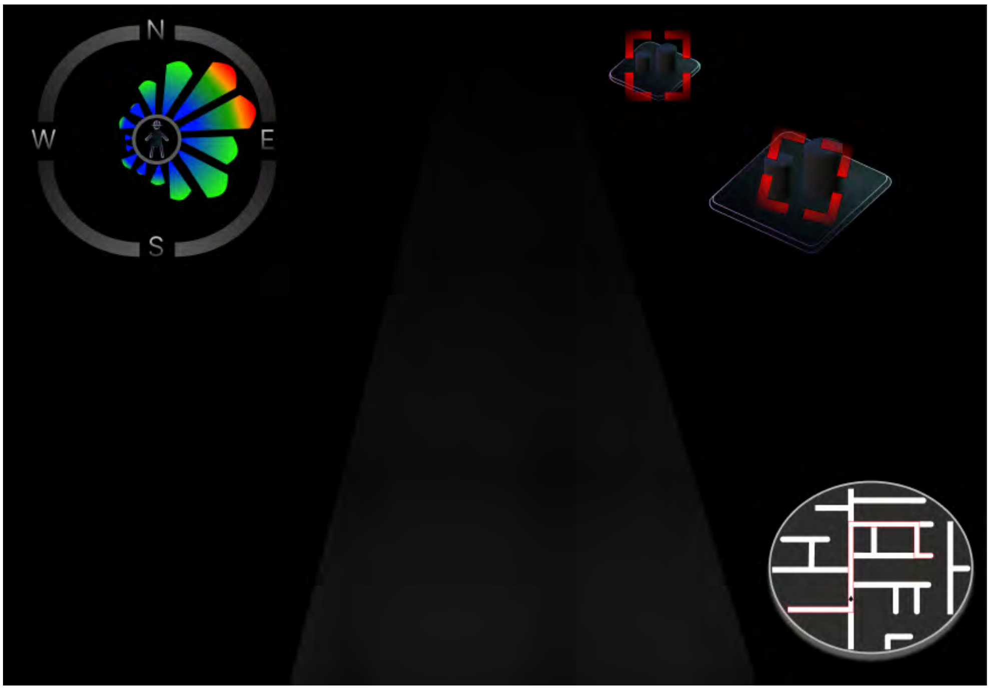


Figure 6.27: Different design elements being constructed and brought together.

For many of the designs, simple shapes and building blocks were used to create the items such as the compass and the danger lock-on target indicator. Figure 6.28 showcase some of the important shapes that were used to build up many of the envisioned solutions and tools. For example the rectangular objects at the lower side of the image were used entirely for the lock-on visual element. The rectangular shapes were duplicated and experimented on to see how they could be transformed into the envisioned lock-on target indicator from the sketching activity. Testing the different shapes and forms in a working area was crucial for understanding and exploring the best design solutions for the final prototype.

The ray shape at the top of Figure 6.28 was one of the early ideas for the bar chart compass where each ray represents a wind direction. At first basic rectangular bars were considered for the wind direction compass but when testing a set of ray shapes they proved to be optimal too. In addition, many of the wind rose example tools found on the internet have rectangular bars as indicators and the aim for this design was to try to make something new with a different perspective. Using Figma the ray shapes could be duplicated and the different copies could be shaped into both small and big sizes. In addition, using the extensive color tool for the shapes in Figma, the ray objects could be full of multiple colors. This was essential in order to connect one color to a certain wind frequency where for instance red was chosen to represent a high wind concentration.

Figure 6.28: Shapes created in Figma for testing.

One major ambition with the designs was to make them as original as possible. Using the free libraries for both Figma and Adobe XD, additional resources could be gathered and used in the design, for example simple icons such as the check-box marker. However, the aim was to not use copyrighted images for the icons of the cards for the safety scenario and therefore all of the icons were made with the functions available in Adobe XD. In Figure 6.29, all of the icons used for the self-inspection checklist were made with the built-in design tools and functionality as well as using icons from the free libraries. Furthermore, when it came to the realistic outdoor images they were taken by the student in order to avoid any copyright incidents.

The icons were developed to be simplistic and comprehensible for the user. Although the header for each of the icons within the cards would help with the perception and understanding of the purpose in the final design the icons themselves had to be clear and understandable enough in order for the user to grasp the situation directly. For example the red color was significant for the icons they highlight some sort of danger or warning. Using this effective trick for the icons would guarantee that they are perceived and identified as important for the validation of the self-inspection checklist safety scenario.

Figure 6.29: The unique icons used for the cards of the self-inspection checklist.

Safety Aspect - Scenario 1

For each of the icons a strong and clear title header was added to highlight the purpose of both the icon as well as the checklist card. Figure 6.30 represents one of the specific cards and the title that is connected to the icon. Short and effective titles were implemented for all of the cards in the checklist design.

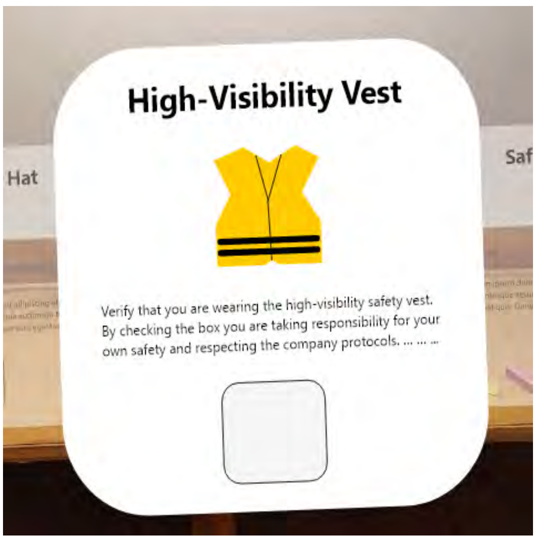


Figure 6.30: The High-Visibility Vest card from the self-inspection checklist.

As the safety scenario for the self-inspection checklist is going to be an interactable prototype with a lot of high-fidelity functionality it was important during the development to remember the prototype perspective and keep track of the different screens that were designed. By using the connection tools in the prototyping area of Adobe XD different designs could be linked together and create an illusion that when one item is clicked the new screen appears to be updated. However, behind the curtains the images just change place and it is crucial to get the connections right. In Figure 6.31 the two status actions can be seen from the perspective when the card is unmarked versus when the card has been marked. In the digital tool the two actions have their own separate screens but when the connections are added with the prototyping tool the change from one screen to the other is not noticeable with the help of precise mathematical computing.

One of the major challenges with especially the safety scenario was the positioning of the design content. The cards were put into a queue with a specific order and in addition the text inside the cards needed to match the position of the other cards even though they had different meanings. In summary, a lot of things had to be in the correct coordinates for the switching of the screens for the interactable user test to look as realistic as possible. For instance, in Figure 6.31 the content of the cards in both of the screens needed to have the same positions in order to put focus on the checkboxes. If the text were to move in the other screen that would make the experience somewhat dull.

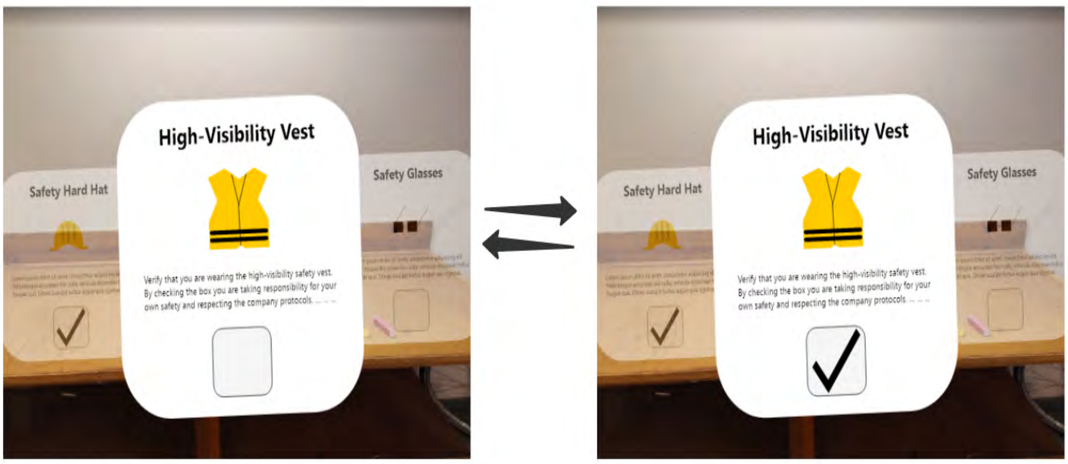


Figure 6.31: The High-Visibility Vest card. The left side is unchecked and the right side is checked and this process can be repeated.

Another interesting challenge with the self-inspection checklist was how to position it while having the augmented reality environment in mind. When designing the solution in the digital tools it was important to remember that the design will be viewed when the user is standing out on the field and then positioning of the items is significant. The background image used for scenario 1 represents a working bench area where the surveyor can make preparations before starting the surveying activities out on the field. Being inspired by the test checklist's third dimension perspective and the fact that the table is not horizontal the decision was made to make the cards of scenario 1 align with the tilting of the table. This in order to make the design feel like it is a part of the augmented reality world and that it is fixed to the table but the user is not standing directly in front of the checklist. In addition, with the validation in mind the student wanted to gather data about the positioning of the checklist and see if participants find it acceptable that the cards align with the table.

For the entire high-fidelity prototype it was important to be consistent. As explained above alignment with the objects in the images was important in order to highlight that the design is augmented and a part of the real world. As explained in Section 6.2.3.1, the theoretical inspiration for this design solution came from the design pattern Carousel where a key part is the ability to focus more on one specific content, "focus plus context" [1]. The key characteristic with the Carousel design pattern is that it allows the user to scroll through a set of items horizontally and encouraging the inspection of the following items [84]. For the self-inspection checklist it is important that every card is carefully understood and the ability to enlarge the object that the user should pay attention to is critical. To build on the consistent nature of the experience, all items that are interactable will be closer to the user's field of view. Tidwell et al. explains that most of the time for the user experience the task at hand is placed front and center of the screen [1]. Although the initial guide card is not part of the checklist queue it is still a relevant and important part of the safety aspect and therefore the object has to be presented in a precise way. Figure 6.32 shows the guide card being aligned to the table's tilt and the card is also at the center stage of the field of view. Although the card is a different size compared to the other cards it has the same position in the coordinate space as the enlarged cards in the queue. Figure 6.32 also represents the first item that the user will see when starting the augmented reality system.

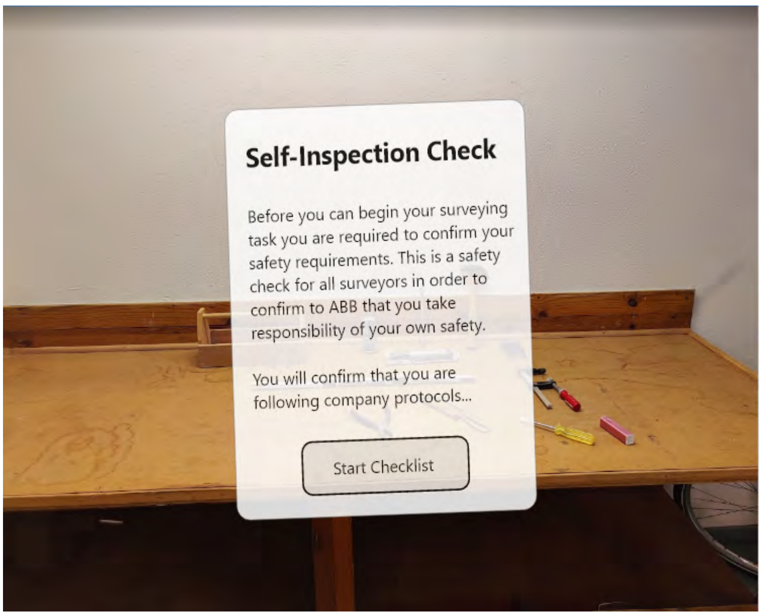


Figure 6.32: Scenario 1: The guide to the Self-Inspection Checklist.

In order to achieve an extensive feeling as well as a cohesive structure, every augmented reality element had to accomplish its purpose. Therefore smaller functionality was added to the checklist in order to enhance the user experience. As the checklist follow the Carousel pattern it felt only natural to have a return functionality as part of the queue, as presented in Figure 6.33. As the return card does not share the same purpose and functionality as the safety checkbox cards, it has a smaller size to confirm to the user that clicking on it will not be the same as clicking on a card to the right of the enlarged card. The return card is smaller than the other cards in the queue but it still has the same position in the coordinate space.

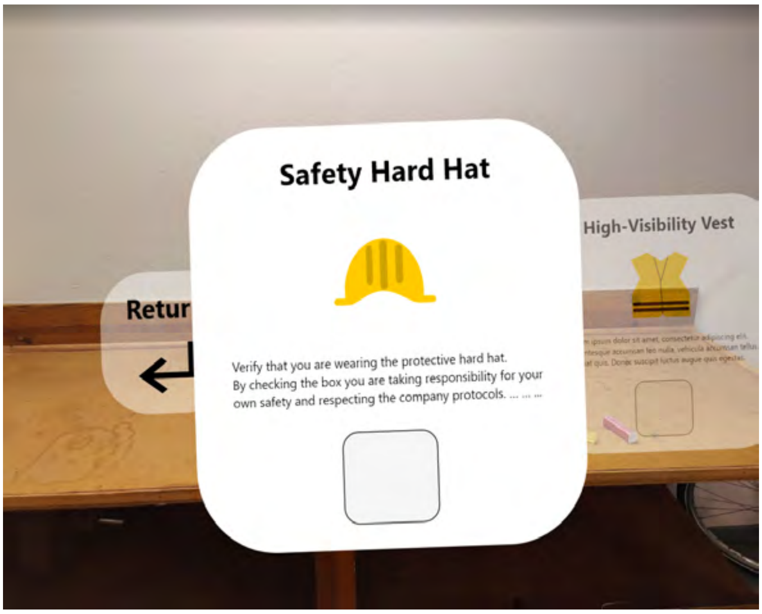


Figure 6.33: The return card to the left on the enlarged safety related card.

Many different possibilities were considered for the eventual interactable experience with the prototype and several screens were made to ensure that the checklist could be scrolled through and that previous actions are saved, namely the marking of the checkboxes. For instance, the capability to scroll through all the cards in the list was implemented in the prototyping setting but with the expense of not being able to click any of the checkboxes, see Figure 6.34 for example image. This is because the amount of screens and connections needed for all possible outcomes would be extremely overwhelming. However, some example screens were made to see how the checklist for scenario 1 would look like if all the cards were marked and if the view focused on the cards that are not enlarged, see Figure 6.35. Of course for a future instance of this design solution the clicks in the checkboxes need to be saved in order for the user to go through the list in a calm manner and without following the correct order. The ability to get back and remove a checkbox mark is essential for a future version as well.

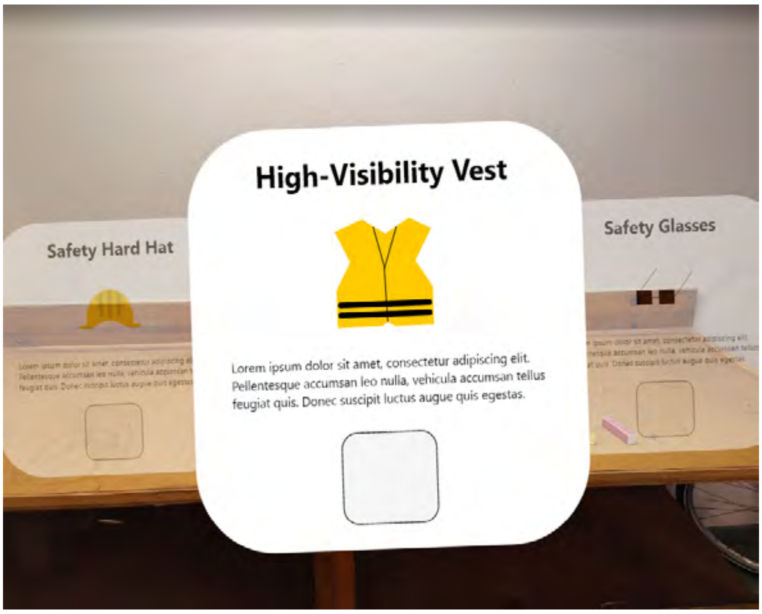


Figure 6.34: Scenario 1: Unchecked cards in the checklist queue.

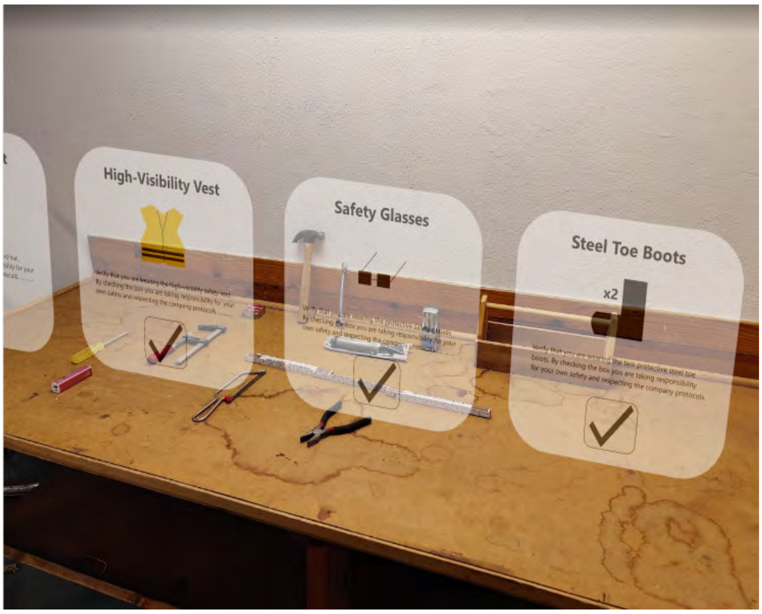


Figure 6.35: Scenario 1: The cards at the end of the queue. They are not in focus and therefore not enlarged. They follow the position of the table.

One interesting discovery during the prototyping phase was how extensive the safety checklist could actually be. The items chosen were based primarily on the data gathered from the expert users but also insights gained from feedback with the advisor. Since the prototype would be tested in the validation it was decided not to spawn on all possible safety aspects as that would of course lead to a longer interview session with participants. For scenario 1 the main safety related questions touched upon things that are expected of the surveyor to have before starting with any surveying task out on the field, see Figure 6.36 with the cards from scenario 1.

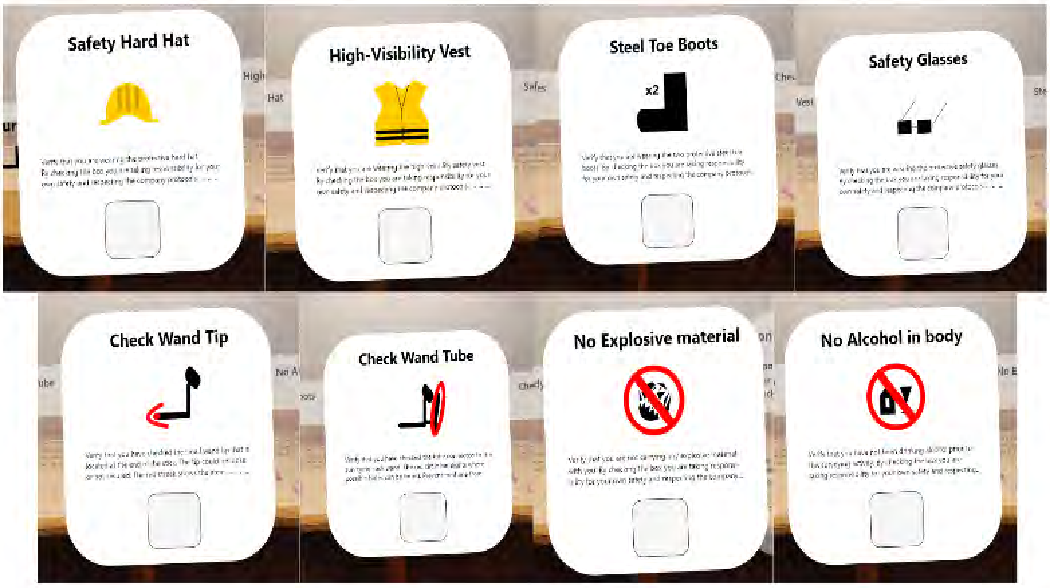


Figure 6.36: Scenario 1: The cards used for the checklist to confirm safety before starting the surveing task.

The content within the cards is simple but effective at the same time. This was one of the ambitions with the design but most importantly the cards should trigger the safety mindset of the users and review the checklist with discipline and care. Since this is a prototype, the explanation text for each of the cards is not definitive. The cards for the self-inspection checklist are the cricial parts of this design solution.

Safety Aspect - Scenario 2

The second scenario of the safety perspective is near identical to the first scenario. The main difference is that the first scenario focuses on the confirmation of safety before starting surveying and the second scenario has a focus on the confirmation of safety during the surveying activity. However, in order to emphasize for the participants in the validation that this new version is during another time and setting, the choice was made to not reuse the previous image of the work table. Instead one of the outdoor images from the Surveying Field Study were used to build up the scenario that the user is outside and doing the self-inspection during the surveying.

Furthermore, as the Carousel pattern can be implemented both in a horizontal direction or a vertical direction [81] the student wanted to make scenario 2 stand out somewhat and the self-inspection checklist is presented in a vertical queue. Although the list is approached from another direction in this second scenario the functionality and safety purpose is still the same with the addition of some new concepts. Figure 6.37 displays some of the cards in the vertical checklist queue, that the surveyor is viewing when standing out on the field.

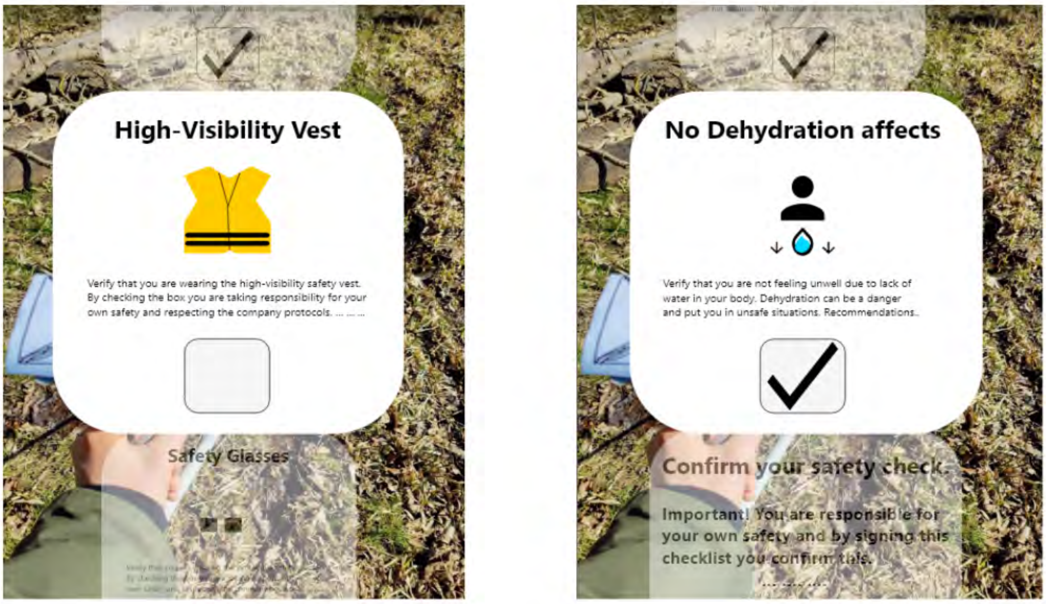


Figure 6.37: Scenario 2: Example cards in the self-inspection checklist.

The two icons at the bottom of Figure 6.29 are used for scenario 2. As the setting is different for this scenario the presence of new warnings and safety requirements felt significant. As the user is already out on the field the warnings about alcohol and explosives did not feel relevant to ask about. However, based on the findings from the expert users it is known that the surveying activity can be quite substantial and extensive. Therefore, asking questions about fatigue as well as dehydration felt critical for the safety aspect of the surveyor out on the field. If the surveyor is performing a certain task for a long full day of work then these new safety cards are extremely relevant in order for safety to be confirmed. Figure 6.38 highlights the cards in more detail and they are part of the vertical checklist of scenario 2.

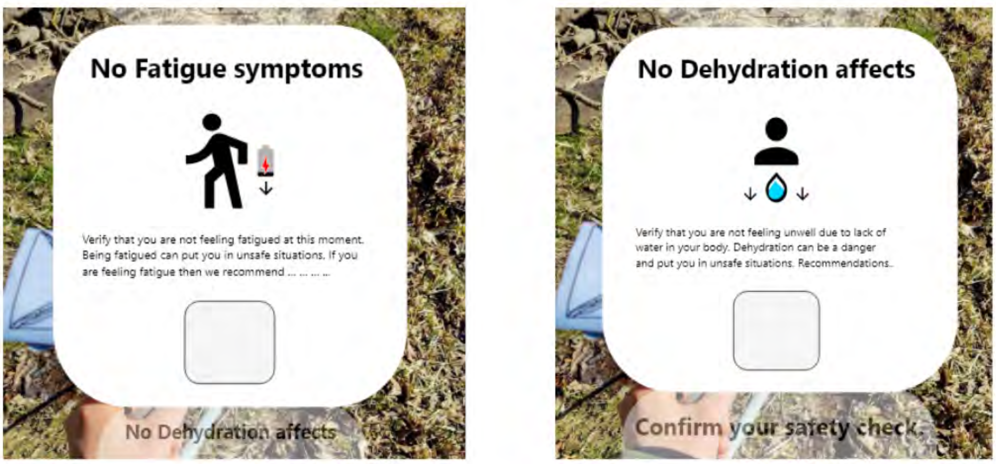


Figure 6.38: Scenario 2: The new cards for the second version of the Safety aspect.

In order to present the surveyor with a good user experience the initial card that the user will see in the augmented reality system will be different than the initial starting card from scenario 1. In Figure 6.39, the two screens for the beginning of the self-inspection are presented. In essence, this solution is practically the same as for scenario 1 with the exception that the visual content will be viewed during the surveying and therefore it feels essential to alert the user to pay attention and find a good spot to confirm the safety requirements.

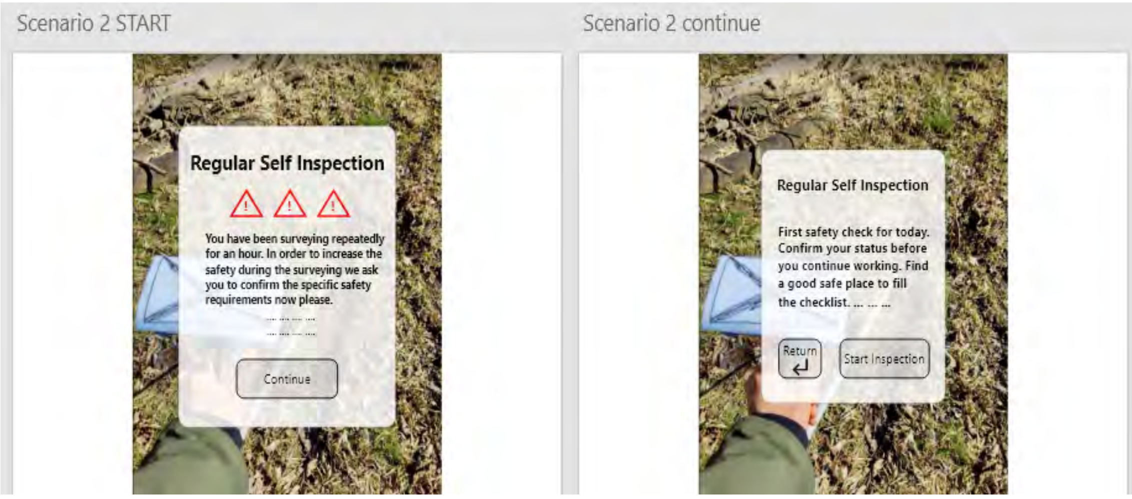


Figure 6.39: Scenario 2: The initial guide cards that inform the user about the upcoming self-inspection.

Although there are differences in the experience for both versions of the safety aspect some of the designs are the same for both scenarios. In Figure 6.40 the final screens of the prototype can be viewed. This is the step in the self-inspection where the surveying user confirms his or her safety and sends it to ABB. This design is the same for both scenarios, the only difference is that one is presented vertically and the other one is presented horizontally. Figure 6.41 shows the interface after the user presses the "confirm"-button for both scenarios.

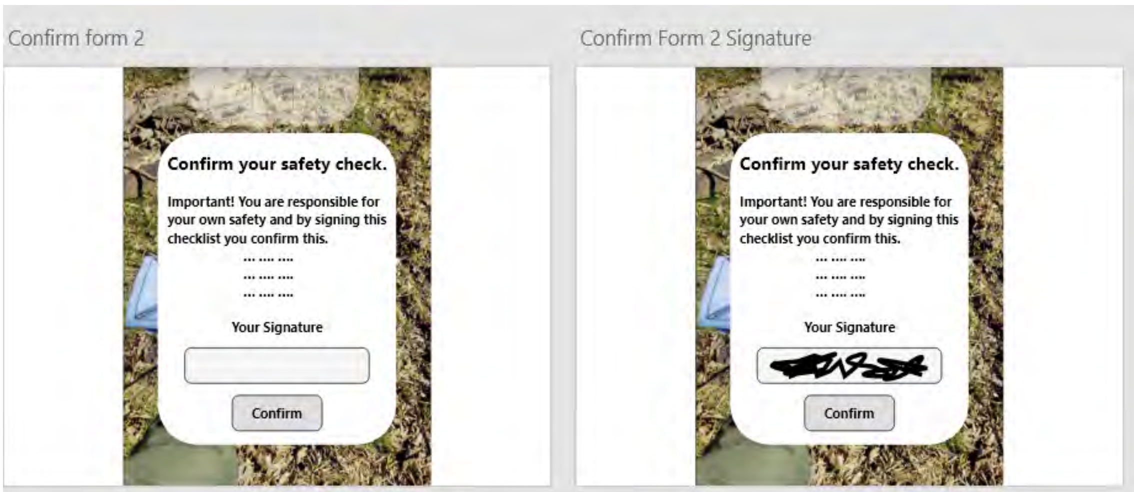


Figure 6.40: Confirming the safety in the augmented environment.

Figure 6.41: The end of the self-inspection.

Efficiency Aspect - Scenario 1

The set of design elements from Figure 6.27 were brought over to a new working area in Figma. This is where the prototype for the efficiency aspect was finalized. Using real life images of outdoor locations the visual design that the student developed in Figma was pasted over the real life image in order to use the product for the validation and to give the participants a good experience so that the can understand how the intended product could function like in the future. Even though Figma provided good functionality for the design of the wind direction compass and the map, the student used Adobe Photoshop for the merging of the lock-on target indicator and the real life images to emphasize that the lock-on is fixed on a critical infrastructure or a hazard area, for instance a petrol station or a secured construction site. Figure 6.42 shows an example screen of the lock-on design in a surveying path environment and the target indicator is behind the trees and the post.

Figure 6.42: The surveyor is nearing a construction site where hazard material is located.

Working with the first scenario of the efficiency aspect was based on the ideas generated from the sketching phase. The key focus was especially on the wind direction compass and how to explore users' perception of its structure and design. As with the safety aspect it was decided during a feedback session that the solution idea would be the most optimal with two versions of it in order to gain more data and understanding from the validation. One of the counter ideas to the bar chart compass developed during the sketch phase, was a radar chart compass. However, since that idea proved to be remarkably similar to the bar chart when put next to each other it was decided that something else would be needed for scenario 2. Although the radar chart was scrapped, the concept of it was kept for the validation phase, particularly the planned questionnaire for the participants. The two wind compass designs can be viewed in Figure 6.43.

a) 

b) 

Figure 6.43: Red is the strongest wind direction and the blue is the weakest. Figure a) showcase the bar chart wind direction compass. Figure b) showcase the radar chart wind direction compass.

For the prototyping part the design was divided into a small number of screens where the user could then observe and interact with the content. Using the storyboarding context in mind for the development of the different path locations that the surveyor is placed at the screens could be structured in the best possible way. Most of the work went into changing either the lock-on design or the minimap to capture the imitation that a person is wearing an augmented reality headset and the images is what that user is seeing. However, for scenario 1 the wind direction compass is static and this is something that will be explored further in the validation with how users perceive that design solution.

Figure 6.44 showcase the different screen paths that the user "walks" through and the strongest winds in red are coming from the northeast and the black arrow on the minimap is the location of the surveyor and the red marker on the map is the path that needs to be surveyed. This design was later transferred into Adobe XD where a rectangular object was added at a certain location. By taking inspiration from how navigation works in Google Street View the rectangle seen in Figure 6.45 works as a function to move between one location on the map to another location. Using the beneficial and unique transition tools in the prototyping mode the visual experience when clicking the rectangular object creates a progression that makes it feel like you as a user have walked forward in space and time.

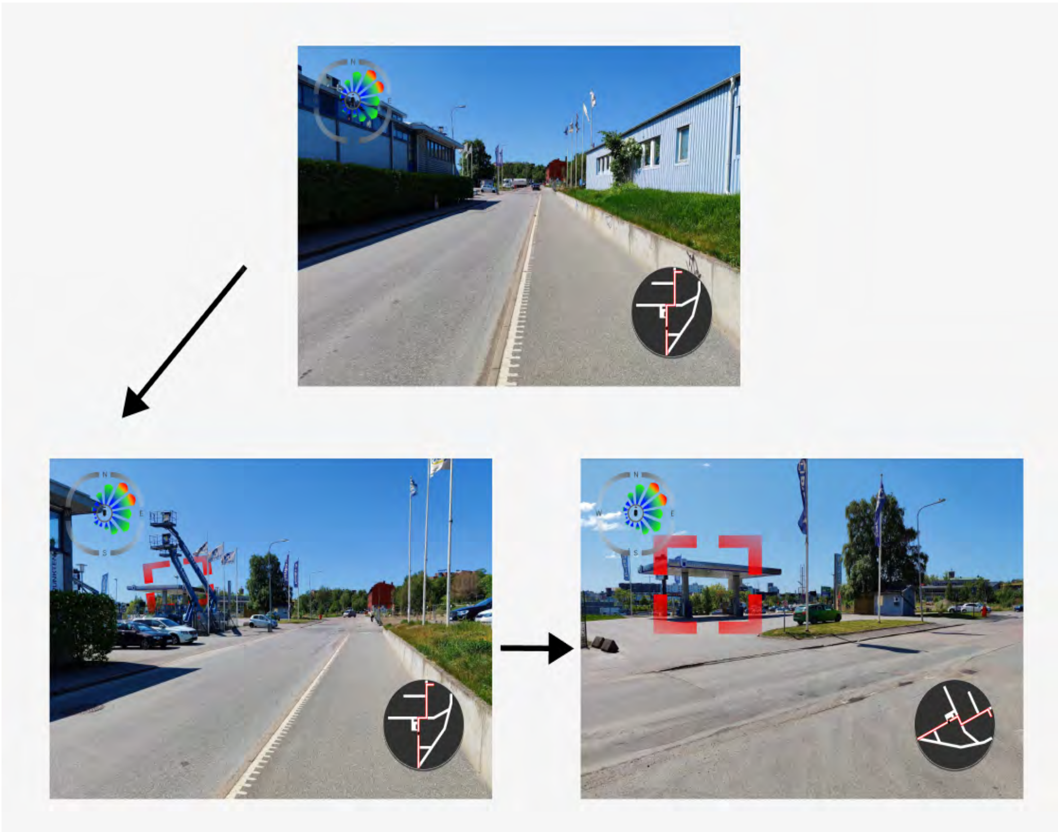


Figure 6.44: The bar chart wind direction compass and the different locations that the user progresses through.

Figure 6.45: Clicking the rectangular object will transition the user to the next location. The functionality resembles the navigation in Google Street View.

Efficiency Aspect - Scenario 2

For the other perspective of the efficiency aspect the task to create something different but still with the same purpose proved to be a challenge. Since scenario 1 was based on the existing wind rose diagram the new version also was inspired by an existing idea. There are several variations of the compass and one of them is the sphere compass. This tool was reimagined into the globe wind direction compass. Compared to the static bar chart compass this specific compass will be constantly moving and in tune with the movements of the surveyor. In Figure 6.46 some test versions of the globe are used as a way of presenting where the strongest winds come from and if they are occuring at the moment. For example, the globe at the bottom has a small blue area to the north which means that the surveyor is facing north and weak light winds. The other two globes represent stronger winds but they are not coming in the direction that the surveyor is walking towards. This design solution was needed for the analysis of the efficiency aspect but it was still a struggle to prototype in a clear and comprehensible manner. Using the minor 3D tools in Figma the globe could be given the desired third dimensional feeling to it but making the globe multiple colors and arranging the wind direction colors was a real challenge.

Figure 6.47 follows the same structure and purpose as scenario 1. The only difference is that the wind directions are represented in the globe compass. The efficiency aspect for this scenario will be the same as for the first scenario, to explore if the compasses can help with making the surveying activity more efficient. The main reason behind working with a wind direction tool came from the data gathered during the interviews with expert users. Several participants expressed concerns about the wind direction slowing down the surveyor since the wind affects the instruments' ability to properly read gasses. In addition the wind could carry with it hazard gasses or other dangerous substances. Some experts also talked about how it would be beneficial and a good advantage to have one indicator of the expected surveying path and at the same time have a good indicator of where the wind is coming from. The two design solutions in these scenarios explore this problem and how efficiency can be improved.

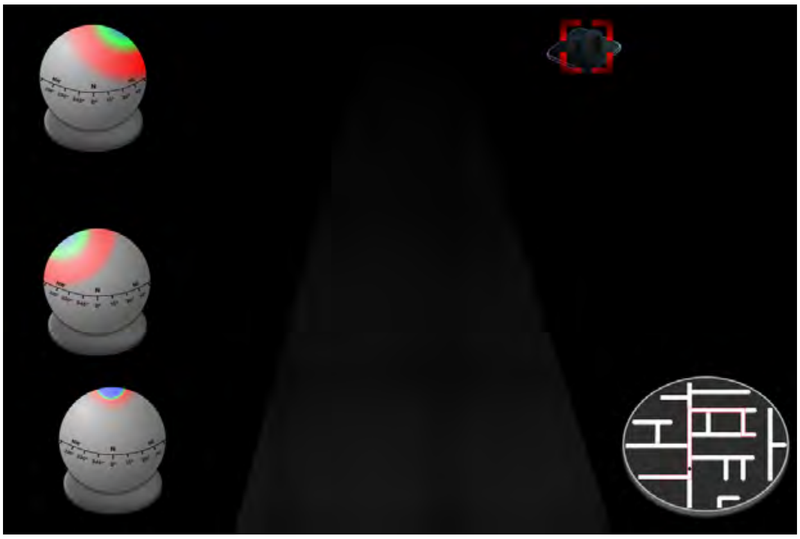


Figure 6.46: Testing different versions of the globe compass in the working area.

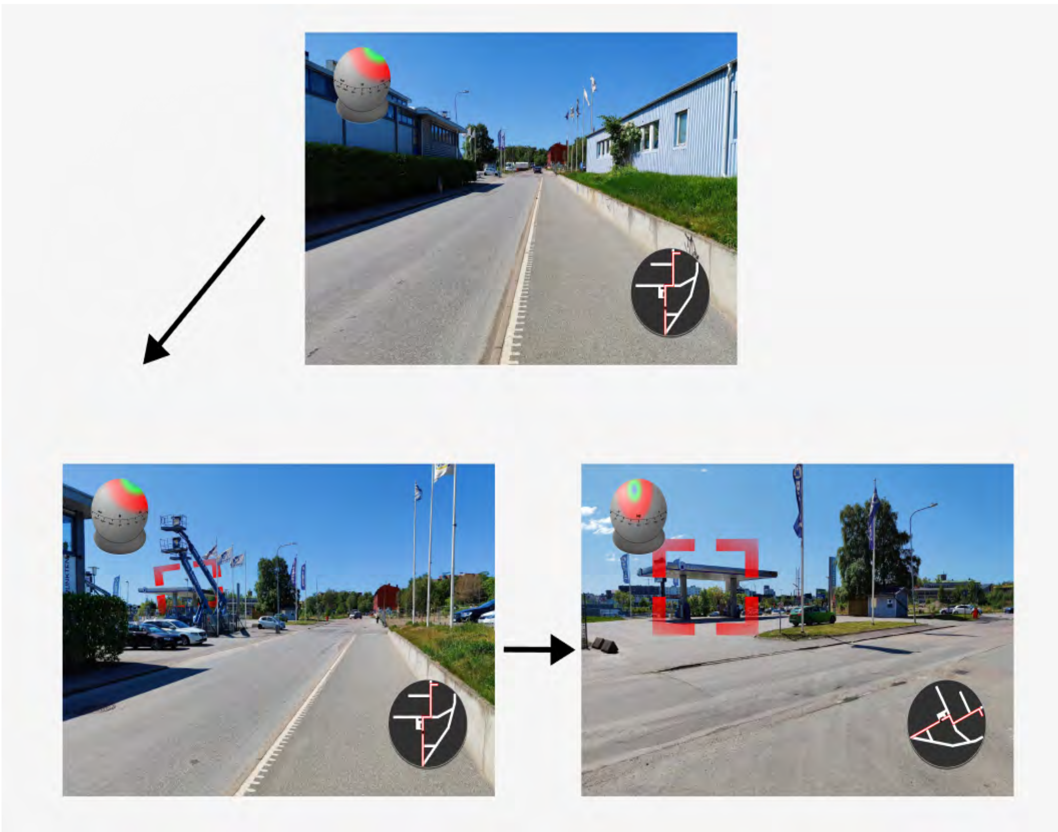


Figure 6.47: The globe wind direction compass and the different locations that the user progresses through.

Once all the prototypes were finished, both for the safety as well as the efficiency aspect, the screens were checked one more time to see if the connections were in order. After that the student moved on to make the high-fidelity prototypes presentable and structured for the validation. For instance, a start screen with a black screen and a title was added to both scenarios for the efficiency aspects. This was added because the instructions for the user test have to be read before the participant can see any of the design. The share function in Adobe XD was tested in order to see if the interactions work via the shared link and that the clickable elements work properly. This final step was important for confirming the prototypes authenticity and reliability as well as making them ready for validation without worrying about complications or errors. Final touches for the transitions and the transformations for the screen of the prototypes were corrected at this stage as well.

6.2.4 Validating

The following section will describe the final methods used to bring the project one step closer to the finish line. The key focus for this part was to validate the design and its connection to safety and efficiency in a surveying context. In order to gain both qualitative and quantitative data from the evaluation, interviews were combined with questionnaires. For both methods, asking the right questions was a significant focus area.

6.2.4.1 Preparations for Evaluation Interviews

The prototypes from Section 6.2.3.3 were discussed several times with the advisor and it was decided, even before the validation phase started, that the two aspects should be split up for the evaluation methods. In essence, the structure would be the same for the two aspects but with different questions connected to the interviews. During the discussion it was discovered that the expected path that a user would take during the testing evaluation of the prototypes would end up being very substantial in time if both perspectives were tested for one user. Of course it would be possible but from the eyes of the participants it would be a long and extensive interview. Tired and exhausted participants would not be able to contribute with proper insights for the final parts of the interview and instead splitting the two aspects would ensure that the interview would be short in time and the data collected from them could then be more lush.

In order to perform a good analysis of the data collected from all the interviews it was decided to balance the number of qualitative interviews. Five participants would perform an evaluation of the safety aspect and five participants would perform an evaluation of the efficiency aspect. Early on it was anticipated that the split of the aspects would create a time frame of around 45-50 minutes per interview, which was discussed as a positive attribute. Letting a user focus on one aspect and then see it from two version scenarios would be enough for them to process and the data collected from that event would end up being advantageous and constructive. As with the interviews from Section 6.1.1.5, the participants had to be ABB employees due to the confidentiality of the project. With the assistance of the advisor, a number of employees with matching skills and understandings of the problem area could be reached via electronic mail. In addition, some of the expert users from the data gathering phase, as discussed in Section 6.1.1.5, were contacted as well via electronic mail. An anticipated fallout from the searching phase was that some employees might not have time available for evaluation interviews and then the search would have to go on. However, at the end of the search exactly ten people were reached and confirmed to do the evaluations. Of course some rescheduling was needed for some of the participants but this was a good experience for the student as the Microsoft Teams meeting functionality was explored. Although not a part of the learning outcome in the planning, the student gained good experience from creating and reorganizing the online meeting invites.

Once the high-fidelity prototypes were ready for user interaction, the development of the interview document started with velocity. As the evaluation interview would be structured in a similar way as the data gathering interviews the student made an effective and perceptive choice for the content of the evaluation document. That decision was to reuse the introductory text from the data gathering interview document, as discussed in Section 6.1.1.4. Of course some edits had to be made for the new structure of the evaluation interview but many of the statements stayed the same, especially the part about informing the users of their rights and to receive their consent, as these are essential things to consider according to Sharp et al [9]. With the introduction content being finished rapidly, the student moved on to the crucial interview questions that are decisive for the success of the whole validation.

Phrasing the questions for both the safety and efficiency perspectives was one of the most challenging and demanding undertakings during the whole project. Figure 6.48 presents some of the essential questions used for both aspects of the interview. These questions went from being somewhat vague to being more clear after working with the wording and flow of the structure. For example, the safety related questions were phrased with the intent of exploring what safety is to the user, "Do the cards and their content increase safety for you?". However, it was discovered that wording a question like this makes the "safety" concept unclear and the user can see the word from many perspectives. Instead the final phrasing became "Do the cards and their content increase safety awareness?", in order to put an emphasis on the keywords "safety awareness", see Figure 6.48.

Figure 6.48: Questions for the evaluation interviews, both for the Safety related interview and Efficiency related interview.

One thing with the document that was easy to phrase was the scenarios for all the versions. The student looked at both the storyboards from Section 6.2.3.1 and the prototypes from Section 6.2.3.3 to receive some kind of vision of how it would be to explore these designs in the shoes of the surveyor. With the help of the surveying wand prototype from Section 6.1.1.2 the student could see the scenarios more clearly. Each version got its own introduction text and this would be read to the users before the actual user test starts so that they can imagine the surveying context that they are in. An example of this text can be seen in Figure 6.49. In essence, the structure of the interview document looks like this:

- Reading introduction to the evaluation and the Consent.
- Reading Scenario 1 introduction, for Safety or Efficiency aspect.
- User test of the Safety or Efficiency prototype, Scenario 1.
- The questions for Scenario 1.
- Reading Scenario 2 introduction, for Safety or Efficiency aspect.
- User test of the Safety or Efficiency prototype, Scenario 2.
- The questions for Scenario 2.
- Final questions.
- Interview ends, the participant answers the Questionnaire connected to the research aspect.

Scenario 2 Efficiency(Globe Compass):

You are performing your surveying task out on the field using an AR system. The screens POV will represent where you are standing on the ground. A path has been provided by ABB. This specific path that you are performing your tasks on is new to you. However, as a surveyor you are aware of the dangers that can hurt you out on the field, for example explosive risks and rough terrain. Your goal for this evaluation is to observe the screens in front of you and answer questions related to safety and efficiency. When you feel finished with observing one screen then interact with the screen to proceed to the next screen. Please use think-aloud.

Figure 6.49: Introduction to the Scenario 2 Efficiency User Test.

After the document was completed the student sent the draft to the advisor for feedback. After correcting the problems in the document based on the feedback, the student could move on to the other methods and preparations.

6.2.4.2 Developing the Questionnaires

In combination with the development of the evaluation interview documents, the student worked with the content of the two questionnaires. As previously mentioned, the aim for the validation was to gain a quantitative result as well and therefore the Questionnaires method was confirmed. Although the questionnaires are simple to produce and administer [10], the phrasing of the questions proved to be equally demanding as the wording of the interview questions for the evaluation.

Although many keywords had been chosen to be explored for both the aspects the first draft of the questionnaires had a distinctive problem and that was that the questions asked for more than one answer. For example, the student wanted to research the design of the wind directions and a good data gathering question for that would be "Are the directions of the wind understandable and clear?", with a Likert scale of rating from 1(low) to 5(high). However, during a discussion with the advisor it was discovered that this type of phrasing would be unfavorable for the analysis since the results for that question would end up being ambiguous. If a user rates the question with a score of 5 does that definitively mean that both keywords, understandable and clear, are rated with a score of 5? Perhaps the user would like to give one keyword a higher score but the likert scale is for the whole question. Phrasing problems like this occurred several times and after the discussion feedback session the student worked with correcting the ambiguous sentences and making them more definitive. Sharp et al. suggests that it is crucial to have careful wording and good typography in the questionnaire [9] and therefore a significant amount of time was put on this specific thing.

Furthermore, after receiving feedback it was decided that the questions would be phrased more as statements since the student believes that the design is acceptable and good, and therefore it should be explored if the users share that view on the design. In addition, having questions be more like statements makes the likert scale fit more into the process. For example, for the safety part there is a question that is phrased "Confirming your safety is your own responsibility" with a disagree or agree likert scale of 1-5. The invisible question in this form is "Do you disagree or agree with the statement that confirming your safety is indeed your own responsibility? Rate if it is closer to disagree or closer to agree.". With the statements in the questions the users can look at the design and then decide for themselves if they agree or disagree with the statements in the questionnaires. Figures 6.50 and 6.51 highlight examples from respective questionnaires.

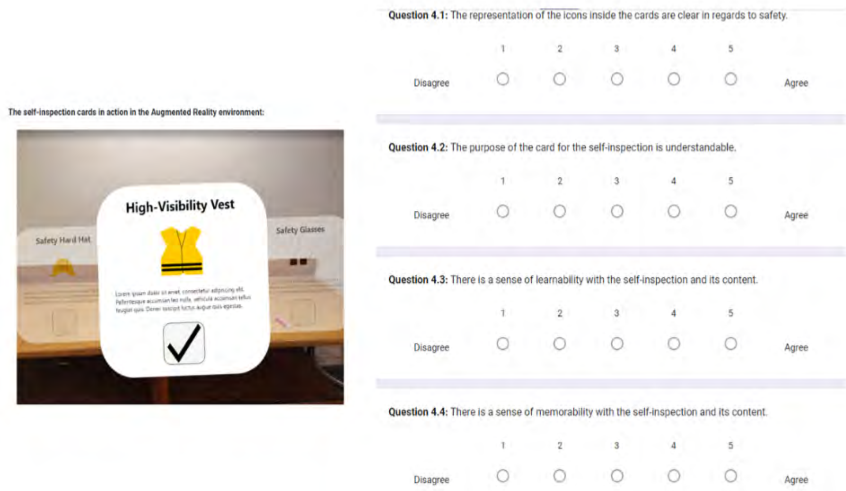


Figure 6.50: A set of questions from the Safety Questionnaire.

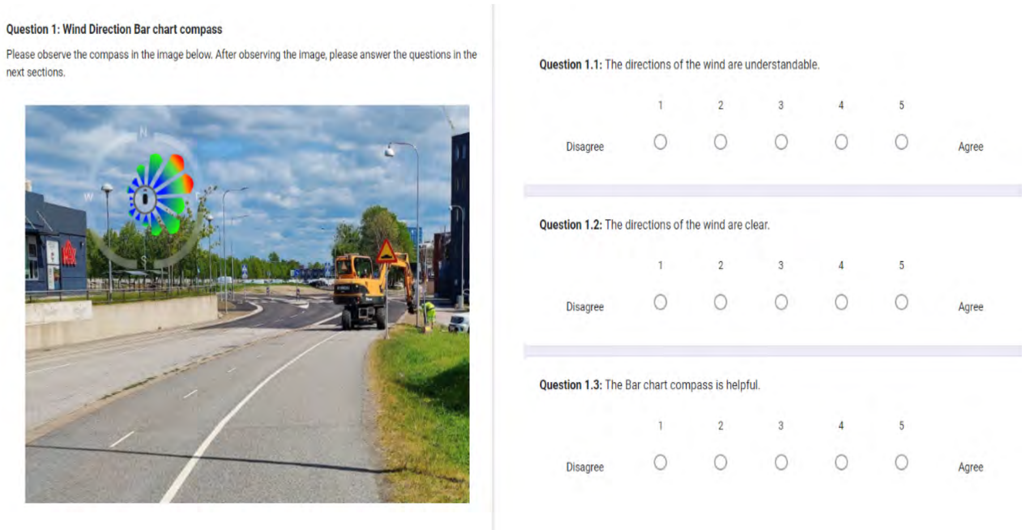


Figure 6.51: A set of questions from the Efficiency Questionnaire.

Early on in the process it was decided that the best advantage for the questionnaires would be that they include images of the design that the users interacted with previously in the interview. The images would allow the user to get a closer look at the design elements and then answering the questions can be much more effective and easy. The student chose big and clear images for the questionnaires as it is important to keep the layout format as compact as possible [9]. As discussed in Section 6.2.3.3, one of the scrapped designs was the radar chart and since images are used for the questionnaires the functionality of the radar chart was explored. The questions for the radar chart were placed after the questions for the bar chart since they are nearly identical in their functionality. Figure 6.52 showcase the structure for the radar chart question.

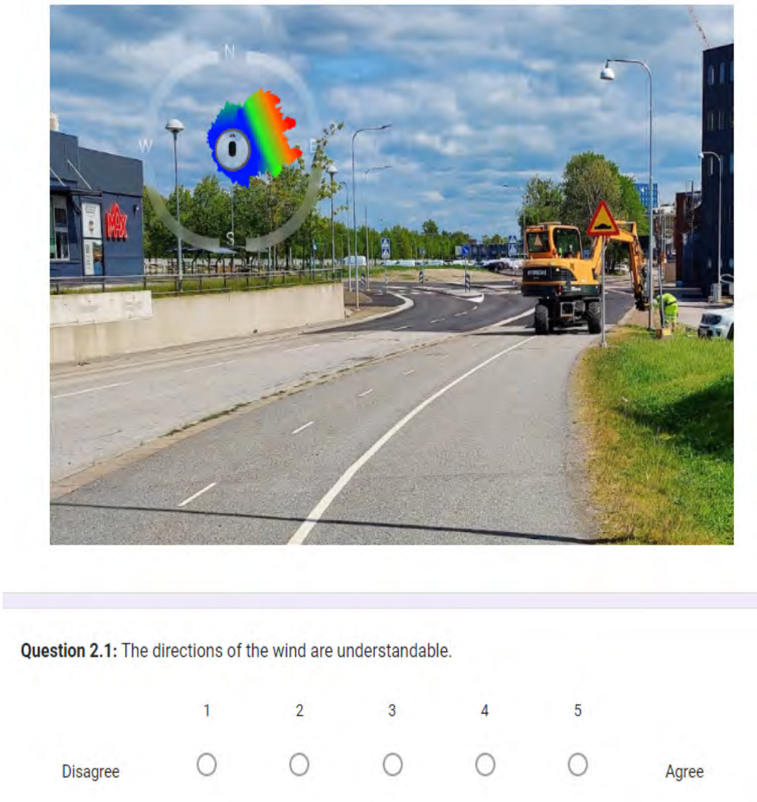


Figure 6.52: The Radar chart image and questions related to it.

Additional styling was added to the questionnaires in order to make them more professional. For instance, every question started with a noticeable bold title. An introduction was added to each form as well, inspired by the introduction for the evaluation interviews. The final part of the development of the questionnaires included things like checking if all the questions were the same for the efficiency questionnaire and to see if the images for both forms had good sizes.

6.2.4.3 Pilot Study

Sharp et al. explains that a pilot study is an essential method for making sure that the main study is viable and potential problems can be found in advance [9]. The student aimed to check the precision of the questions for the methods and therefore it felt critical to perform this trial run of the evaluation. With the help from one of the team members from the UX team, the other Thesis Student with sufficient

UX experience, the student could perform this event. The feedback received was positive and the questions were viewed as being clear and understandable. The only drawback from this event was that it took longer time than expected due to some technical issues. First of all the Microsoft Teams invite lacked a proper link and also even though the student had tested the Adobe XD links the window size was not optimal for the participant. However, these problems were useful since now the student learned how to send a correct invite where the Teams link is clearly visible in the mail and the student learned how to change the view of the prototype so that it is visible on the shared screen as well as readable for the user during the interview. In conclusion, the pilot study helped with making the student ready for the main interviews and the expected runtime could now be reached since the technical issues had been solved.

6.2.4.4 Evaluation Interviews and Questionnaires

The interviews were conducted via Microsoft Teams as this suited all the participants the best. Although it was planned to have some interviews at the office, the student had to adapt to the schedule of the users. The list below highlights the expertise of the ABB employees that participated in the evaluation.

- **Participant 1 for Safety Aspect** - Engineer with limited knowledge about surveying. Good knowledge about AR.
- **Participant 2 for Safety Aspect** - Engineer with limited knowledge about surveying.
- **Participant 3 for Safety Aspect** - Engineer with sufficient knowledge about surveying and AR.
- **Participant 4 for Safety Aspect** - Engineer with limited knowledge about surveying.
- **Participant 5 for Safety Aspect** - Engineer with limited knowledge about surveying and AR.
- **Participant 1 for Efficiency Aspect** - Engineer with limited knowledge about surveying. Previous experience with AR.
- **Participant 2 for Efficiency Aspect** - Engineer with limited knowledge about surveying.
- **Participant 3 for Efficiency Aspect** - Engineer with limited knowledge about surveying.
- **Participant 4 for Efficiency Aspect** - Expert User. Engineer with extensive knowledge about surveying.
- **Participant 5 for Efficiency Aspect** - Expert User. Engineer with extensive knowledge about surveying.

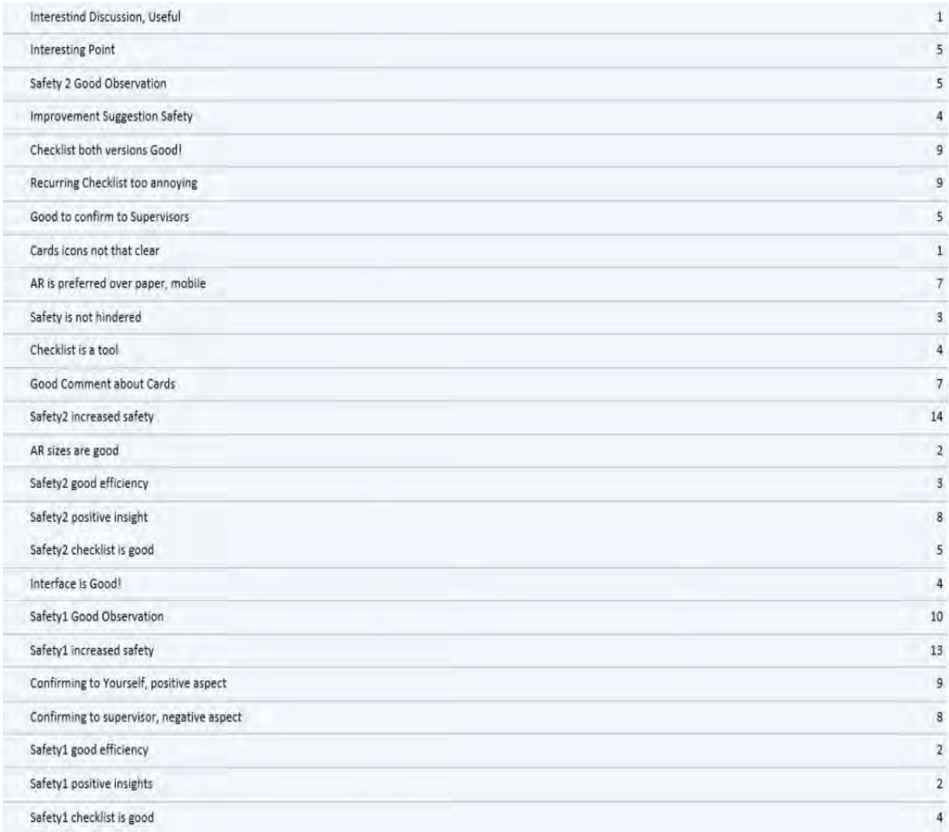
The interviews started with the introduction and once the student received the verbal consent to record and perform the interview the method began. After each interview the recorded video and transcript were saved to a folder and the items would later be analyzed. The final part of each interview concluded with the questionnaire for the respective user test and the participant could fill out the form at their own pace while the student remained in the meeting to help with possible puzzling questions or unclear sentences in the questionnaire. The numerous data gathered by the questionnaires were stored automatically in the form and this would later be analyzed by taking the numbers from each question and calculating the mean value, the median value and the mode value.

Result of the Efficiency Scenario Walkthrough:
The goal of the efficiency design is for the user to first observe the screens and then click on the rectangular object. The user is presented with a black starting screen and the scenario setting is read to the participant. The user will come to the first screen, the user will observe the design and environment and then answer the related questions to this efficiency aspect. When the questions are done for the first screen, the user navigates via the rectangular object to the second screen and observes the design and answers the questions. Later the user will navigate to the final screen and observe the design there and answer the connected questions. The user can navigate to the previous screen as well. When all questions have been answered the task is complete.

Result of the Safety Scenario Walkthrough:
The goal of the safety design is to perform the surveying self-inspection checklist. The user will be presented with a starting screen and read the instructions. When the user is ready the button will be pressed on the instructions screen and take the user to the checklist. The objective is to complete the checklist that is in the field of view for the user. The user can navigate through the list of card elements and choose which safety cards to confirm. When the user has performed the checking of the required cards in the queue the user will move on to the final elements in the list. The user will be presented with a consent form that has to be read through and signed. The user will confirm the safety procedure and sign it. The checklist will be sent to the supervisors and the user can move on with the surveying task as the self-inspection is complete.

6.2.4.5 Analyzing the evaluation

Since the Thesis now had a total of ten interviews to analyze it was necessary to use an effective tool. Therefore the student approached the significant application MAXQDA, a tool for working with qualitative and quantitative data. With this tool the student could efficiently go through all of the transcripts and analyze them with precision. With the help of the code functionality in MAXQDA, the relevant data from the transcripts could be highlighted and ordered in an effective way, see Figure 6.54 for the Efficiency groups and Figure 6.53 for the Safety groups. The qualitative data was grouped and organized for both versions of the same scenario for both the safety and efficiency aspects. For the quantitative data the results from the questionnaires can be observed in the diagrams of the form and from this observation a definitive analysis can begin.



Interestind Discussion, Useful	1
Interesting Point	5
Safety 2 Good Observation	5
Improvement Suggestion Safety	4
Checklist both versions Good!	9
Recurring Checklist too annoying	9
Good to confirm to Supervisors	5
Cards icons not that clear	1
AR is preferred over paper, mobile	7
Safety is not hindered	3
Checklist is a tool	4
Good Comment about Cards	7
Safety2 increased safety	14
AR sizes are good	2
Safety2 good efficiency	3
Safety2 positive insight	8
Safety2 checklist is good	5
Interface is Good!	4
Safety1 Good Observation	10
Safety1 increased safety	13
Confirming to Yourself, positive aspect	9
Confirming to supervisor, negative aspect	8
Safety1 good efficiency	2
Safety1 positive insights	2
Safety1 checklist is good	4

Figure 6.53: The Radar chart image and questions related to it.

Safety with the Compass	1
Positive Interface UX	2
Wind Compass Positive	3
Expert identifying Compass	4
Efficiency is bad	1
Comparing the 2 versions	8
Globe Compass positive	9
Understanding Directions, Globe wind	4
Not understanding the Globe	28
Lock-on is confusing	10
Interesting Observation	22
Identifying Lock-on as Danger/Hazard	12
Understanding Directions, Wind	10
Efficiency is OK	28
Improvement Suggestion efficiency	12
Map not informative enough	3
Interface is confusing	19
Red path is not clear at first sight	4
Not understanding Wind Compass	21
Understanding the map	19
Experience	19

Figure 6.54: The Radar chart image and questions related to it.

7
Results

This chapter shows the results of the evaluation interviews and the questionnaires. As both methods are either of the qualitative or quantitative aspect the results will be presented as two categories. At the end, the results from both categories will be crucial for the research questions. The results from the qualitative category as well as the quantitative category should provide satisfactory and acceptable evidence that confirms the believeableness of the research purpose. The results will give the Thesis a strong foundation for the research questions to be answered.

The result for the qualitative data will be organized into groups where certain themes can be identified, for example positive themes for Scenario 1 and negative themes for Scenario 2. The method used in essence is Thematic Networks as the technique is significant for summarizing main themes that can later be communicated with [10]. For the quantitative data numbers will be the primary method for giving the result an indication that the design can be either peceived as positive or negative. The mathematical methods used for this will be presented in tables and they are the mean, median and the mode. The following list will give a brief explanation to the calculations of the result:

- The mean is the average of a data set.

$$Mean = \frac{\text{Sum of All Data Points}}{\text{Number of Data Points}}$$

- Median is the value which occupies the middle position when all the observations are arranged in an ascending/descending order [85].
- Mode is defined as the value that occurs most frequently in the data [85].

7.1 The terms positive and negative in the results

In this chapter the two terms *"positive"* and *"negative"* will be used extensively. The two terms are not connected to any statistical analysis and they are not used to definitively conclude comments from the expert users or that the terms gives a conclusion to what is mentioned in the results. The two terms will be used as adjectives for some cases of the result to confirm what the participants from the evaluations expressed. From another perspective the two terms are used as titles to suggest that the comments received belong to either a good perspective of the design solutions or a bad side of the design solutions. The data from the evaluation is extensive and rich in a lot of information, however it would be an exceedingly large Thesis if all the comments were shared in this chapter and therefore only the crucial items have been chosen. The selected comments and insights are therefore grouped into categories that use the terms positive and negative in order to present the findings in a clear language. An attribute from the evaluation that falls into the positive or negative category is decided based on how the expert users express their opinion on the design solution. For example, "I do not know where the wind is coming from in this design." is a negative comment in the common language and therefore it will be discussed as such. "I feel like the self-inspection checklist makes me more safe." is a positive comment in the common language and therefore it will be discussed as such. For minor comments that are excessive to share in the result will be described with one of the two terms in order to confirm that the participants have shared their opinions and their opinions matter.

In conclusion, the two terms can be confusing and unclear in the context of the flowing text but they are not connected to the statistical analysis perspective and they are not making conclusive remarks about the findings, they only mediate the opinions of users and highlight what is good or bad with the developed design solutions.

7.2 The Efficiency Aspect

For the efficiency design the results from the five evaluations proved to be contrasting and disruptive, both from the data gathered by the interviews and the questionnaires. However, when it came to the perception of the two versions of the same efficiency scenario, the data received directs favorably towards the version of the bar chart compass design.

The two versions of the efficiency aspect focus on two different wind compass designs. The later analysis will be directed on these designs but for the user test the minimap and lock-on are part of the designs as well. The opinions on those designs will be discussed in Scenario 1, although the designs occur in the second scenario the users get their first time reaction to all the elements in the first scenario and that is where the most essential data was captured.

7.2.1 Qualitative data for Scenario 1 - Efficiency

The data received for the first scenario is interesting and useful for discussion when it comes to the perception of the design solutions. When the users arrived at the first screen for the efficiency design they talked freely about the design that they saw in front of them. From the coded segments in MAXQDA a total number of 19 comments were received that expressed positive attitudes towards the minimap and the content inside it. Although some parts of the minimap were unclear, the users understood that it was a map and how it functions. However, the other element on the first screen, the bar chart compass, was something that 4/5 users could not distinguish as a compass for wind directions. 21 coded comments from four participants gave the student interesting and beneficial insights into the problem, this group is called "Not Understanding the Bar chart compass". Table 7.1 highlights some of the captured comments about the users' first impression of the bar chart compass design. The observations were made before the question *"Where is the wind compass located?"* could be asked and this result shows that the design is not that optimal for first-time users.

User No.	**Interview comments - Not Understanding Bar chart compass**
User 1	Green, blue, red, which means this more traffic, less traffic. What does it mean this?
User 1	Is it a wind compass then? ... I really didn't guess that this is the wind compass, but OK, the question was where it is located.
User 2	And then I have some indication on the top left, which I'm not sure what's it's about. ... So I guess that's the dangers that you described, but I'm not completely sure.
User 3	It's not very clear to me what the colored colored the, let's say bars means, but it give me at least the compass, some kind of orientation.
User 4	and the top left corner that has at least some sort of yes, intensity or. Directional navigation associated with it.

Table 7.1: Comments from the interviews about the Bar chart compass.

User No.	**Identifying Lock-on as a danger/hazard**
User 1	It's kind of hazard. No, in my opinion it's. It's a kind of dangerous area.
User 2	I would navigate away from this from this gas station simply because red indicators are usually use for like warning of potential dangers.
User 3	Something I have to keep an eye on. Maybe something that I have to survey more carefully during my path along my path.
User 4	Critical infrastructure. ... it's offset nature and maybe it looks a little more important, looks like it's trying to get your attention.
User 5	There could be a flammable environments over there, so it's recognizing hazard or a potential hazard. ... the red box would either increase in size or maybe there's like a as you get closer it might like change color or start flashing or something along those lines being like, OK, you're you're in a more you're approaching and even hazardous sort of position.

Table 7.2: Comments from the interviews about the lock-on being identified as a danger or hazard.

Another thing that was also difficult to understand for the users was the safety lock-on target indicator. In MAXQDA there were two groups for the comments directed at the lock-on design. One group was called "Lock-on is confusing" with 10 coded comments and the other "Identifying Lock-on as a danger/hazard" with 12 coded comments. This result proved to be fascinating as it confirms that the lock-on target indicator has a good purpose but it might not be an optimal design for all types of users. Tables 7.2 and 7.3 highlights some of the comments about the perception of the lock-on target indicator after being asked the following questions *"what do you think the red box markers are trying to highlight on the screen?"* and *"what do you think would happen if you move closer versus walking further away from this structure that is highlighted?"*.

Although the lock-on target indicator was not that precise for all users, the minimap on the other hand proved to be more striking and observable. For all five participants the minimap was something that they understood and could identify, the design was perceived to be a map element and not something else.

User No.	**Lock-on is confusing for the participants**
User 1	If I get closer I can have more information about the gas price. The more yeah, the availability of the machines, it gives me more information about this station.
User 1	these red because for me it's not anymore a danger sign....However, if you see destination, why I have these long pass to this point I don't know. It's it's not informative.
User 2	I mean I it's difficult for me, I would be guessing, but I I would guess that if I move farther away, maybe the market even turns green, but I don't know the functionality behind this.
User 2	So yes, I guess that's like some kind of warning, but I I I wasn't able to see it at first. .... I mean, it's clearly highlighting the the gas station. I don't know why, but yes, I mean it's a clear indication that, hey there, it's a gas station and it's red.
User 4	Or maybe it presents a warning. I didn't gather that, you know, petrol. I don't know. my initial thought wasn't that this was a a marker of a safety, but the analyzer is meant to analyze natural gas, not petrol.
User 5	Either a potential source of. Of a leak or umm, if in the methane concentration which we we can't see in this view, maybe there's a in in, maybe there's a there's a rise and with the the rise in concentration and the wind direction, it could be sort of predicting where the where an emission could be coming from either or it's just not clear with the because there's no methane readout.

Table 7.3: Comments from the interviews about the lock-on target indicator being confusing and not clear.

7.2.1.1 Positive reactions towards Scenario 1 - Efficiency

When it came to the crucial questions *How does the mini map contribute to the efficiency of your surveying tasks?* and *Does the mini map hinder the efficiency aspect in any way for you?* from the interview document, the resulting data collected was productive even though some users had a few critiques towards some unclear items within the map. For the efficiency questions the minimap received confirmation that it helps with the efficiency for the users, although not all of the participants expanded their answers. The comments from users who did add more views on the designs can be seen in Table 7.4. When asked about how the compass helps with efficient surveying with questions like *"Do the wind direction indications in some way assist you in your navigation during surveying?"*, *"Does the wind direction compass highlight for you how to be more efficient in your surveying?"* and *Do the wind direction indications help you with choosing a new position that you can survey on?* one user expressed positive feedback surrounding the design of the compass and one user could agree that the compass helps with directions, the results can be seen in Table 7.5. When it came to understanding the directions of the wind from the bar chart compass all five users could understand where both the strongest and the weakest directions come from.

User No.	**Perception of the minimap**
User 4	It looks extremely precise. ... It definitely gives me a a a route to explore, so I would say that that would improve my efficiency.
User 4	Does it hinder? No, it does not hinder.
User 5	it looks like it snapped to like a street that I'm currently at. So it looks very accurate, yeah. ... I need to figure that out, so I I like that a lot in terms of the efficiency it allows allows for looking ahead, yeah.
User 3	Ohh seems pretty fine to me, it's precise as the map.

Table 7.4: Comments from the interviews about the navigation and efficiency of the minimap.

The qualitative data collected shows that there are some productive aspects of the bar chart compass, mainly based on the data gathered by User 5. Furthermore, User 5 expressed positive insights on the minimap and the fact that it rotates with the view of the surveyor. When asked about safety related perspectives of the compass the participant confirmed that the design "provides appropriate intelligence for safety" and that it is useful. Several users also explained that the bar chart compass was the version that they liked better than the globe compass although this praise was not definitive. The coded comments concluded with 10 comments for identifying winds with the bar chart compass compared with only 4 comments for identifying winds with the globe compass. In addition, some positive comments received were made after users clearly identified the bar chart design as a compass, therefore a majority of the users expressed this. This means that if they did not understand it to be a compass then the results could end up being very different.

User No.	Perception of the Bar chart compass
User 5	It’s definitely very helpful not just to have an arrow, but to have kind of a like A and it it at least sort of a conglomeration of many points. The uh, but the instantaneous wind direction is also really is also important to like average wind and instantaneous wind are both important.
User 5	Yeah, definitely. Yeah, I think something something like, that’s pretty helpful as long as the the map and the windows are in kind of the same orientation. Uh looks great to me.
User 5	It helps a lot in terms of. Figuring out, kind of which way to walk relative to the wind direction. ... even though it’s decoupled from the the map direction, it’s still very helpful of.
User 4	Definitely. It’s going to be in the direction of the source, so based on how I’m looking now, I would expect the gas to be NE
User 4	It guides me in in the direction that I should be going. That’s for sure.

Table 7.5: Comments from the interviews about how the Bar chart compass helps with efficiency and navigation.

7.2.1.2 Negative reactions towards Scenario 1 - Efficiency

A total of 21 coded comments were made for the category called "Not understanding the Bar chart wind compass". This qualitative data highlights that even though some of the users could identify and observe parts of the bar chart design, many of them did not understand the purpose of it directly. Users 1 and 2 could not comprehend the design at first and even after learning that it was a wind compass the elements of the design did not assist them in any way. For example, User 3 perceived the compass to give a sense of orientation but the colors of the directions were not understood, while User 1 did not perceive any orientation from the compass. User 4 thought the design showed intensity or directional navigation, and the orientation of the compass was different than the user expected. Table 7.6 provides a set of comments that touch upon the negative aspects of the bar chart and how it is confusing for the participants. From a lot of discussion during the interviews the users confirmed that if they were to comprehend the compass then the perception would be different and after they began to see the bar chart design as a compass the data gathered was very interesting.

In addition, one item that was perceived poorly by some participants in the user interface was the black arrow that represented the current position of the surveyor. Although many users could identify that when they arrived at a new position in the test they saw the arrow move along the map but the size of the black arrow was somewhat small and hard to distinguish. Although this item had no part in the design of the compasses, it is still a relevant detail to remember for future instances of the design. For instance, User 4 concluded that the arrow was "almost impossible to see" even though the user comprehended the purpose of the whole minimap.

User No.	Negative aspects about the Bar chart
User 4	The color displayed on the compass, I seems opposite of what I would expect for severity of concentration of gas. You know, I would think blue being less methana, red being more methane, you know, kind of blue from cold red hot.
User 2	I mean, I mean I again, I don't know if the wind is blowing from the northeast to me or from the southwest to the northeast.
User 1	So if I assume that I stay in the north direction, then this red light red colors here are about 80 % compatible with this target, but it's not a good uh map in my opinion, because at least there could be a flag here showing that OK, you are standing in this orientation
User 1	Yeah, in case of a fire, I would understand in which direction I should stay to come upwith the to play as a firefighter. Of course, look if if these wind compass is correct, which in my opinion it's not.

Table 7.6: Comments from the interviews about negative aspects with the Bar chart.

7.2.2 Qualitative data for Scenario 2 - Efficiency

The feedback and criticism for the second scenario was overwhelmingly negative and poor. Even though the design had a new perspective on how to survey and keep track on the wind, this perspective was not something that was clear to the users. A lot of comments could be created from this and at the end a total of 28 coded comments touched upon negative aspects and these ended up in a group called "Not understanding the Globe Compass". When it came to understanding the winds only 4 coded comments could be grouped into a small category called "Understanding wind directions from Globe compass". However, all of these results proved to be of value to the Thesis and the analysis of the design. A lot of things can be learned from the negative results and this can be used in the future to be more effective.

Furthermore, since the users had already seen the lock-on design and the minimap design they could understand this and imagine themselves being in the same scenario as before but with a new design to look at. Identifying the globe compass as the wind direction compass was an easy task for the participants but when it came to comprehending the colors and items within this new design the results were poor.

7.2.2.1 Positive reactions towards Scenario 2 - Efficiency

One of the interesting good things with the globe compass was that one user actually liked the globe compass more than the bar chart compass. User 2 describes it as "I think it's an improvement over the previous one, but I'm still a bit confused with this one." and this is good feedback although the design needs to be reworked to make it less confusing. User 5 confirms that the design for this scenario represents a tool that is not static, compared with the bar chart which is static. User 5 says that "It's not static and I think that is a good thing generally." as a positive remark for the globe compass compared to saying for the bar chart that "but uh, in the still frames it's a little harder to interpret". Table 7.7 highlights some examples of positive opinions on the second scenario.

User No.	Positive comments for the Globe wind compass
User 1	If I'm addressing these gas station as a Hazard area where there could be danger in case of fire, it would be very useful.
User 2	I think it's an improvement over the previous one, but I'm still a bit confused with this one. ... And I think a bit better because now I can tell that the wind is coming from the gas station.
User 5	Ohh yeah, it would both help you I think find be able to locate the the locate in an emission more effectively and also move to a safer place. It would help. It would help you walk up wind to escape a hazardous location, and it would also help you stay downwind if you were gonna find a less hazardous emission.
User 5	Oh yeah, so I like the 3D aspect a lot and how.. It's like a little gyro or like a little gimbal ball or something. Ohh I liked I do like that aspect but with the and the the 3D aspect is, uh can be nice, especially if the user's kind of moving around so a little bit of motion might be might as the like as the users move and a little bit and the the sphere is kind of moving with the user it could help potentially help the user a lot with kind of visualizing what's going on.

Table 7.7: Comments from the interviews about the positives of the Globe wind compass.

7.2.2.2 Negative reactions towards Scenario 2 - Efficiency

All users expressed some sort of negative feedback or major confusion with the design that they were looking at. As mentioned before the student managed to create 28 coded segments that address some sort of negative attitude towards the globe design. In essence, the qualitative result can be summarized as being poor, too complex and difficult. Table 7.8 presents some of the negative comments directed at the design. The questions regarding efficiency, location awareness and navigation assistance can be summarized as being of low quality as the result from the table shows that the users did not understand the globe design that well and this affected their ability to see its functionality being used out on the field. Although the design for this version did end up being well-received, the data collected from the qualitative interviews was very beneficial as it gave the student a new perspective on how to create an effective wind direction tool and what to think about for future iterations. These things will be analyzed in the Discussion chapter in more detail and the results from this part will be considered.

User No.	Negative comments for the Globe wind compass
User 1	No, for me, it's it's really not clear. Because now it's going to show that the wind is going from north. To South East. I don't know at this. This is very not clear, at least for me. I'm I'm I can't understand it very well. ... I need to I need to think a lot to understand it. You know, I need to understand the IT seems the the wind is going from north.
User 2	No, it's I I don't know how to read this 45 degrees maybe. I mean, it's difficult to me to understand why this is a circle. ... I mean, yes, I I have really a lot of trouble with this compass as well. I don't understand the new compass. ... What the colors mean? Because I have blue, green and red and they have bigger and larger areas. So it's it's I I I can't even guess what they mean.
User 3	I'm not really that he used to this kind of like visualization. I could be in Northwest, but I'm not really sure. Like it's degree of not really, no. I don't understand really what the all the code color I could be like. Low intensity wind but. ... No, like miss, I'm not sure about this, not sure about this. The blue area that the green address him centred now on the and the gasoline station so. Is it really wind like? I don't understand this.
User 4	I think you know maybe in the 30 degree range it it's much harder for me to read, read this compass on this. ... I find the globe is kind of confusing.
User 5	This kind of indicating that it's coming from the Northeast even though, but uh or it could be the Southwest, it's hard to tell if it's going into the border out of the board I think yeah, like which direction is coming from, but yeah, I'm not sure.

Table 7.8: Comments from the interviews about the negative attributes of the Globe wind compass.

7.2.3 Qualitative Result for both Scenarios

A final comparison can be made between the data for Scenario 1 and Scenario 2 by viewing the opinions and feedback of the users. The result is generally divisive and both versions received extensive criticism that suggests that the designs have a good purpose but that the appearance and usability is of low quality. Apart from the example comments in the tables the users shared countless other opinions and answers that are crucial data for understanding the problems with the design but also to understand what parts actually worked for a few users. Grouping and organizing the data result with thematic networks was a good choice since it helped with identifying numerous themes that validates every single part of the design. The following list presents the number of instances a comment was made for a specific theme:

- *Positive:* Understanding Bar Chart Wind Directions - **10**
- *Positive:* Understanding Globe Wind Directions - **4**

- *Negative:* Not Understanding Bar Chart Wind Directions - **21**
- *Negative:* Not Understanding Globe Wind Directions - **28**
- *Positive:* Expert user identifying design as a Compass - **4**
- *Negative:* The Interface is confusing - **19**

The results from this list puts an emphasis on the total amount of qualitative data and the fact is that there are more negative comments towards both versions than there is positive reactions. However, when it comes to the result that determines which Scenario was accepted as the better version the qualitative data points towards the first scenario, the bar chart compass. Although the bar chart compass was divisive, as seen by the results of the tables, the final attitude directed at it was more confident especially since the globe compass design received overwhelming criticism. Qualitative data collected from the interview also suggests that some users prefer Scenario 1, as they stated that verbally in the interviews:

- **User 1:** Still, I would. I would rate more the previous compass and design it this circle one needs more thing thinking to understand the the previous one was quite easier, yeah.
- **User 4:** They both help. I preferred the first compass over the globe style.
- **User 5:** So I think the, UM the the static compass like the first compass is really good for is probably is probably really good for keeping track of long term or longer time scale sort of trends.

In essence, the qualitative result can be seen as constructive and beneficial when it comes to the broader discussion and analysis of the designs. However, when it comes to the result of which version achieves the efficiency aspect better, Scenario 1 takes the top spot.

7.2.4 Quantitative data for Scenario 1 - Efficiency

The qualitative data hinted that the bar chart design is not perfect and that some improvements could be made for especially first-time users when it comes to what the bars and colors actually represents. However, the quantitative data portrays a different light on the design of the bar chart compass. The final result of the questionnaire can be viewed in Table 7.9 and the values are strong for several keywords such as "understandable", "clear", "helpful" and "efficient". The data in the result suggests that the design is of good quality and that the purpose of the bar chart compass is beneficial and essential for the surveying activity.

However, the result has to be viewed from a more detailed perspective when it comes to the individual users and their reactions. Although the result for questions 1 and 2 is remarkably strong and effective the values to not represent that all five users perceived the bar chart to be understandable and clear. When viewing Figure 7.1 it is clear that the individual result for one user in particular suggests that the final result does not represent the opinions of the user who disagrees with a rating of 1. In addition, for questions 3 and 4 the mean values in the result suggests that all five users are somewhat in the middle of the disagree and agree likert scale. However, Figure 7.2 highlights that the individual ratings for these questions are spread out depending on the opinion of the individual participant. These specific insights are crucial for the final discussion of the result.

Questions from the Questionnaire	**Mean**	**Median**	**Mode**
1. The directions of the wind are understandable? ...	4.2	5	5
2. The directions of the wind are clear? ...	4	5	5
3. The Bar chart compass is helpful? ...	3.6	4	4
4. The Bar chart compass and cardinal directions assist you in the overall navigation of your surveying?	3.4	3	3
5. You want to survey to the North, without heavy winds affecting the surveying. The Bar chart compass shows you that this is possible?	1.8	1	1
6. The Bar chart compass helps with making the surveying activity efficient?	3.6	4	4
7. The Bar chart compass is noticeable? ...	4.8	5	5
8. The size of the Bar chart compass is sufficient? ...	4.6	5	5

Table 7.9: The results of the questionnaire for the Bar chart compass.

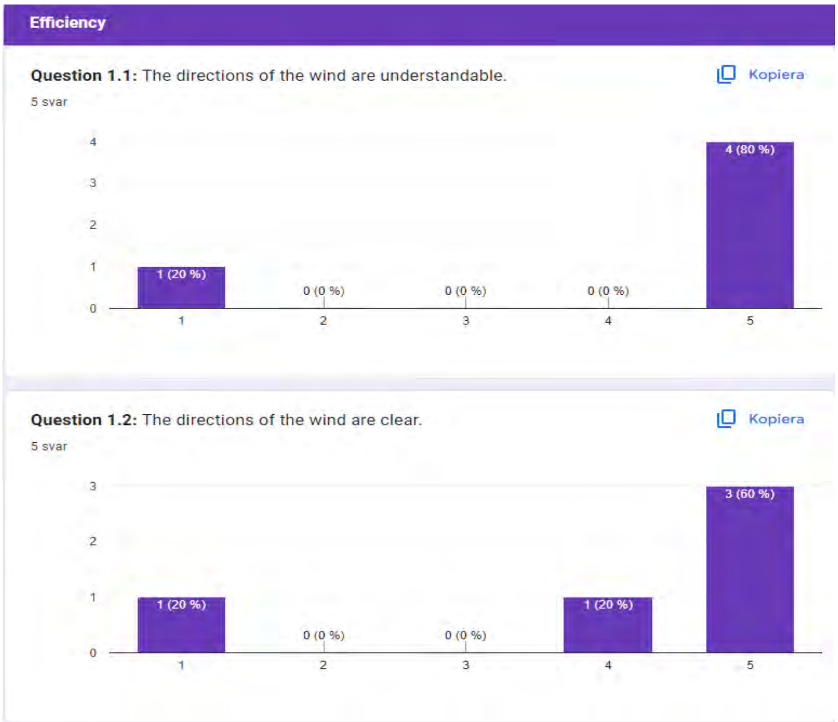


Figure 7.1: The diagrams for the data of Q1 and Q2.

Figure 7.2: The diagrams for the data of Q3 and Q4.

7.2.4.1 Quantitative data for the Radar Chart Compass design

As the radar chart design is similar to the bar chart design it was crucial to receive information about how the shape is perceived by users. The results from the questionnaire can be viewed in Table 7.10. When the values of the mean, median and mode are put next to the values of the bar chart table it is clear that the participants did not appreciate the radar design in the compass. The result gives an indication that the bar chart design is a more advantageous model and tool that user can comprehend better.

Questions from the Questionnaire	Mean	Median	Mode
1. The directions of the wind are understandable? ...	2.2	2	2
2. The directions of the wind are clear? ...	2.4	2	2
3. The Radar chart compass is helpful? ...	2.6	2	2 and 4
4. The Radar compass and cardinal directions assist you in the overall navigation of your surveying?	2.8	3	2 and 3
5. You want to survey to the North, without heavy winds affecting the surveying. The Radar chart compass shows you that this is possible?	1.8	1	1
6. The radar chart compass helps with making the surveying activity efficient?	2.6	2	2
7. The Radar chart compass is noticeable? ...	4.8	5	5
8. The size of the Radar chart compass is sufficient? ...	4.6	5	5

Table 7.10: The results of the questionnaire for the Radar chart compass.

7.2.5 Quantitative data for Scenario 2 - Efficiency

The qualitative data for the globe compass provided the student with constructive feedback that the design might not be optimal and sufficient for certain users. The result of the questionnaire resembles the result of the interview and the keywords explored in the form have mainly been rated with low scores in the likert scale. Table 7.11 presents the data result and for many questions the numbers emphasize that the design fails in both efficiency and comprehension. However, the scores for the noticeability and size of the globe received strikingly good values which is one productive aspect that can be established with the final result.

However, as with the bar chart quantitative results the individual opinions have a deciding factor on the overall result. For instance, when looking at question 1 the general feeling is that the design of the globe is good for making the wind directions understandable and the mean value 3.2 suggests that some users must have ranked their perception with a score of 3. When looking at the individual result, as seen in Figure 7.3, the image points out that none of the users ranked the understandability to be a score of 3. Instead the opinions are spread out and suggests that some users could understand the globe and other could not. For question 2 the individual opinions are shown to be divisive, see Figure 7.3, and the final result of course feels like it can be in the middle but the opinion of the other users are still interesting and crucial for the later analysis. For question 6 about the efficiency of the globe compass, Figure 7.4 highlights that some users believe that the design does help with the surveying activity and that the globe's functionality in some way can assist the user in being more efficient. However, the resulting mode value of 2 suggests that the globe is not efficient at all for the users even though some users perceive it as such. This divisive result of the tables will be discussed in the Discussion chapter.

Questions from the Questionnaire	**Mean**	**Median**	**Mode**
1. The directions of the wind are understandable? ...	3.2	4	4
2. The directions of the wind are clear? ...	2.8	3	4
3. The Globe compass is helpful? ...	3.2	3	2
4. The globe and cardinal directions assist you in the overall navigation of your surveying?	3.2	3	2
5. You are walking and surveying towards the North cardinal direction. You do not want heavy winds to affect the surveying. The Globe compass shows you that you can continue surveying in this direction?	1.8	1	1
6. The globe compass helps with making the surveying activity efficient?	3.2	3	2
7. The Globe compass is noticeable? ...	4.4	5	5
8. The size of the Globe compass is sufficient? ...	4.4	5	5

Table 7.11: The results of the questionnaire for the Globe compass.

Figure 7.3: The diagrams for the data of Q1 and Q2.

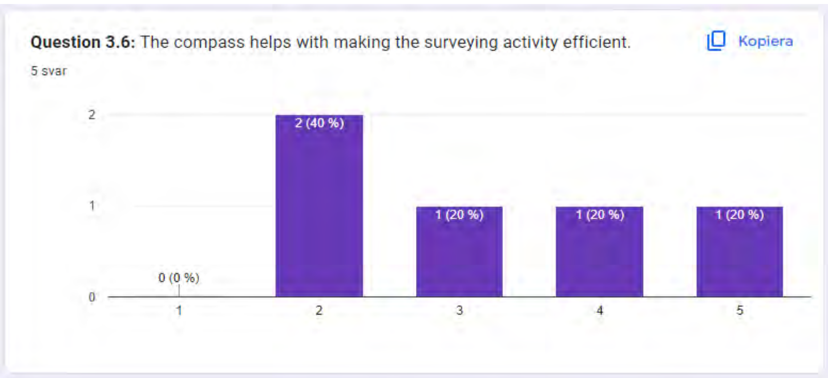


Figure 7.4: The diagram for the data of Q6.

7.2.6 Quantitative Result for both Scenarios

As the critical qualitative data emphasized that the perception and reaction towards both scenarios was divisive, so does the quantitative data emphasize. The results that can be viewed in the tables highlight that for some parts of the design the functionality and performance do not meet a good quality. And as the result showed in Section 7.1.4 and 7.1.5, the individual opinions splinter the final values that can be observed in the tables. However, when Table 7.9 and Table 7.11 are put next to each other and the comparison of the mean, median and mode values begin, the contest is leaning towards the favour of Scenario 1. All for one question, the mean values are higher for Scenario 1 which proves that the result of that version achieves efficiency better, from a quantitative perspective.

In addition, since the radar chart was nearly identical to the bar chart the quantitative result for the two designs help with deciding which shape, in essence, is better. When observing the mean, median and mode values of the radar chart questionnaire the conclusion is that result is very poor and the bar chart scored a better result.

7.3 The Safety Aspect

Although usability testing is not part of the research questions the final result for the success of the participant is that 5/5 managed to complete both versions of the self-inspection checklist without getting stuck or not understanding the interface. In terms of providing the participants with a good user experience, the result was perfect. The experience with the high-fidelity prototype proved to be useful for the users as well since they could answer the questions in a more natural way.

As with the efficiency aspect, the main ambition was to receive good and beneficial answers that can help with the credibility of the design. The semi-structured interview format was a crucial method for giving this aspect good results as many of the participants spoke freely about the design that they interacted with and how it could be used in certain scenarios and how important safety is for engineers. The summarized result can be concluded to be very constructive and valuable, especially since almost all the qualitative and quantitative data highlights something extremely positive.

7.3.1 Qualitative data for Scenario 1 - Safety

The coded groups from MAXQDA highlights many unique perspectives of Scenario 1 and how it can be an advantage for safety. Some of the most interesting groups include "Safety 1 positive insights", "Safety 1 checklist is good", "Safety 1 good efficiency" and "Safety 1 increased safety". All of these groups together build 21 coded segments which proves that there are many good things with the design. Of course there are more groups but those highlight comments about things that are not necessarily the first version but touch upon the entire scenario of using the self-inspection checklist.

The following tables, 7.12 and 7.13 , will present some of the questions, and the corresponding answers, related to the first scenario and they give a qualitative confirmation that Scenario 1 is of good quality and that is definitely contributes to the safety related keywords and themes. The answers in the tables are of different lengths since some users chose to give an expanded answer to their opinion and other gave a simple confirmation to the question. From the two tables the result is clearly conclusive and confirms that safety awareness is strong and that the self-inspection decreases harm and dangers for the user.

User No.	Do you feel that the self-inspection(version 1) will decrease the risk of harm and dangers for you?
User 1	Yeah, and yes, yes, I think so, yes, because I don't need to remember some of the aspects steps by myself.
User 2	So yes, it it is a step by step guide to check all the necessary components for me. If I am wearing them, if I have them with me in order to have like the most secure, let's say equipment before I move into my surveying task. So yes.
User 3	Umm. Yeah.
User 4	Yes, yes, it would decrease it.
User 5	Yes. Before you go it will I mean you when you go on the field, you will confirm that everything is what you have and you are ready for surveying.

Table 7.12: Comments from the interviews answering the specific safety related question.

User No.	How does this version contribute to the safety awareness for the surveying activity overall?
User 1	I think it it improves the performance. If it's defined in a clear way, I think definitely it helps because it's somehow it's some self check at the beginning and I think I think it increased the performance.
User 2	It's both psychologically and practically. So psychologically, in a sense that I have my company, my employer, the gives me all the necessary information and cares about my well being as well and also practically because practically I'm a like a a let's say secured by potential threat by potential hazards that I'm going to face.
User 3	I think it's a a very meaningful to have checklist before you conduct a task because it can provide you a lot of insure ensure that you will have the necessary steps and ensure you have necessary equipments that can help you to go through this this task.
User 4	I would say it's a positive self check like you do, like a checklist. Do you know that you went through this? So it's it's definitely a positive step.
User 5	I think it's fine.

Table 7.13: Comments from the interviews answering the specific safety related question.

7.3.1.1 Positive reactions towards Scenario 1 - Safety

Many of the participants expressed different kinds of positive feedback when it came to what the first scenario could contribute with for the user. The constructive qualitative data gathered from the interviewees highlights what makes the essence of the checklist design work so well for the context that you are preparing for the surveying activity. One positive aspect for Scenario 1 was that it was not seen by the participants to be something that slows down the surveying activity, the results can be viewed in Table 7.14.

Several example comments about certain positive aspects and how safety is increased can be viewed in Table 7.15. Overall the constructive and positive feedback for Scenario 1 gives a strong indication that the design has a good purpose and that the quality of the solution is relevant too, based on the results in the tables. Furthermore, a lot of data during the later parts of the interview focused on both versions but some information could be collected on how the first scenario was positive as well. These parts will be discussed more in the next chapter where the two versions can be compared with each other to highlight what positives exist with both versions and how they relate to each other.

User No.	**Does the self-inspection procedure feel like it slows down the surveying job?**
User 1	No, I don't think so. ... I can look at it as a some as a some warm up for the surveying. I mean, if I think that I start surveying and in the middle, I notice that I forgot some things.
User 2	No, no. I think it's necessary. I think it's very good if if there is some danger ahead, I think that this. Meticulous, let's say approach is very nice, at least for me and it it helps me like not to forget anything.
User 3	No, doesn't feel slow Me down it's necessary.
User 4	Ah, no, I think it was very straightforward and fast. So I don't think it would slow things down.
User 5	this is the self inspection. I think before that I think you you already should have done that.

Table 7.14: Comments from the interviews answering the specific safety related question connected to Scenario 1.

User No.	Positive comments for Scenario 1
User 4	I think having a checklist for your self is always a good thing. Uh, sometimes you tend to forget things that like the if, especially if you go through them on a daily basis, then they become part of the routine. And then, because they are part of the routine, you might skip one of them and not realize that you skipped it. So I would say it's generally a positive experience.
User 1	I mean, it's intuitive. I mean, it remembers me, the devices that I'm looking for, but at the same time it needs it's it's forced me to focus, to somehow identify the picture. So it's it's somehow it works like a double check for me to completely understand.
User 1	It's like some useful info at the beginning. Maybe that's also. It's a somehow it's normal process for mine that now I'm going for surveying and this is something that's helped me to Concentrate more.
User 1	I think it increased the safety. I mean, it works like a a step by step. So and I need to check each step by itself, so I think it increased the safety.
User 3	checklist is usually it's very good accuracy guaranteed and also it is very good for checklist to to to sort of give the user some indications about the task and and and accountabilities that they need to take in order to complete the tasks like how you gonna use this tool for example and who is who is here to ensure the countability for for the actions like explosive.

Table 7.15: Positive comments from the interviews for Scenario 1.

7.3.1.2 Negative reactions towards Scenario 1 - Safety

For the negative aspects there were only two comments that could be seen as some sort of negative, although they did not directly focus on the essence of Scenario 1. These comments were not directed at the specific purpose of the design and it was also not directed at the safety perspective. The following list details the comments:

- **User 4:** Check one tube if you're connected to the surveying stick wound this one. I do not know exactly what that is. (Card icon can be interpreted to be of poor quality)
- **User 1:** I mean, if honestly if I have I if I see this one as a some self check for myself, this gives you more good feeling instead of knowing that this is something that it's reporting to some super to one manager. (Confirming to supervisor not seen as a good thing)

7.3.2 Qualitative data for Scenario 2 - Safety

The coded groups from MAXQDA highlights the same groups as with Scenario 1, the difference being that they focus on the second scenario. The names of the groups are the same but with a focus on that they belong to the second scenario, namely

"Safety 2 positive insights", "Safety 2 checklist is good", "Safety 2 good efficiency" and "Safety 2 increased safety". For this version the total coded segments from these unique groups conclude in 30 comments. Although the version is very similar in structure, the new setting allowed the users to come forward with new feedback and this produced a good and beneficial result.

As the flow for the prototype is similar to the first version the usability proved to be successful for all users, 5/5. As the questions in the interview document are mostly the same the resulting data collected could be seen as similar and repetitive for some parts. However, for all interviews the participants shared extended insights and thoughts on the new version and this proved to be good for the final result and for the future analysis. The qualitative data ended up being overwhelmingly positive and many fascinating discussions sparked from this user test. The data for this version can be viewed as being of the same value as for version 1, since all users praise this version equally as much as they did with the first. Tables 7.16 and 7.17 presents the result from the safety related questions asked that explored if the design solution contributes with safety aspects. From this result it is clear that the second version is useful and relevant as well.

User No.	**Do you feel that the self-inspection(version 2) will decrease the risk of harm and dangers for you?**
User 1	Yeah, for sure. It's includes some, also some healthy questions that definitely it helps a lot.
User 2	It will sure for sure. Remind me what I need to wear at every point, at every level of my survey task. Yes. And it will verify and also it will secure legally secure the the employer that I am wearing this so he has done the best of he to the best of his abilities.
User 3	I think so because you never know. I mean, if there is a leakage or or or damage in your tube you wanna find that out but you I mean it it provides a good opportunity for you to stop a little bit and check the intactness of your equipment to make sure everything is great.
User 4	Most likely yes.
User 5	Yes. Yeah, it has quite all like that. Uh, elements that need to be considered during the safety check, yeah.

Table 7.16: Comments from the interviews answering the specific safety related question.

User No.	How does this version contribute to the safety awareness for the surveying activity overall?
User 1	Uh, it increased the IT definitely. It increased the level of safety in the system and it's and also, as I said, it's very good that it.
User 2	Umm, I think it is a good add on. I mean including including the initial like safety list, this is a good reminder and a good add-on. And also I like the fact that there are additional like the slides, additional cards. Regarding your physical, like uh, shelf, your physical performance.
User 3	It is good. .. but this one is not for readiness is for capturing new hazards. Um, for example, you might. You might, you know, doing survey to an extent that you don't even feel fatigue, but actually you are tired, so helps.
User 4	I think it's definitely a positive thing, like it helps you maintain the. The fact that you you are supposed to continue, for example, wearing all the safety equipment and helps you go through the fact that yeah, if you have a slightly diverged from the safety process that you are supposed to also be reminded about it.
User 5	Yes, I think it has a bit more. Uh, like two other elements, so I think it increase the safety when you are on the field, yeah.

Table 7.17: Comments from the interviews answering the specific safety related question.

7.3.2.1 Positive reactions towards Scenario 2 - Safety

The reactions for this version were equally positive as for the first version of the self-inspection checklist. However, for this version the participants mentioned several intriguing things about the new perspective, for example that the checklist occurs during the surveying and the new cards that are inspecting health and physical conditions were perceived in a good way, see Table 7.19 for example comments about Scenario 2. The result benefits from this data as it suggests that users like the new setting that the self-inspection checklist is in and that it explores new safety related items. Table 7.19 also highlights other positive opinions and remarks on Scenario 2 and these are good for the final result that confirms that there is safety awareness and a good purpose with the user experience as well as design.

As with Scenario 1 the comments about if the self-inspection checklist slows down the surveyor confirmed that the users think that the checklist for Scenario 2 is not a tiring or demanding task. However, this totally depends on how often the checklist occurs, as pointed out my users in Table 7.18. Some users do not think that the checklist is a nagging task and some users think that it could be a distressing task if it attacks the users field of vision to often. An interesting thing here is that the design and setting of the second version was well-received but the users thought of how it could look like from another perspective.

User No.	Does the self-inspection procedure feel like it slows down the surveying job?
User 1	No, I mean based on the because the time it's the time is not too much. So I don't think it's a slowdown in the process, no.
User 2	A little bit, a little bit, but again it depends on how often this this procedure will repeat itself. So how? How many times I will be required to answer this questions if it is too often then it will be. It can be irritating if it's not too often.
User 3	Not really. It's quick. I mean, I'm not taking like a 10-20 minutes to finish it. I think it like using several minutes to finish it. It's fine.
User 4	Depends on how often this will pop up, but if it pops up way too often, then yes, I would.
User 5	And no, I don't think so it because they are can be very fast and when you are. Working this like pure checking this all the time. Before that you will you. It can go pretty fast. Maybe you can do it like less than a minute or yeah.

Table 7.18: Comments from the interviews answering the specific safety related question connected to Scenario 2.

User No.	Positive comments for Scenario 2
User 1	It's specially these, it's related to the health. And some the it's related, it's more directly to the in somehow internal filling your healthiness, your health. So it's it's forced me to think more about now. My feeling, not just the devices that I need, so I need to double check my myself and it's it's a good feeling.
User 2	Yes, I totally agree on this. They increase a security awareness. They make you, they provide you a very simplified version of a very simplified, let's say, checklist. Visually. Also visual checklist in order for you to be as much secure as possible.
User 5	So I to me is I think the second is more much better because that's what I was also thinking that to tell you in in the first one that you should have also this other elements also included uh in the first uh that was I feel it there were missing in the first one yeah. ... Yeah, it will increase more safety like A and uh, if you use the second one instead of the first one.
User 4	so I instead of the system like randomly deciding that I need to do this, it gives me some freedom so that I can take the process myself whenever I feel like it's the safest to do so.
User 2	This uh regards my condition, especially if the there are tasks that my physical presence and my physical fitness is actually required. So I think that it was good to have them and give you some some recommendations of how to react if that is the case.
User 3	It's a it's a very good idea and there could be other hazards as well, like even for example the winds or environment. And also yeah also also like for example like asking the operators to pay attention to like changing conditions like is there any changes in the conditions or any on the expect factors that come into play.

Table 7.19: Positive comments from the interviews for Scenario 2.

7.3.2.2 Negative reactions towards Scenario 2 - Safety

As mentioned in Section 7.2.2.1 the result for the occurrence of the checklist was not seen through a positive perspective by some users, even though they had no direct grievance with the actual design. The results in this section will highlight some negative comments, however they all touch upon the occurrence of the checklist and this does not directly mean that the second scenario is of poor quality but that situation of the design can make some users feel a negative attitude towards it. Conclusively this result is still significant to remember and analyze, as a frequent occurrence of the design could affect both the safety aspects but also efficiency aspects. The comments received about the checklist being recurring can be viewed in Table 7.20.

User No.	Negative comments for Scenario 2
User 2	A a little bit, a little bit, but again it depends on how often this this procedure will repeat itself.
User 2	If it is reoccurring 8 times like once per hour then it's OK, but if it is like a more often like four times per hour then it can be irritating as especially if I am under concentration that I need to concentrate on my task not to forget anything to and I'm concentrating on specific like
User 3	If I'm in judgment in the middle of the task and this self inspection checklist or pops up and blocking me from continuing my job, then it will be probably feel frustrated.
User 3	I mean some of the questions, I think it's unnecessary. For example, the boots, I mean I don't take off the boots when I do the survey, so it's kind of a for me it's it's not necessary
User 4	I I think it might actually worsen things like if it pops up while I'm in a dangerous situation. For example, in suddenly I lose my 100% field of view towards the danger and I think it might actually become more dangerous to have this. So it's very crucial that this thing pops up at the proper timing and not like randomly
User 5	Maybe you should not do it continuously because you have done all the the safety checks you are already in the field, so maybe you just do it. Uh, only once.

Table 7.20: Negative comments from the interviews for Scenario 2.

7.3.3 Qualitative Result for both Scenarios

As with the efficiency aspect, a final comparison can be made between the qualitative data for Scenario 1 and Scenario 2 by viewing the opinions and feedback of the users. The result of the qualitative information suggests that Scenario 1 takes the top spot for the users by a very slim margin. In essence, it comes down to the negative attitude towards the occurrence of Scenario 2, as explained in Section 7.2.2.2. However, overall the result can be viewed as positive and fascinating from several perspectives as all users expressed good and constructive opinions on the self-inspection checklist. The following list highlights some of the essential coded groups that were made with the inspiration of thematic networks. The themes in the list touch upon different things about the scenarios and many beneficial comments were observed from the interviews:

- *Positive:* Safety 1 checklist is good - **4**
- *Positive:* Safety 1 positive insights - **2**
- *Positive:* Safety 1 good efficiency - **2**
- *Positive:* Safety 1 increased safety - **13**

- *Positive:* Safety 1 good observation - **10**
- *Positive:* Safety 2 checklist is good - **5**
- *Positive:* Safety 2 positive insights - **8**
- *Positive:* Safety 2 good efficiency - **3**
- *Positive:* Safety 2 increased safety - **14**
- *Positive:* Safety 2 good observation - **5**
- *Negative:* Recurring checklist too annoying - **9**

The positive result from the qualitative data gives the design solution a very respectable advantageous prestige. Both Scenario 1 and Scenario 2 are important and beneficial for the general safety of the surveyor.

7.3.4 Quantitative data for the Safety Scenarios 1 and 2

The purpose of the quantitative result is to see how users perceived and reacted to the overall design of the checklist and its intended use as an augmented reality interface. Since the two versions of the self-inspection are very similar in their general purpose, the only difference being their setting, the questionnaire only explored the difference between the versions with a few questions. The rest of the questions in the questionnaire aimed to explore both the interface of the checklist and then the significance of performing the self-inspection. The interface and user experience related questions can be viewed in Table 7.21. Then the questions that focus on the task of performing the checklist and sending it forward to supervisors can be viewed in Table 7.22.

For the augmented reality interface questions the result can be seen as exceedingly positive and definitive. Many of the essential keywords being explored in the questionnaire received high scores, such as "understandable", "clear", "learnability", "navigation", "clickability", "memorability" and "effective". This result resembles the qualitative data from the interview in that the perception and reaction to the design of the checklist and its functionality is very good. The result for the interface related questions, 1-9, suggests that the self-inspection design is excellent. As some of these questions were not asked explicitly in the qualitative interview the result from the questionnaire can be seen as exceptionally positive from an interface and user experience aspect.

For questions 10-16 the result is largely positive and many unique key statements are perceived to be of good quality, for example that performing the self-inspection increases the surveying safety and that confirming one's safety is significant. The result for these questions reflect that many users see the checklist event as something useful and important. However, there are some divisive questions for the users and these are mainly connected to the negative comments towards where the confirmation is sent and to who. Especially question 12, see Figure 7.7, is an interesting result since the opinions on who actually has responsibility over the surveyor was a challenging question to address for some users depending on how they view the employer-employee relationship. The image gives the result another perspective and this is critical to remember for future work with this kind of solution that involves user confirmation and signing of something.

Questions from the Questionnaire	**Mean**	**Median**	**Mode**
1. The representation of the icons inside the cards are clear in regards to safety.	4.6	5	5
2. The purpose of the card for the self-inspection is understandable.	4.8	5	5
3. There is a sense of learnability with the self-inspection and its content.	4.2	4	4 and 5
4. There is a sense of memorability with the self-inspection and its content.	4.2	5	5
5. The self-inspection checklist is an effective tool to use. ...	5	5	5
6. The navigation of the augmented reality environment is comprehensible.	4.8	5	5
7. The clickability for the augmented reality elements is recognizable.	4.8	5	5
8. Performing a self-inspection before the surveying activity is relevant.	5	5	5
9.Performing a self-inspection during the surveying activity is relevant.	4.2	5	5

Table 7.21: The results of the questionnaire for the Safety self-inspection checklist; AR user interface related questions.

Questions from the Questionnaire	Mean	Median	Mode
10. Performing the AR individual self-inspection increases the surveying safety.	4.6	5	5
11. The AR individual self-inspection is reassuring. ...	3.8	3	3
12. Confirming your safety is your own responsibility. ...	3.6	4	4
13. Confirming your own safety is significant. ...	4.8	5	5
14. Confirming and sending the self-inspection checklist to ABB is reasonable.	4.4	5	5
15. Confirming to ABB that you take responsibility for your own safety is crucial.	3.8	5	5
16. Confirming your safety several times via a self-inspection is important to do during an eight hour workday.	3.8	4	3 and 4

Table 7.22: The results of the questionnaire for the Safety self-inspection checklist; confirmation-of-checklist related questions.

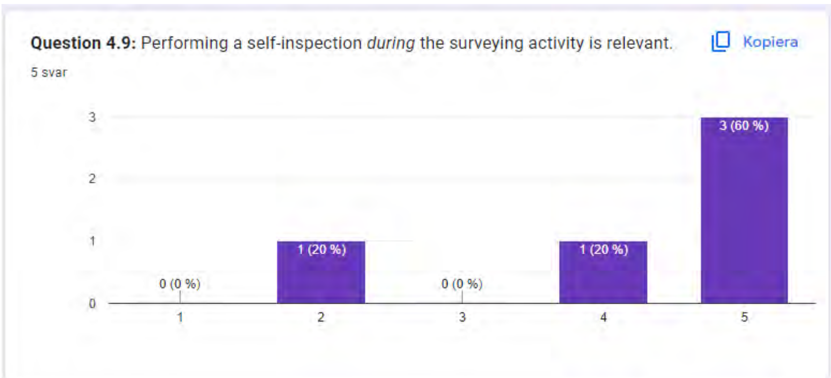


Figure 7.5: The diagram for the data of Q9.

Figure 7.6: The diagram for the data of Q16.

Figure 7.7: The diagram for the data of Q12.

7.3.5 Quantitative Result for both Scenarios

For the comparison of the results from Scenario 1 vs. Scenario 2, questions 8 and 9 can be observed closer. Table 7.21 highlights that all users agree with the significance of the self-inspection checklist before starting the surveying activity. However, for the self-inspection during the surveying, some users do not agree with this statement entirely, see Figure 7.5. Furthermore, the answers for question 16, as seen in Figure 7.6 highlights a divisive attitude towards the occurrence of the self-inspection during a surveying workday, as mentioned in Section 7.2.2.2. The quantitative result points in the favour of Scenario 1 and that this version is, in essence, the preferred aspect to use in a surveying context. However, it is important to remember that the result seen for some questions in Figure 7.21 and Figure 7.22 do not specifically deem one version to be better or worse. For example, the card design is the same for both versions and can therefore not lean towards one of the specific scenarios. It is essential to remember that the only difference is that the environment setting is different.

7.4 Guidelines

The result chapter concludes with this section about recommended guidelines for the safety aspect and the efficiency aspect. The guidelines can be seen as critical parts that help with answering the research questions since the result of the design solutions highlights essential themes of the research.

7.4.1 Use clear icons for safety related items

In order to stay safe it is important that something can highlight this visually. By having icons in the checklist cards the purpose of safety becomes more precise and the user will understand the gravity of the safety awareness. The icons must be clear and simple when it comes to what they are portraying and in addition the title needs to fit the character of the safety icon.

7.4.2 Use effective design patterns for AR display

Although the augmented reality interaction is in another dimension compared with mobile and computer interfaces, design patterns can be used with precision for the environment. Design patterns are essential tools for the interaction design and using for instance Carousel can offer an engaging interface [1], which is something that is paramount for users to confirm their safety in the augmented environment. The checklist can be expanded which means that there is room for more beneficial design patterns to be used for this expansion.

7.4.3 Provide good navigation for the user

When it comes to using a product in the real world the user must know about the orientation of the interfaces. Providing a clear interface with recognizable elements and anticipated movements will ensure that the user can navigate through the augmented environment without getting lost or confused. Although some of the design aspect can be hard to interpret the focus has to be on making sure that the user can get from point A to point B.

7.4.4 Safety Awareness before the surveying begins

It is very important that the surveyor is safe during the surveying activity but it is also significant not to overlook the importance of safety before any task is initiated. Using effective design to increase the safety awareness before departure is crucial for the surveying user as the comprehension level of potential dangers and hazards can be established early on and therefore prevented entirely.

7.4.5 More informative minimap and lock-on indicator

There is a lot of potential with the minimap and the lock-on target indicator based on feedback from the participants. However, not everything was sufficient enough and the ambition is to make the material more informative. This includes making sure that the minimap is precise in all regards and that the lock-on has some additional information connected to it in order to highlight its functionality.

7.4.6 Wind Direction compasses should be non-static

Based on the extensive negative comments received from the interviews it is apparent that the efficiency of the compasses can be improved by making them move with the orientation of the users' point of view. By doing this the behaviour of the compasses become more familiar with how people perceive objects in the augmented environment to move and behave. Aiming for a conventional performance and actions is key to ensuring that the surveyor can be efficient because of the familiarity of the design.

7.4.7 Connect the compass with the minimap

As the two elements are both focusing on navigation and location awareness, it will be an advantage to have them connect in some way. When the user views the elements and tries to determine his/hers position it will be important that the cardinal directions of the compass mirror the directions of the minimap tool.

7.4.8 Explore conventional colors for the compass

The evaluation suggests that there are some confusions towards the colors being use to display wind directions and the surveying path on the minimap as well as the lock-on box. It will be an advantage to use conventional colors as that it easier for users to comprehend and the colors should also not be used extensively all over the screen. Eliminating confusion is a key strategy for ensuring an efficient surveying activity.

7.4.9 Clarify who has responsibility of safety

Different people have different interpretations of responsibility when it comes to performing tasks as a worker out on the field. Based on the interviews and questionnaire it is apparent that some participants feel a strong desire for the company to take authority and help the employees with the safety aspects. With solutions in design it can be explored if responsibility lies on the employee or the employer.

7.4.10 Have acceptable sizes for the augmented interface

The design of the solutions need to be seen by the user in a correct way. The questionnaires in particular highlights that the sizes of the compasses are crucial and therefore this is something to remember for future instances. If the sizes are not of good quality then the user can not experience the interaction to the full effect.

8
Discussion

This chapter mainly discusses the extensive and versatile result part of the project. In addition to the result the design process will be discussed and how it contributed with the final design solutions. Ethical considerations will also be a significant part of this chapter and future work will be explained in order to indicate that the work in this Thesis has constructive and beneficial value for the eventual engineers and developers who continue with this project. As a focus area is user experience and the chapter will touch upon how the design can be implemented into the augmented reality environment and contribute with an overall better and significant experience. The design process and how problems have been solved is also an essential part of the discussion as these items shaped the structure of the project. Throughout the discussions in this chapter valuable information will be presented that indicate the final answers to the research questions, especially in the results sections.

8.1 Results

The results for the project are the most paramount building blocks and this section will highlight why the collected data during the final parts of the design process verify the believableness of the design solutions. The results can be seen from two perspectives, the efficiency aspect and the safety aspect. The results are divided into two parts, one for the efficiency aspect and one for the safety aspect. The two categories of the result will be discussed to answer the research questions of the Thesis, both the first and the second item:

- ***When performing the surveying tasks, what actions can influence an augmented surveyor system in relation to the safety and efficiency of the user?***
- ***What are the essential design recommendations to establish a safe and an efficient augmented surveyor system?***

8.1.1 The Result of the Efficiency Aspect

The qualitative and quantitative data gathered from the validation for the efficiency scenarios are worthy of a conclusive discussion. As the result suggests neither version was perceived to be exceptionally optimal or significant for the efficiency of the surveying profession. Generally the comments were divisive towards the intended solutions and many users expressed constructive feedback that highlighted the problems with the design that they interacted with. On the other hand, a few users did occasionally raise their voice and expressed positive remarks towards the purpose of the design. Often the users would point out that if they were to understand the compass design, then the efficiency of their surveying task could definitely be improved. The data collected from all the five interviews suggest that there is a balance between positive and negative comments and opinions towards the entire design of the scenarios. However, one interesting analysis is that when merging all the data together, the result of the questionnaire for the bar chart compass strikes as being the item that was most well-received. This analysis is unfortunately not that conclusive since the qualitative comments from the interview weigh heavier, especially when taking into consideration the numerous confusing comments that users expressed towards the design of the bar chart and its static nature. A lot of complexity has surrounded the efficiency design, its inception and its validation. This can be seen as one of the reasons why the final result shows a serious and substantial discord.

A lot of discussion will surround the wind direction designs of the efficiency aspect but there were other elements for the scenario that provided an overall augmented solution with both efficiency and safety perspectives. An analysis can be made on the significance of the minimap and based on the reactions towards the element it is sufficient enough to say that the minimap design is an essential part to include when a surveyor is using augmented reality out on the field. Many of the users expressed mainly positive comments about the design of the minimap and when it came to navigation and efficiency the users concluded that the minimap helped with those aspects. From this analysis it can be concluded that the minimap is a crucial part for the efficiency of the surveyor and it has to be included. Positive feedback was received by the users that the minimap moved with the eyes of the surveyor and this was a good result. However, since the design and movement of the compass did not work well with the users, they began to question the functionality of the minimap since it moved and the bar chart compass did not etc. In addition, the qualitative data suggest that some users did not appreciate the colors of the compass and thought they might be connected with the red surveying path on the minimap.

Another item that was complex for some users to comprehend was the lock-on target indicator and the result shows that the red color of the lock-on was sometimes perceived to be a danger and sometimes it was seen as an objective. It was interesting to see how the participants understood the lock-on more when told in a question that it was related to safety. The lock-on was received as being sufficient although the interface did confuse some other users and the reaction to its functionality was mixed as well. When it came to safety and efficiency the purpose of the lock-on target indicator was well-received but overall the qualitative data suggests that the lock-on design needs to be reworked to fit more into the warning and danger aspect. One interesting discussion here is that the design might be difficult to comprehend fully when only using still images. If the design was tested on the display of an augmented reality headset certain flashing sequences and audio signals could be used to highlight warnings and danger. There are current augmented reality design solutions that shows the potential of the lock-on design. In their study on maritime navigation Francesco Laera et al. explains that augmented reality was used to identify obstacles on the seas with an obstacle being marked with a lock-on indication design [87]. For the example in the article, ice sheets are the obstacles and the lock-on highlights the area and a label is connected to the lock-on that shows critical data such as thickness, ice age and recommended speed [87]. This solution is exceptionally creative since it strengthens the purpose of the lock-on and gives an explanation to why it is there. The lock-on target indicator for this project could benefit from having a label connected to it since many users did not comprehend it directly as a warning. The label could explain that there is a "danger" and mention "Petrol station" and "Explosive risk".

One part of the validation that resulted in a conclusive path was the questionnaire for the radar chart. As mentioned in the execution phase, the radar chart is a similar design of the static wind compass and the difference is that Scenario 1 is built up with direction bars while the radar chart is built up with spiky radar directions. When doing the analysis of the table for the radar chart and the bar chart it was clear that the users did not like the radar chart and the idea of having radars to highlight wind direction is not optimal. Overall, a set of low scores for the radar chart were chosen by all the five participants.

With the efficiency aspect in mind, the research question *"When performing the surveying tasks, what actions can influence an augmented surveyor system in relation to the safety and efficiency of the user?"* can be highlighted in a more clear perspective. As the scenarios imitate the real life context of using the augmented reality equipment and systems the result of the evaluation of the design hints towards a conclusive answer to the research question. As the discussion shows, the comprehension of the design elements in the augmented environment relate to the actions that a user can perform when perceiving this specific design. The compass, minimap and lock-on indicator all highlight that the surveyor should walk in a specific way and follow the recommended markings from the tools in the augmented environment. By doing this the surveying user can be both more efficient as well as safe, based on the findings and the discussions.

For the second research question, *What are the essential design recommendations to establish a safe and an efficient augmented surveyor system?* the efficiency aspect provides an essential answer to that question. By reviewing the results and analyzing the discussions it is clear that there are many flaws in the current design for making the surveyor comprehend the wind direction versus the walking directions. By learning from the errors made and listening to expert users from evaluations critical recommendations can be spawned and saved for future instances of the project. With the design recommendations in mind, the answer to the question comes in the form of several recommendations that have experience from the evaluation and they highlight what is needed for establishing a safe and efficient surveying.

8.1.1.1 Expert users vs. non-expert users in the evaluation

What makes the efficiency result even more interesting is the fact that two of the users who participated are expert users in that they have good experience with the surveying profession. The other three users who participated were engineers but had little to no experience with surveying but a sufficient understanding of augmented reality. This made the final reaction towards the design of the two scenarios extremely fascinating and helpful. Especially the attitude of user 5 suggested that the design had a strong value for the efficiency and navigation of surveying, even though the user also expressed some confusions. Compared with the other users, the fifth user was the only one who comprehended the bar chart design and directly pointed out that it was a wind compass. This is definitely an interesting analysis since it creates a disturbance in the final result and the conclusion that both scenario designs are of poor quality and have a weak purpose does not represent the opinions of all the participating users.

The main discussion to unravel and dissect is do the combined comments from the interviews and the combined numbers of the questionnaire actually conclude that the efficiency design is weak and insufficient. This discussion needs to be seen from multiple perspectives of course but one of the main areas is that the expert users have a strong voice in the analysis of the problem. Since the future intended user of the product will most likely be an experienced surveyor then the data gathered from the expert user holds some evidence that the design solution is a helpful and efficient tool. And from another perspective the qualitative data suggests that User 5 was pleased with the unique design of the globe and that it gave the surveyor another context of the environment, and this means that for future implementation the second scenario could be considered and reviewed even though the result of this validation leans more towards the first scenario.

However, the voice of the non-expert users is also significant and relevant for the future of this design solution. Some qualitative data collected from the non-experts implies that the designs and their functionality should be scrapped entirely, especially the globe compass. And as these users mention critical reactions to the flaws and deficiencies of the design, their views have to be respected since they have extensive engineering experience and comprehension of the solution space. An interesting analysis from this is that the design could definitely be reworked based on the comments of the non-expert users and then tested again with both expert and non-expert in order to explore if the experts are exceedingly positive to an improved new design and if the non-experts are satisfied with a more clear and understandable interface. Of course this analysis suggests that the design could be brought into a future development and explored further, which is something that the final result in a way hints on since the reactions are very divisive.

Furthermore, at the core the purpose of the designs are to increase the surveying efficiency as well as navigation and orientation. When asking questions that were connected to the efficiency keyword both expert users concluded with positive remarks that the purpose of the designs are relevant, although User 4 had more difficulties with understanding the interface design. This part of the evaluation proves that for some users there is an advantageous efficiency feature with the designs and as the result highlighted that Scenario 1 is better well-received then the bar chart compass is worthy of being further developed for future instances of the project. But from another perspective, as the non-experts expressed some negative opinions on the bar chart compass as well then the future implementation will need to be discussed first before going into the real development. The final results of the questionnaires also give future developers a good analysis and understanding of the very essence with the two scenarios. Based on the higher numbers in the table for the bar chart, developers have a good indication that they should explore the efficiency aspects of that design.

8.1.1.2 Divisiveness in the Questionnaire

As explained with the qualitative interviews, some users deemed the many perspectives of the design to be both positive and negative. From this event it was clear that the design of compasses were not for every user. This thing was also prevalent in the result of the questionnaire and the scores for the mean, median and mode do not actually resemble the entire population, see Section 7.1.4 and 7.1.5 for the complete presentation of the result. This divisiveness in the individual scores for some of the questions created a fascinating and complex analysis of the solutions. When the table for the bar chart design is presented the scores for many of the questions hold strong numbers. Especially when looking at the median and mode values for the understandability and clearness of the wind directions, the ranking of 5 feels reassuring and excellent. One could decide to choose this solution and move forward with a direct implementation of it in an augmented reality environment. However, as the result highlights in the named sections, one or two users may not comprehend the design entirely and their voice is significant as well. The median and mode values suggest that everything is perfect, however the mathematical formulas function in a unique way and do not take everything into account. Then one could argue that the mean values, 4.2 and 4, are a better representation of the reaction. However, the mean values suggest that the participants should be mostly in agreement while there are at most two users who do not agree and rank low scores for the design. It is this conflict in the result that makes the analysis extremely difficult to conclude and the discussion about how to interpret and respect the views of the outlying participants can be extensive and endless.

The divisiveness has to be respected and when using the result of the questionnaire to present Scenario 1 as the preferred version it is important to share the outlying perspectives as well. If the solutions were to be presented to a group of stakeholders then it should be a mandatory requirement to showcase the divisiveness and conflict of the users' different perceptions. For this Thesis five people were chosen and at most one or two users often expressed negative feedback in the qualitative interviews. From a different perspective, imagine if 20 engineers were evaluated and the same conflict occurred then the outcome would lead to at most 5-8 users expressing similar negative opinions. Of course this is a speculation and can be discussed back and forth but it does provide some crucial insights to the purpose of the product. If

12 users rank the bar chart compass with high scores in the questionnaire then the final mean, median and mode values can be expected to be high and then since there are 20 participants the conclusion will be that the solution is excellent and perfect. Nevertheless, the voice of the few can suggest that there are flaws and deficiencies with the solution that are seen from a unique angle and this has to be respected and the best thing to do would be to continue working with the problem in iterations.

8.1.1.3 Difficulties with the development of Scenario 2

During the design process it was discovered that to make the design solutions credible and believable, the design would have to be presented from two scenarios. After feedback with the advisor the decision was made to do this with both the safety aspect and the efficiency aspect. The student observed the design of the bar chart compass and compared it to the functionality of the wind rose. It was clear that the bar chart design would be static and not change with the user's field of view and only the wind directions would change from time to time. With this perspective in mind the right choice for a second version felt that it should be opposite, therefore not static and that it should move in another way. However, this was one of the parts of the project where the ideation thinking process was not functioning as effectively as hoped. It was a challenge to find a unique second version as the student wanted to try to come up with something that was based on tools but not copy the conventional wind direction arrow design.

Eventually the student took inspiration from the sphere compass and started to transform the essence of the bar chart and transfer that into the globe compass design. It was this transfer that caused a lot of insecurities since the functions of the digital tools did not allow the student to make the wind direction design as intended. The coloring of the 3D globe in Figma was also a difficult task since the program had multiple constraints and the planned version did not become that optimal. It was this struggle that made the student realize during the evaluations that the globe compass design was always destined to be the least favorite of the two versions. The design was complex even from the inception of the idea and since the aim was to make something unconventional the outcome at the end suggested that a conventional solution would most likely be better well-received by the users. Of course at the end of the day, the exploration of this unconventional solution proved to be extremely beneficial and useful since the evaluation hinted at a lot of negative attitudes towards the design and this meant that the future for the globe compass was bleak. Perhaps the solution should be scrapped entirely or perhaps it should be reimagined with the help of the qualitative feedback, this is something that can be continued to be discussed by future developers. Unconventional solutions are not a bad thing for augmented reality systems and the wind direction augmented solution presented by Francesco Laera et al. suggests that real life tools can be made into augmented elements that assist with navigation [86]. In their work the wind direction indicator is an arrow inspired by the Windsock, a meteorological instrument, and the wind rose tool is implemented in their solution as well on the horizon to show the heading angle and wind degrees [86]. This academic literature highlights that unique solutions are possible for augmented reality and efficient wind direction indications inside that environment, although it requires visionary and decisive problem solving. Therefore keeping the idea of a sphere or globe could be beneficial since it is unconventional and the only thing that is missing is how to perfect the wind directions on the 3D globe or sphere compass.

8.1.2 The Result of the Safety Aspect

The result of the safety self-inspection checklist scenarios is a fascinating item to discuss since the outcome was extensively positive and the major concerns that the users had with the prototypes were not even related to the user experience and visual feeling of the design. The purpose was to explore how an augmented reality interface could contribute with safety, and also some efficiency, and the hope was that the users would perhaps express some constructive feedback on the safety aspect but at the end the most interesting feedback touched upon the ethics and morality of the signing of the performed checklist. Of course this is a key area that can have an effect on the safety of the surveyor and it needs to be analyzed and discussed to some extent.

In addition, there are many unique aspects of the checklist for both scenarios and the qualitative data and especially the quantitative data suggests that the core purpose and structure of the design is excellent and exceedingly significant for future augmented reality surveying systems. The mean, median and mode values for the safety related items in the tables proves that the users have an excellent perception and respect for the design and how the very essence of the tool helps with making the surveying activity safe overall.

One extremely interesting and fascinating discussion to focus on with the self-inspection checklist is that Scenario 1, the idea that was spawned during the sketching ideation, is not technically part of the surveying actions or tasks. Since the user does the self-inspection before the work even begins the checklist does not have anything to do with the examinations of leaks and underground pipes. When the user is performing land surveying over a hazardous area the actual checklist can not be used to make sure that the surveyor is safe at that very moment. However, from another perspective the checklist can be seen as an integral part of the surveying activity as it can prevent harm and dangers for the user when they are out on the field. Although the checklist is not there with them out on the field, the confirmation that the users have made can be seen as a secured and reinforced action that guarantees that the surveyors will have good safety when they reach certain areas of the rough terrain. When taking into account Scenario 2 the evidence is clear that there are many important things to check and consider when the surveyor is performing the task and action during the event.

One good sentence that can summarize the essence of the self-inspection checklist is "safety planning". It is discussed that common applications with augmented reality, as well as virtual reality, in construction safety management consist of safety planning, safety training and education, and safety inspection [88]. Xiao Li et al.

emphasize that the safety planning item receives an exceptionally high prioritization because that item can help with identifying the hazards or risks before actual work at the site begins [88]. Therefore one can analyze the design solution for this project and deduce that the self-inspection is a form of safety planning and this can be a very significant aspect for the surveyor. The study by Chan-Sik Park and Hyeon-Jin Kim suggests that most accidents on the site can be reduced and, more importantly, be prevented entirely with the establishment of proper and consistent safety management process [89]. Even programs of planning, education and trainings as well as inspections are things that can be established to achieve extensive safety [89] and this is something that the self-inspection upholds. The checklist design can help the surveyor to identify risks and dangers and then communicate this awareness to the other people involved. The authors explain that a well planned process helps significantly with the identification and recognition of safety risks and that this can be communicated with for instance site managers [89].

In addition, Chan-Sik Park and Hyeon-Jin Kim highlights that 3D site models have a considerable potential to improve the identification of safety risks as well as worker's risk cognition and safety education [89]. An augmented checklist model therefore holds a lot of potential since there are many types of safety cards to identify and the surveying user can learn from this experience which can be beneficial for future events. Another good sentence to describe the self-inspection checklist with is "self-test" as Robyn R. Lutz explains that when designing for safety and focusing on hazard detection and control, self-tests are a key mechanism [90].

The safety aspect helps in a small way to answer the question *"When performing the surveying tasks, what actions can influence an augmented surveyor system in relation to the safety and efficiency of the user?"*. As the discussion and result shows the self-inspection checklist increases safety extensively and the users perceived it as an effective tool. Although the tool does not take part in the surveying of leakages out on the field, the interface helps with safety and the actions that influence this are the basic movements that are required to complete the checklist. For the second research question, *What are the essential design recommendations to establish a safe and an efficient augmented surveyor system?* the discussions also highlight that many users appreciate the essence of the tool and their comments spawned the creation of many beneficial recommendations. By viewing the guidelines of the results it is clear that many perspectives of the self-inspection checklist contribute with safety and efficiency attributes.

8.1.2.1 Expansion of the checklist Safety Cards

The cards received praise from the users and it was concluded that they contributed with safety awareness based especially on the qualitative feedback. Interestingly the second scenario was appreciated a lot even though only two cards were new and the rest had been explored in Scenario 1. Several interesting keywords were mentioned by the users when it came to the new cards for Scenario 2 and one of them was "health". This reaction from the users was positive since the second scenario was something that spawned really quickly and then the thinking process was not that effective since the student struggled with finding new good safety related items. The data from the experts helped and therefore a focus on dehydration and fatigue were explored.

As the checklist was a high-fidelity prototype it technically had the potential to include an extensive set of safety related cards. However, for the evaluation that would of course mean a longer test for the users and therefore only a few would be tested to see if the experience and connection to safety was appreciated. As safety is such a broad term it can be crucial to include multiple items that help raise safety awareness for the surveyor. One interesting thing would be to analyze the entire surveying profession and even research what requirements construction workers have and expand the checklist items based on that information. Apparently construction workers need to have and maintain a completely clear understanding of the real objects and safety hazards around them and the augmented reality technologies assist the workers in an effective way to make the comprehension precise [92]. Perhaps a safety card related to some sort of protective gloves could be a potential thing to explore if it is significant for the surveyor and their performance abilities.

One puzzling aspect with the expansion of the checklist is that it can be endless if new safety requirements are discovered after the product is released. Then the augmented self-inspection would have to be updated for the safety awareness to be more compatible with the new emerging things. Of course the discussion about what to include and how extensive the checklist should be is certainly for the whole company to discuss as there are many players involved in the creation of surveying equipment and everyone probably has their own perceptions of safety requirements. For example, do people with glasses need safety glasses on them and is that relevant since there is a screen of the augmented reality headset. This is one of the discussions that can be continued when the solution is nearing the finland development phase.

A recommendation for exploring new items to include in the checklist would be to investigate the “safety culture” perspective. For the safety culture the three major domains are “environment”, “person” and "behavior” [91]. By delving into each of these areas a larger comprehension can be established of what is involved in safety for employees and how it can be improved by considering certain things. For example, in the “environment” category items like equipment and tools are included but for the “person” category the focus is on “skills”, “intelligence”, “knowledge” etc [91]. Exploring these key areas can be critical in finding new safety perspectives, for instance if a surveyor lacks “knowledge” about the new surveying wand stick “tool”, how can this be made into a safety card for them to self-inspect?

8.1.2.2 Scenario 1 and 2 being identical in design, not in setting

An interesting observation that was actually not mentioned by any of the five participants was that Scenario 2 had the checklist being positioned vertically and the scroll navigation through the cards was performed in the vertical direction as well. The student made this decision for two reasons, the first being that the second scenario would look a bit different to indicate to the users that they are in a new setting. The second reason was that the student wanted to see the users' reaction towards a vertical scrolling of the items, as some implementations of the Carousel design pattern use vertical scrolling [81] instead of the more common horizontal scrolling functionality. The hope was that the users would give qualitative feedback on the new setting and state the obvious that the second version has a vertical checklist and then they would talk about what they think about that. None of the users did and although the positioning was not part of the exploration with the design, the student hoped that some first-time response data could be collected, for instance "I see that this self-inspection is vertical, personally I like it/do not like it because... ". This result would have been beneficial for future developers who want to explore the potential of augmented reality queues and which direction they come from on the headset display.

The design on the other hand was not changed in any new position but stayed within the boundaries of the card element. The purpose was to explore the safety aspect with the checklist design but from different settings and therefore that became the only difference between the two scenarios. The discussion that is fascinating to analyze here is should the self-inspection checklist design that is performed during the surveying activity have a more unique design. Since the checklist that is performed before the surveying is only done once, but the other checklist that is during can occur multiple times and therefore it could be beneficial to separate the two versions in order to highlight the distinction. One could argue that if the two versions have unique design then the user can learn that they are for different settings and appear for special situations. If a user sees an interface for a checklist before doing the surveying and knows that this interface will always be used for "before"-situations then the user will never have to be confused. From another perspective, having the same interface will make the user more secure and comfortable because they know how it works. The interface will be easier to memorize and to navigate through when it is the same for the entire augmented environment, which can be seen as positive. Most users want to achieve safe exploration and not get lost or get into trouble in the interface [1] and having the same design for both versions can help with this design aspect.

8.1.2.3 Signing and sending the checklist to supervisors

One of the fascinating events that happened in the qualitative evaluation was that some users expressed deep doubtfulness and indecisiveness towards the questions that reassured the user that their confirmation of the checklist would go straight to the employers or supervisors. Although the users did not react poorly to the design, they did express their disagreement with the supervisors receiving the confirmation and one of the comments was that "The responsibility is being transferred to yourself" and "I am assuming the responsibility for myself and basically it feels like the company says Ohh we're not liable anymore if something happens".

This is interesting since the student did not think about the responsibility aspect of the design and who actually has the control of the safety for the surveyor, the user or the user's employer. This whole perspective is good to analyze and discuss since the conflict can actually affect the performance of the self-inspection checklist. If a user does not want to confirm their safety to another person, but only do it to themself, then the effectiveness and functionality of the checklist could lose power when the final confirmation step comes. When developing the checklist it felt natural that the surveyor would confirm various safety related items to the people with a higher position in order for them to keep track of their employees and see that they stick to the safety recommendations. If they do wear the recommended equipment then the people in charge would have to talk with the person involved and establish why the requirements have to be followed etc. However, after the evaluation the opinions of the users weigh heavily and their reasoning is rational and logical. The employers are the people with a higher position and naturally they would be responsible for the people who are beneath them. If the employers are not responsible for the employees then the ethical and moral questions arise and there will suddenly be a lot of perspectives to consider.

In conclusion, since the research for this Thesis is about safety, efficiency and user experience the actual dilemma of who has the main responsibility when it comes to the self-inspection checklist is extremely difficult to answer. The analysis is that the data can be considered for future implementations of the project where more information is known about who would actually be receiving the checklist confirmation if the augmented system was a real product and would the supervisors have good communication with the surveyors etc. In addition, this skepticism towards the safety responsibility left a mark in the quantitative questionnaires where some of the questions suggest that a few users did not agree with the fact that they should have full accountability for their safety self-inspection and the items that are included in that inspection.

8.1.2.4 A recurring self-inspection

The negative comments received for Scenario 2 were solely focused on the fact that the self-inspection might be too recurring and frequent. When doing the development of Scenario 2 the focus was on the new setting, the fact that the checklist would be conducted during the surveying activity and no real thought was put into the occurrence of the new version. The student did however use the information from the first data gathering phase and concluded that some surveyors might work for a possible eight hour shift and then it feels natural to have the list being recurring to achieve a greater safety awareness for the user.

The comments received from the participants in the evaluation were of course respected and considered but the whole attitude towards the occurrence of the checklist felt like it belongs to a future group of developers to discuss. If the checklist is ready to be tested with a real augmented system headset then the developers could explore the cognitive aspects, for example if the visual interface makes the user's ability to function properly better or worse. Perhaps the recurring checklist would make the user feel unwell after seeing it more than five times during an eight hour shift, then the decision will have to be made that the self-inspection should be executed a limited amount of times.

As with the discussion in Section 8.1.2.3, the analysis of the checklist being too recurring or sufficiently recurring is something that can be expanded upon and seen from many different perspectives. It is an essential discussion but one that should be saved for a future implementation where the product is closer to the final stage and the effects can be measured more closely. It is good to have the data from the users, as this proves that the safety of the surveyor can be improved and increased, but the users should not be irritated by the safety solution.

8.2 Design Process

For the entire project the core assistance have been the interaction design models, especially the The Double Diamond of Design and the Interaction Design lifecycle Model. These two models were the crucial main methodologies that helped the student to see the entire process as an iterative and adjustable journey. A direct analysis of the models is that they work as powerful tools next to the designer and when a problem is difficult to solve the models can help with the structure and plan of attack for the next steps. Needless to say, the models did contribute with good assistance during several parts of the project where the process was not moving as fast as intended.

In addition, following the Google design sprint methodology model was important as the student could see the bigger picture more clearly and plan ahead what event would be in the next couple of weeks. An important discussion here is how the project would look like if only one model was followed. The general feeling is that the process of the project would most likely end up being one-sided and the student would not get any additional perspective on how to see things from another view-point. Of course this project is small in comparison to the future projects that will occur and a good analysis is that it can be beneficial to have worked with interaction design models previously.

Imagine if this project stretched over several years and the focus would be on sharpening the design of the solutions to the extreme. Then of course the first iterations would not conclude in a final design that is ready for development but the design would have to be passed through multiple iterations. Imagine if one of the iterations is exceedingly difficult and the student forgets about the theory and design recommendations then the image of the models can be crucial for the student to get back on track. Especially the models that contain arrows can help the people to see that they can go back to a previous area, correct the problems in that area and then follow the arrows to the next areas, and perhaps go back again based on feedback etc. Working with models for this Thesis project was very beneficial and essential, the experience gained will be remembered for the future.

8.3 Problem Solving

Every problem has a solution and the extensive twists and turns of the project made it essential to embrace a problem solving attitude. A good example is the surveying wand prototype, as presented in Section 6.1.1.2. of the Thesis, and this part of the project was not in the planning phase but the idea came after the student faced an unexpected obstacle. Instead of scrapping the preliminary study completely the planned phase was reorganized into a new study that had a different perspective but a really strong purpose. This kind of problem solving was beneficial for the confidence of the student as it made the process move along in a good speed and the solution to the problem was met with positive recognition.

Throughout the process it was necessary to tackle problems that surrounded planning and structure, but also the problems that occurred with the products that were being developed. Especially for the design it was good to go back to the comments of the expert users and look at the information from the data gathering phase. By doing this a greater understanding could be made about what the actual problem is and then when going to the sketching of the design the problems could be solved by finding the right solution. For the high-fidelity prototyping phase it was important to look into theoretical examples of final products in order to understand how potential solutions can look visually and graphically. Here the problems could be solved by using the extensive academic books and significant literature from online sources. Needless to say, theory helped with solving problems.

8.4 User Experience

As a focus is on user experience for the augmented surveyor project it was important to explore that particular area of the solutions. Although the main focus was always on the research connected to safety and efficiency the student chose to see the user experience as a crucial decking factor into strengthening the safety and efficiency for the surveying users. For example, when performing the Crazy 8's method the student always had the keywords “safety”, “efficiency” and “user experience” in mind when creating certain solutions. The idea for the self-inspection checklist actually came from an idea generated by thinking about the term “user experience” first and then thinking about how an interactable interface in the augmented environment could help with safety aspects.

Although user experience was not part of the evaluation it was interesting to observe the participants and how they talked about the designed elements as well as interacted with them. For instance, all of the users for the safety aspect understood the navigation of the checklist in the Adobe XD prototype and they did not click incorrectly on any element which means that the user experience was sufficient. User experience describes in essence the perceptions and reactions of a person before, during and after the use of a product, system or service [95] and this was something that was explored for both design solutions.

A lot of design patterns were considered for the behavior and cognition of the users, as the student thought it would be intriguing to explore design solutions that will enable the surveyor to think from another perspective than just locating gas and moving the stick from one side to the other. For example, Instant Gratification is a pattern used to make sure that people get immediate results from their actions and obvious entry points have to be provided to the users [1], something that was added to both the efficiency and safety aspect. For the checklist it was seen as a positive to have a checkbox that looks clear and attractive and thus it becomes a clear entry point. For the wind direction the student wanted the user to know that the minimap rotates with the POV and so for the later screen it does that and the user receives an immediate result.

A lot of analysis and discussion can be made surrounding the user experience of the design solutions. Since the reactions for the efficiency aspect were particularly poor one can argue that there are perspectives to the user experience that need to be improved and for the safety aspect one can conclude that almost no considerations are needed since the user tests of the checklist tasks went flawlessly. That being said it is crucial to remember that no direct questions were asked about the user experience of the design and then it is difficult to draw definitive conclusions. However, the final results, both the positive and negative, suggest that there are some aspects of the augmented reality visualizations that users perceive in a fascinating way and this will be important to include in future work.

8.5 Ethical Problems and Considerations

For this project there are ethical issues to consider when both working with the research and when performing evaluations. One issue could be that people with health conditions or impairments will not be able to perform the surveying the same way as other surveyor users. When designing for inclusiveness the goal will be to consider the users from the vulnerable groups and think about what current functionality with the augmented design is non-inclusive. For example, Sharp et al. explains that there are several types of impairments such as sensory and cognitive as well as situational categorizations [9]. With the current design there are no plans to include audio but if the solutions are seen from a future perspective there is definitely potential with using audio for the lock-on target indicator of the efficiency aspect. Having a danger sound when the user is nearing a petrol station can be significant and strengthen the meaning of the design. However, surveyors with sensory impairments would need another assistance and then in order to achieve good ethical levels for the design the developers would have to explore inclusive ideas.

Immersive technologies, such as augmented reality, can be used as visual aids to support environmental awareness and promote sensory substitution according to Chris Creed et al [93]. People are different and the needs of the users have to be respected and inclusiveness is paramount. Innovative solutions can have great potential and help users with cognitive impairments and neurodiversity simply by manipulating and targeting cognitive, sensory, interpersonal and motor processes [93]. The accessibility of many of the functions in the design solutions have to be reconstructed to a definitive point in order to include the many unique users.

Another ethical issue could arise when the surveying user is interacting too long with the augmented reality glasses and headset. Perhaps being frequently close to a screen would make the user feel unwell when the eyes are not seeing the real world for some time. This problem is difficult to detect and would require time and specific testing in order to see how the augmented visualizations affect certain users. In addition, the visualizations might be mentally demanding for the user and this could be an issue as well. One good solution would be to have some kind of recommendation in the system that tells the user to remove the headset if they are feeling unwell or that they should remove the headset after a couple of hours if they have been looking at augmented visualizations for a continuous prolonged time. Hurting the eyes of the surveying users is not a positive thing and can be a clear ethical problem.

An ethical issue regarding the physical effect of the augmented reality tools needs to be considered as well. Some equipment or parts of the augmented surveyor might be too heavy or strenuous over time. Of course, the weight and physical demand is something that needs to be explored over time because some users might not get exhausted by the tools until after some time has passed. Another possible ethical issue could be about the personalization of an augmented system. If a surveyor receives their own set of augmented tools, equipment and applications connected to the system then their personal information needs to be protected and should only be shared with ABB if the information is of interest to the company or if there are safety aspects that the user has to communicate. This problem could occur with the self-inspection checklist as the cards perhaps could be personalized for a specific user or that the overall interface is customized for an experienced surveyor.

With the self-inspection checklist the GDPR aspects are crucial of course when it comes to the signing of the list and the users fundamental rights and freedoms have to be protected. Therefore this will be one of the major ethical considerations with the future of the self-inspection design solution. For some users the confirmation of their safety could be a private matter and therefore the sending of this information can be seen as an attack on the users' privacy. A discussion surrounding the safety terms and the privacy terms should be established in future developments of the self-inspection checklist because the surveyor has to be safe when doing their work but of course the privacy of the individual has to be respected as well.

8.6 Future Work

There were many things in the research that could have been investigated even further and the research could have been extensive if more time was added to the project. However, due to the limitations of the structure, access to resources and lack of proper programming skills, the research focused on a smaller scale of safety and efficiency for surveying. The result that was established shows that the safety aspect was perceived in an excellent way and then of course for the future it would be interesting to precise an already perfect solution and sharpen the smaller details. The efficiency aspect was divisive and this creates a challenge to rework some of the things in that solution and a future vision could surround how to learn from the mistakes and how to transform the negative data into a definitive guideline that helps with finding a design that shows the wind directions in a flawless way and makes the interaction extremely efficient.

8.6.1 Augmented Reality headset testing

One thing that would be fascinating and beneficial to explore in the future is the high-fidelity prototypes but in an augmented reality environment instead of interactive screens on a computer. By doing this process the movements, the navigation, the perception of sizes and many other things can be explored in a scenario that is very close to the intended final product. Especially for the checklist it would be interesting to see how much cognitive effort is needed by the user and how much physical energy is needed to swipe the cards and then click on the checkbox. Seeing in action how the user acts with the solution will give the entire team a better understanding of the user experience and how well the augmented system works with an interface that is technically interacted with in the air. For the wind direction solution it would be constructive to see the users move around in a room and see that the wind is changing on the headset display depending on which direction they face. When later answering questions for an evaluation of the design in the augmented environment, the users might comprehend the solution better and express more feedback towards the user experience and their perception of the design.

8.6.2 Further Development of the Design Solutions

The design solutions have a lot of potential but of course there are always things that can be improved and sharpened to perfect the draft. Since the student now knows what the user thinks of the design the plan would be to go back to the requirements phase and then from that build up new rules to follow. By doing this step the design can be reworked in the sketching phase and the new improvements can be brought to life on paper and later worked on in a digital tool. As the four activities of interaction design are related [9], the work could then continue to be an iterative process and the design solutions could end up being further developed to a point where they are acceptable and sufficient.

Of course this would technically be easy for the self-inspection design as that was already perceived as positive form the beginning. However, since the wind direction design was poorly perceived the future work could benefit greatly from extensive iterations of the design. Perhaps instead of two scenarios the new validation would explore five scenarios and this can be crucial for the entire team as many different solution alternatives are explored and reviewed. In essence, the iterations can fix small things since there were many issues with the current designs. For instance, one iteration could solely focus on what colors to use for the different strengths of the wind in order to see what users think of the different versions. The potential in using iterations to solve problems is key, although the time and resource aspect has to be considered and therefore this is not something that can be conducted for too long in the project.

8.6.3 Mobile Augmented Reality

One thing that would be intriguing to explore is mobile augmented reality because the current system has a mobile device connected to the surveying wand. When creating the wand prototype it was clear that the mobile device has a relevant purpose in the tool and the different potentials of the screen should be explored, especially since there is not enough research on how users perceive mobile augmented reality application emotionally and this is an area that needs to be explored [94]. For the future work it would be fascinating to see if the mobile device can help with the safety and efficiency aspects in combination with the augmented reality headset. For the safety aspects it would be a significant thing to have danger warnings come from the mobile device as well as the headset display if the hazard is extremely lethal then two warnings are crucial. A lot of potential lies in the mobile device and this would be fun to investigate. For instance, the developed wand prototype can have paper screens attached to it and an evaluation could be made on various interfaces.

Dirin and Laine mentions that with mobile augmented reality the user experience design for that area is not the same as with mobile user experience design [94]. This suggests that new and innovative solutions would be needed for a development of something unique that can help the surveyor with both efficiency and with safety. The authors emphasize that with mobile augmented reality user experience design, the users will be more mentally and physically involved with the application [94]. These are things that would also be interesting to explore in a validation, for example what the participants think of design in the mobile augmented device versus the augmented reality headset system.

8.6.4 A larger Evaluation of the Design

One very interesting thing to do in the future would be to perform the user test and interviews on a larger set of people, especially real surveyors and other expert users. This would of course be extremely beneficial and constructive for the final result as more qualitative as well as quantitative data can be analyzed. Perhaps the scenarios could be expanded as well so that users walk through the design for a little longer time and then the goal will be to capture their experience of imagining that they are in the augmented environment. As there are 125 design methods in the book “Universal Methods of Design” [10] it would be both a challenge and a fun activity to use some of the more unconventional methods to see if they can contribute with a new perspective and help with collecting more data for the crucial validation phase.

9
Conclusion

The Thesis started with an ambition to explore the safety and efficiency aspects and how design could be used to both create a good user experience but also provide the surveyor with a solution that is beneficial and authentic. Throughout the project, the student learned about new areas in the world of augmented reality and the literature gave the student new insights into how previous problems have been solved and how new problems can be tackled. The evaluation and validation of the design solutions proved to be the most paramount part of the project that set in stone the essential purpose of the design solutions and how they can answer the research questions. The final results from the Results chapter painted a unique perspective on the developed solutions and the analysis of the Discussion chapter further bolstered the believableness and credibility of the design result. The two research questions of the Thesis can be concluded to have the following justifications:

- ***When performing the surveying tasks, what actions can influence an augmented surveyor system in relation to the safety and efficiency of the user?***
  The negligent actions that can lead to safety and efficiency not being respected are if the surveyors do not follow the interface and what it is trying to represent. Not following the interface or learning from it will lead to the actions not achieving proper safety and efficiency for the surveyor. Performing careless actions that ignore the guidance from the augmented system will influence safety and efficiency in a poor way.
- ***What are the essential design recommendations to establish a safe and an efficient augmented surveyor system?***
  The essential design recommendations that can be brought forward are connected to a good user experience. Having an interface that is clear, understandable and easy to navigate in is something that should be recommended for the design. Creating a simple and effective self-inspection checklist will contribute with a safe surveying experience as the surveyor knows that he or she is following the safety requirements. The surveyors can be efficient in their surveying activity when they know that the safety has been established.

In conclusion, the design solutions have a good purpose and they are simple and conventional in theory. But when they are connected to the crucial aspects of safety and efficiency the simple and clear aspects of the design can be a definitive factor. The methodology and problem solving techniques presented in this Thesis highlight how user experience design can be implemented in future augmented systems and how the solutions help with both safety and efficiency for the surveying user. The student hopes that the research can inspire future work that will focus on developing the solutions further or even take parts of the ideas and integrate them into other projects connected to augmented reality and land surveying. The result from this research is conclusively the strongest and most beneficial attribute since it will give a unique perspective on design that contributes to safety and efficiency. Most importantly that result highlights both positive reactions and negative reactions which means that future developers have an extensive foundation of data that they can iteratively work on and improve.

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A

Appendix - Evaluation Document

Surveying Experience Question:

Do you have any previous experience with surveying?

What do you know about the surveying equipment?

Are you familiar with augmented reality being used for surveying?

Start of the Evaluation Interview
During this evaluation you will be shown a scenario of a surveying activity connected to the safety and efficiency aspects. The scenario will have two solutions, meaning that you will walk through two versions of the same scenario. The versions will be presented with realistic outdoor images that represent the path that a surveyor takes during the surveying task and the augmented reality elements will be there on the screens. Some areas of the screens will have interactable elements in order for the user to progress through the realistic images . Furthermore, you will be asked to observe the screens that you see in the scenario, then we ask of you to use think-aloud in order for us to capture your perception of the design.

Scenario 1 Efficiency (Bar Chart Compass):
You are performing your surveying task out on the field using an AR system. The screens POV will represent where you are standing on the ground. A path has been provided by ABB. This specific path that you are performing your tasks on is new to you. However, as a surveyor you are aware of the dangers that can hurt you out on the field, for example explosive risks and rough terrain. Your goal for this evaluation is to observe the screens in front of you and answer questions related to safety and efficiency. When you feel finished with observing one screen then interact with the rectangular object in the middle of the screen. The rectangular object has a functionality like the navigation on Google Street view, to give you a sense that you are moving in the direction of the screens. Please use think-aloud.

Interview Questions:

Where can you see where to move in this environment?

What does the red line on the mini map represent to you?

How precise for you, is the red line in regards to navigation?

What are some easy or challenging things to identify on the mini map?

How does the mini map contribute to the efficiency of your surveying tasks?

Where is the wind compass located?

Where do the strongest wind directions come from in this position?

Where do the weakest wind directions come from in this position?

Do the wind direction indications in some way assist you in your navigation during surveying?

Do the wind direction indications help you with choosing a new position that you can survey on?

Click on the rectangular object when you feel like you have observed your surroundings and do not have any further observations.

Is there any indication on the screen that you have moved to a new position?

What do you think the red box markers are trying to highlight on the screen?

What is the difference between the red box markers and the other two augmented reality visualizations on screen in your opinion?

Click on the rectangular object when you feel like you have observed your surroundings and do not have any further observations.

Have the items on the screen changed in any way compared to the previous screens?

If yes, how does the new perspective and change of position affect the efficiency aspect when performing your surveying tasks?

Does the wind direction compass highlight for you how to be more efficient in your surveying? Explain in your own words.

What do the red box markers highlight in this screen?

How do the markers contribute to the safety aspect of your surveying profession?

In your own words, what you think would happen if you move closer the structure that the markers are highlighting? What would happen if you move further away from the structure?

Does the red box marker lock on hinder the safety aspect for you in any way ?

Scenario 2 Efficiency(Globe Compass):
You are performing your surveying task out on the field using an AR system. The screens POV will represent where you are standing on the ground. A path has been provided by ABB. This specific path that you are performing your tasks on is new to you. However, as a surveyor you are aware of the dangers that can hurt you out on the field, for example explosive risks and rough terrain. Your goal for this evaluation is to observe the screens in front of you and answer questions related to safety and efficiency. When you feel finished with observing one screen then interact with the screen to proceed to the next screen. Please use think-aloud.

Interview Questions:

Where is the wind compass located?

Where do the strongest wind directions come from in this position?

What does the grey area above the cardinal directions mean to you?

Click on the rectangular object when you feel like you have observed your surroundings and do not have any further observations.

Is there any indication on the screen that you have moved to a new position?

Click on the rectangular object when you feel like you have observed your surroundings and do not have any further observations.

Where do the strongest wind directions come from in this position?

Do the wind direction indications in some way assist you in your navigation during surveying?

Do the wind direction indications help you with choosing a new position that you can survey on?

Final Questions on Efficiency:

Does the mini map hinder the efficiency aspect in any way for you?

Do the compasses hinder the efficiency aspect in any way for you?

How do the compasses contribute to the location awareness of your surveying tasks?

How do the compasses contribute to the navigation assistance of your surveying tasks?

How do the wind direction on both compasses contribute to the efficiency of your surveying tasks?

Evaluation Safety

Scenario 1 Safety:
You are about to perform your surveying tasks and will soon leave this place to go out into the field to do your job. You put on all the required safety equipment, activate the AR system and prepare your surveying stick as well. You have everything you need to complete your surveying tasks and you are ready to begin. However, before you can start with the surveying activity the system is asking you to complete a safety self-inspection. You will conduct this self-inspection in the following step. The screens you will see are POV when you are wearing the AR headset and they can be interacted with. Some text will be readable and other text will be dummy placeholder text, in order to achieve a more immersive experience. Please use think-aloud when approaching this scenario.

Interview Questions(after interaction with checklist is completed):

This scenario has been a representation of a self-inspection checklist before conducting the surveying activity. With this perspective in mind, do you feel that the self-inspection will decrease the risk of harm and dangers for you?

What safety awareness feeling did the icons of the cards trigger for you?

Does the self-inspection procedure feel like it slows down the surveying job out on the field for you?

How do you feel about confirming your safety to the company administrators?

How do you feel about confirming it for to yourself?

Do the cards and their content increase safety awareness?

How does this version contribute to the safety awareness for the surveying activity overall?

Any other safety aspects that you can think about with this perspective in mind? How does this version increase or decrease certain safety aspects?

Scenario 2 Safety:
You have performed your surveying activity for a couple of hours. The system will now ask you to conduct a self-inspection in order to reassure ABB that you still follow the safety recommendations, even though you have confirmed it before departing to

your tasks. This will serve as check to make sure that safety is respected throughout the surveying activity. You will conduct this self-inspection in the following step. The screens you will see are POV when you are wearing the AR headset and they can be interacted with. Please use think-aloud when approaching this scenario.

Interview Questions(after interaction with checklist is completed):

This scenario has been a representation of a self-inspection checklist during the surveying activity. With this perspective in mind, do you feel that the self-inspection will decrease the risk of harm and dangers for you?

What safety awareness feeling did the new icons of the cards trigger for you?

Does the self-inspection procedure feel like it slows down the surveying job out on the field for you?

Imagine you are surveying for a full eight hour work day. This checklist procedure during the surveying activity is recurring, how does that affect your safety awareness?

How do you feel about confirming your safety to the company administrators?

How do you feel about confirming it for to yourself?

Do the cards and their content increase safety awareness?

Imagine if you are doing this check at a secure position out on the field. Do the sizes of the cards affect your field of view in an unsafe way or affect the orientation of your position?

How does this version contribute to the safety awareness for the surveying activity overall?

Any other safety aspects that you can think about with this perspective in mind? How does the version increase or decrease certain safety aspects?

Final Questions on Safety:

You perform a self-inspection before and during a surveying task. What does that mean for you in regards to safety?

How do the checklists affect safety awareness for you?

Do you see the safety self-inspection as a tool or as an instructive guideline?

Does the self-inspection hinder safety awareness for you in any way?

How does it feel to confirm your safety via AR, compared to for example a physical paper checklist or in a mobile application?