UiT The Arctic University of Norway

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VR in Risk Communication

Investigating sea level rise risk communication amongst stakeholders

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Abstract

The use of VR in research is growing, but lacks study in diverse cases. Specifically, investigations into VR as a tool to foster risk communication is scant, but increasingly relevant. As the sea level is predicted to rise in Tromsø, it is an example of a temporally distant but nonetheless impending risk with relatively little current attention. With focus on this risk as a case study, this project explores if and how VR impacts risk communication differently between stakeholders. The three stakeholder groups investigated are municipal planners, local business owners and citizens. They are interviewed about their risk understanding and risk perception after using a 2D map and a VR simulation of predicted sea level rise and storm surge risks in Tromsø in 2090.

The findings show many differences between individual interviewees, with some common factors emerging between the stakeholder groups. Citizens are most impacted in terms of their perception and understanding, as they sense little control over the risk. The local business owners have diverse responses, have the most vulnerable stakes, but show relative little concern. Municipal planners are the least impacted, as they have a prior established and solid understanding of the risk.

Keywords

Virtual reality, sea level rise, risk, risk communication, stakeholder communication,

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1 Introduction

Technology develops at an ever accelerated speed, leading to a constant feed of improved products. The spatial planning industry is certainly benefiting from the various new tools for analyses, mapping, simulating, and so on. The advance of these planning support systems is now at such a pace that both theory and practise perpetually experience new systems to explore, at a speed faster than researching these tools can keep up with. These emerging products and functions are a constantly renewing field full of potential. With this in mind, and with a strong personal interest in urban planning communication, this thesis aims to pursue studying a new planning support system within spatial visualisation.

Despite not being a literal new technology, it is only as of recent that Virtual Reality (VR) has developed to a degree of being commercially available. It has become a growing tool within multiple industries, including as a support system within urban planning (Jiang et al., 2023). Diverse projects within planning may involve collaboration between multiple actors and stakeholders, where VR can strengthen the communication of spatial elements through immersing the user within a virtual space. The tool is established within urban planning practices to generally aid in participation, engagement, and understanding across various cases (eg.; Jamei et al., 2017; Jiang et al., 2023; Van Leeuwen et al., 2018). However, due to fast paced development and its relatively recent widespread accessibility, studies and practises are missing in more diverse cases. There is a lack in empirical studies of various aspects of the tool's usefulness within different parts of the planning process (Meenar & Kitson, 2020; Van Dessel, 2019). General positive attributes and potentials are established, yet the nuances of the different possible variables and planning stages require more attention to clarify how and when VR is applicable within a process.

There are multiple possible purposes for a 3D visualisation to be relevant to urban planning. One spatial element less researched in relation to VR however is that of risk communication. Many potential risks can influence the spaces people use and live in, and awareness of these risks are relevant to inhabitants and planners. This awareness (or lack thereof) may require attention. For example, with emerging, temporally distant risks which do not feel pertinent to those it affects would be a highly relevant case for increased attention on risk communication. Holding conversations about impending risks, risk perceptions and risk understanding can contribute to an overall better understanding of creating safe places. This leads to the question however of how to approach this communication, and the potential of new planning support systems such as VR in contributing to these conversations.

Furthermore, communication requires the exchange of information between different parties. Who the relevant audience is within a risk communication project plays a role in the use of the supporting systems. Prior studies have tested VR in cases that focus on one specific audience, yet rarely compare the stakeholders relevance and impact, studying a group as a monolith. As such, this research project aims to investigate the risk communication potential of VR amongst different relevant stakeholders.

To address this aim, as well as the relevant research gaps of lacking empirical studies, this project is based around a specific case. There are many potential risks with different stakeholders VR could address. Hence, it is to be narrowed down through an ongoing project to base the study within a realistic scope and relevant urban risk.

1.1 Torghuken case

Specifically, this paper will focus on one of the ongoing projects by the company *Tromsø Havn* (Tromsø Havn, 2024) which is working on a plan on developing a section of Tromsø's inner harbour, henceforth referred to the *Torghuken* area or case (Figure 1.1). The area is furthermore relevant to the upcoming risks of rising sea levels, being a harbour construction.

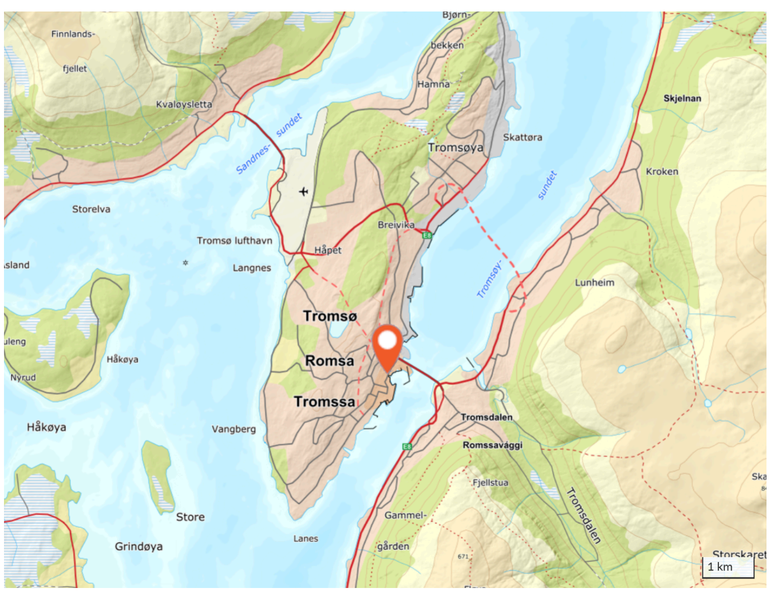


Figure 1.1 - Location of Torghuken (Norgeskart, n.d.)

As elaborated by project participants in the Nordlys news article by Olsen (2023), the inner harbour has been described as the least active amongst Tromsø's 3 main harbour areas. The 3 harbours are split between purposes for small, medium and large boat traffic. This specific harbour mostly holds functions for tourism and leisure. One of the existing docks is to be replaced with another floating dock. The aim is to create stronger cohesion between the floating dock, the Torghuken area and activities both in the water and on land, and promote traffic for smaller boats.

At the time of this thesis, Tromsø Havn has finalised a proposal, and plans to initiate construction by summer 2024 (Figure 1.2). As a part of the process, neighbours have been informed of the project and been given the opportunity to raise questions and/or concerns. Different risk considerations have gone into making the design a safe platform for use. In regards to the future sea related risks, the only implementation is the attachments for the docks allowing the surface to move up and down with the water in regards to future changes. The life expectancy of the project is 50 years.

This paper will not be working with the project as it progresses, rather it will use the existing plan as a starting point with relevance to a growing risk in Tromsø. Furthermore it is a real, ongoing planning case, providing a more grounded starting point for investigating communication within a planning project in comparison to creating a fictional case.

Figure 1.2 - Proposed new harbour (highlighted in light green)

1.2 Brief Tromsø climate context

As will be further explored in the chapter 2 literature review, there are a multitude of relevant studies regarding stakeholder and risk communication, and the impact of VR. However case studies will always be contextual, and this case is located in a frequently under-studied sub-arctic environment. The project takes place in northern Norway, on the island city of Tromsø. With 3 main ports in the city centre and more located around the island, the area experiences much sea and shore traffic. The ports are relevant to the tourism industry, transportation but also to the identity of the city. The view of and connection to the water is a prominent element to be nourished. This creates a conflict however with projected climate change. Despite the rise in sea level in the coming century not being of great concern on its own in Norway when balanced out by the rise in landmass, the storm surges and weather changes that accompany it are. The current prevailing communication method for sea level changes and storm surge risks is through Norway's National mapping authority, *Kartverket*. The institute provides live data on different locations, as well as an interactive map with predicted sea level and storm surge impact changes until 2090, including the project area as shown in Figure 1.3 (*Se Havnivå i Kart*, n.d.).

Furthemore, Tromsø experiences relatively extreme high and low tides, ranging between roughly 2 metres throughout a day, with the potential to range closer to 3 metres (*Se havnivå, tidevann og vannstand*, n.d.). This leads to an already existing awareness of having to account for such water level changes.

The risk and case study in question are inherently tied into various climate change consequences, which impact the arctic environment differently. Arctic regions are known to experience a rise in temperatures threefold to that of the rest of the world, leading to disproportionate precipitation, snow melts, and importantly: more uncertainty (Einangshaug, 2023). This is not to state that Tromsø will experience a disproportionate sea level rise, rather that general climate change consequences will be more unpredictable, and the accompanying insecurity could have implications on stakeholder’s risk perceptions. This thesis does not focus on the ramifications of the risk and how to tackle it specifically, nonetheless a risk that is tied into this sense of an uncertain future may be important to consider when studying the communication of said risk.

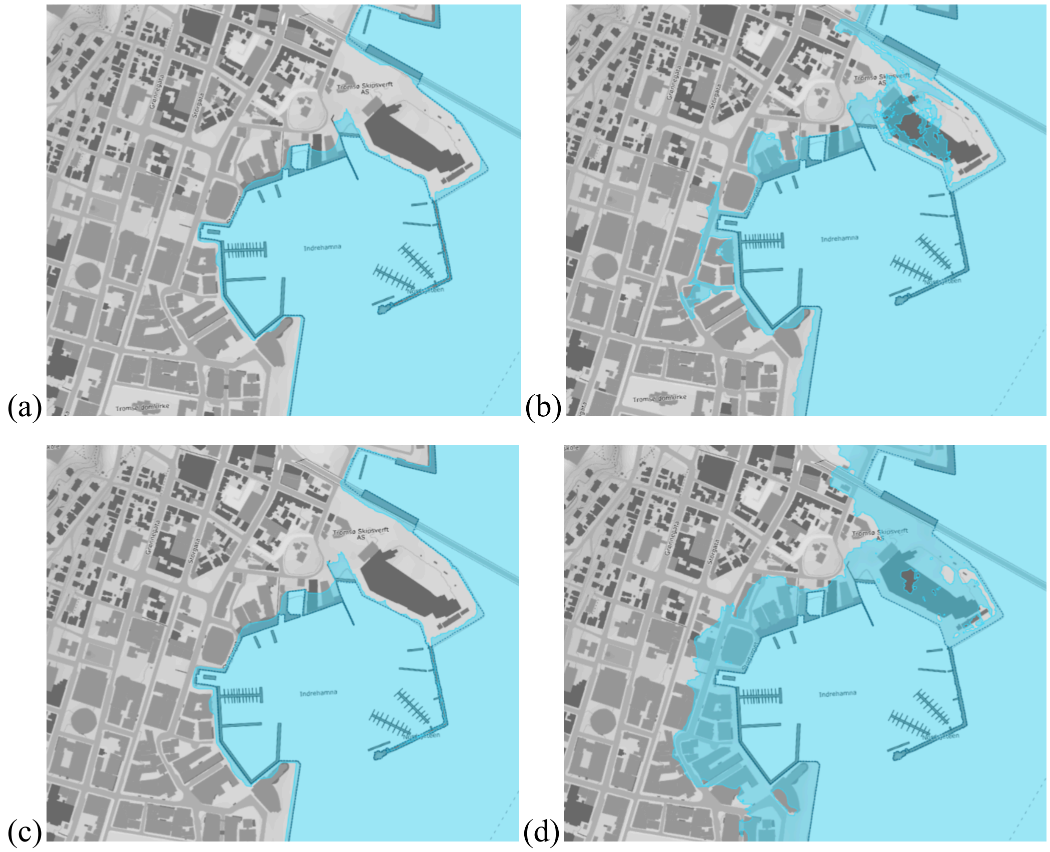


Figure 1.3 - Kartverket's "havnivå i kart" of the Torghuken area showing: (a) current sea level, (b) 200 yr storm surge, (c) 2090 sea level projection and (d) 200 yr storm surge in 2090 projection (Se Havnivå i Kart, n.d.)

1.3 Problem formulation

In summary, this study will investigate the potential of VR in communicating a specific, distant spatial risk to different stakeholders within the scope of an ongoing harbour renewal project (Figure 1.4).

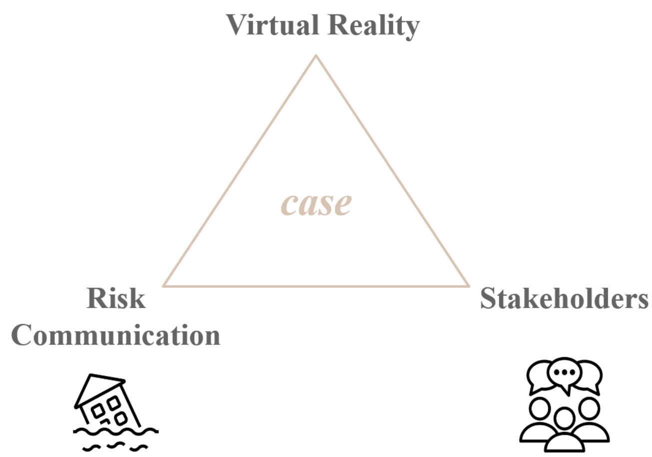


Figure 1.4 - The 3 main concepts of the study, tied together by the Torghuken case study

These concepts are tied together into the following research question:

Does VR differently impact risk communication between urban planning stakeholders?

Impact in this question will refer to changes in the stakeholder's risk perception and risk understanding. These concepts will be elaborated on further throughout the study. Furthermore, three stakeholder sub-groups will be further investigated in order to clarify and limit the scope of the project to more accurately address the main research question. Hence, the sub questions:

- What is the impact of using VR for risk communication with local business owners?
- What is the impact of using VR for risk communication with municipal planners?
- What is the impact of using VR for risk communication with citizens?

This thesis builds on, and is supervised by two members of a prior project by the IMPETUS team at UiT (*IMPETUS*, n.d.). This project simulated future sea level risks in VR, to be presented to mayoral candidates, as well as to a design and architecture association in Tromsø. This thesis expands on the original project by investigating the impacts across stakeholders in relation to a specific planning project. The above introduction gives an overview of the overall aim, where chapter 2 (literature review) and chapter 3 (theoretical framework) will provide a basis for delimiting the scope. Based on this background research, terms will be defined more clearly within the confines of this project.

2 Literature review

In order to more clearly delimitate this thesis, an initial review of existing literature is conducted. This section outlines some established work and their findings regarding the relevant concepts to then further define the project aim and how to execute the research. The review will delve into the history and current relevance of VR, risk and communication to the field of urban planning.

2.1 Virtual Reality: definition and review

2.1.1 Brief history

Virtual Reality (VR) is not a tool with a single method of execution, and hence difficult to strictly define. In most cases it comes down to being an immersive, computer-generated environment that can be experienced through the use of some form of equipment (Portman et al., 2015). Commonly, this equipment is a Head Mounted Display (HMD), aided by controllers, sensors or further tools. VR simulations can also take the form of immersive rooms or other equipment aside from HMDs. VR simulations, unlike other 3D environmental and interactive visualisations, are designed to play to the user's senses, making it appear as though one is within the environment. Level of interaction and senses involved varies.

VR is acknowledged to originate from the 1960s, slowly evolving and gaining traction within industries and research through costly equipment and set-up (Wohlgenannt et al., 2020). Research on the potential and use of VR in urban planning have become more prevalent since the early 2000s. Despite VR technology being available for a longer period, considering the rate at which the technology develops much of early VR is not comparable to what the technology can do today. VR headsets became commercially available through the early 2010s, and has since grown in accessibility and in terms of what it is capable of. It has become higher resolution, faster, more lightweight, wireless, affordable, immersive and so on. This has fundamentally changed both the cost of using VR as well as impacted its experience. As such, this paper will place more emphasis on recent studies conducted within the past decade for relevance.

2.1.2 VR in urban planning

VR is a growing concept in urban planning studies. The process of planning requires the imagination to create said spatial plans, and subsequently the communication of these imagined plans for troubleshooting, assessing and decision making. Hence, the communication of these potential spatial scenarios — often presented in 2D maps — are of great importance in the process where VR is an increasingly common tool applied in research and practice. Audiences may face barriers to understanding spatial planning proposals or changes due to reluctance of reading long reports or lack of map-reading skills (Ernst et al., 2021). Efficient visualisations are intended to bypass barriers of understanding depending on audience and context, by making information more easily digestible, which an immersive simulation can provide. VR has for example been used in encouraging public participation and engagement (e.g. Schrom-Feiertag et al., 2020), for planners to collaborate on planning proposals (e.g. Yao et al., 2005), for raising awareness (e.g. Dhunnoo et al., 2023) for stakeholder consultation (e.g. Jiang et al., 2023), and so on.

Studies using VR as a method to answer a research question or study a case are more and more prevalent (e.g. Kim et al., 2020; Silvennoinen et al., 2022; Winkler et al., 2018). However, these do not tend to place much focus on studying the technology itself, rather using it as a tool. Studies that investigate VR as a method within planning are slightly less common. Portman et al. (2015) wrote one of the more influential papers exploring VR within architecture, landscape planning and environmental planning. Referring to these different disciplines as having inaccessibility to certain realities. They note the strong potential of modern VR tools to visualise an environment that is temporally or spatially distant. Furthermore, the potential of VR within both landscape architecture and environmental planning is said to be especially useful in stakeholder communication, fostering stronger information sharing. This is also noted in relation to communicating climate change effects and visual impact assessments. However, this is further elaborated to require a strong basis in science, with the visualisations needing to be able to be defensible and credible.

When focusing on studying VR in planning in particular, there are a few studies emphasising on the tool's potential in public participation processes. The conversational element in planning is a prevalent emphasis, as VR is foremost a visual communication tool in planning. In different case studies, VR is described to be able to empower citizens (Van Leeuwen et al., 2018), allowing stronger two-way communication with non-expert stakeholders (Imottesjo & Kain, 2022). Meenar & Kitson (2020) note the difference between an interactive visual experience and a 3D visual accompanied only with verbal presentations in public participation. The former is described as having increased participation, memory recall and emotional responses, highlighting the impact of combining senses. Kim et al. (2020) investigate public square preferences using VR as a tool, taking note of the general European focus in urban research and the lacking in other cultures. This is further applicable to VR focused urban studies, as they may be scant yet are also geographically concentrated.

2.2 Risk communication

Risk communication, as insinuated, refers to the communication of current or potential risks with a non-expert audience (Covello et al., 1989). Ensuring clear communication is one of the main challenges regarding risk management, as all involved parties need to understand the implications of both a risk and potential adaptive measures (Jude et al., 2015). It is a broad field requiring interdisciplinary perspectives and is often considered in relation to health, safety and environmental risks. As it is such a complex and long standing concept, what it entails and how to approach it has changed much over time. Addressing risk communication is inherently tied to what risks are pertinent at the time, as well as our understanding of said risks (Balog‐Way et al., 2020). Hence, as one field develops so does the other. For example, cyber security is a risk appearing only with the large-scale introduction of technology for personal and professional use. Climate change can also be seen as a (relatively) recent risk. Nonetheless a few common principles have been developed in regards to the communication of risks. This brief literature review will focus on environmental risk communication literature, some established principles regarding the communication and any literature relating to sea level rise risk communication in particular.

The people involved within a risk communication process are an integral part; the experts, the authority or company in question and the public are highly relevant pillars to the field of study. Community engagement is therefore a significant element, and understanding the different groups within a community is a part of the process. Hence, this section will combine the two concepts of risk communication and stakeholders from chapter 1.3. Furthermore, this topic is not as dependent on recent research as a literature review on VR is.

2.2.1 Environmental / climate change risk communication

Studies and literature regarding how to approach environmental risk communication are extensive. Covello et al. (1988) note in their early works on risk communication that governments often express frustrations at perceived incorrect understandings regarding a risk from the public. Equally, the public may express frustrations at the lack of actions taken towards what they perceive as risks. This leads to an importance of communication between parties on differing perspectives and understandings, (authority, expert and public groups) to both strengthen all groups abilities to adapt and/or minimise the risk. Participation and inclusion of relevant stakeholders then becomes a significant aspect to tackling risks. WHO (World Health Organization, 2017) also provides a guide on how they handle health risks communication, stating the aim of the guide to ensure trust between parties, clarify uncertainties and engage affected groups in the case of a sudden emergency risk.

Environmental/climate change risks in particular face some unique challenges. Many of the related risks are both gradual and temporally distant. The risk considered for this thesis for example is not one that would appear significant for at least a few decades. This does not mean it is not significant however, but temporal distance fosters psychological distance for stakeholders (Covello et al., 1989; Poortvliet et al., 2020). Climate change is also noted to be a politicised topic, which is known to require collective action to mitigate or adapt to. If the risk can only be addressed by unified action, a singular person might feel powerless, fostering a larger psychological distance for some stakeholders. Furthermore, climate change scepticism is a unique barrier. Despite a strong and growing scientific consensus regarding the changing climate and many of its consequences, denial or heavy scepticism of the concept is generally high and in some cases growing (Berger & Wyss, 2021). A lack in belief of the risk leads to a weak risk understanding and perception, which then in turn leads to a lack in action taken by said stakeholders.

The above barriers are both reasons as to why environmental risk communication is difficult, as well as why it is needed. General environmental literacy is lacking, and in need of strengthening through risk communication (Calil et al., 2021; Poortvliet et al., 2020). In order to do so, the communication needs to consider a few elements to tackle the barriers. Poortvliet et al. (2020) research the IPCC's risk communication to policy makers and and the public, evaluating it based on how well the report communicates the threat, its efficacy and psychological distance of the threat. They found a significant lack in communication of potential solutions and that the information tended to be more abstract than concrete. They note the importance of including goals and graspable adaptations within the communication. .

When emphasising a problem, and communicating a risk it should be noted however that a main principle within the field is to balance the emotional response. Too much negative information may not lead to anything productive except for excess worry, fear, rage and/or anxiousness (Covello et al., 1989). Furthermore, risk communication requires thoughtful emphasis, as increased communication about less pertinent risks may take important resources as attention away from other, more impending risks. Risk communication within a field, such as environmental risks, are intended to increase awareness and discussion around the more significant risks, reduce outrage, and assist in a productive outcome where the involved parties can to some degree take actions.

2.2.1 Sea level rise risk communication

Although flood and water related risks are a large and significant topic of study in many areas, it is a more particular and narrow topic than that of overarching environmental risk. Nonetheless, there exist a notable amount of studies from various locations investigating how groups perceive and understand flood / water risks. Specifically, sea level change risk perception studies focus on varying elements that can impact communication, often based on the positioning of the audience. For example comparing expert and public perceptions (e.g. Thomas et al. 2015), socio-economic factors (e.g. Harvatt et al., 2011), risk knowledge (e.g. Covie & Cain, 2016), etc. Although there is notable variation amongst location and context, some patterns emerge amongst perceptions that lead to recommendations on what to communicate or emphasise. As mentioned previously with overall climate change risks, sea level change is very commonly seen as a risk that is both far away in location and time. Many studies find high awareness about sea level rise as a problem that is happening, but partially due to its slow rise it is commonly seen as a problem that is happening to others or will never affect them (Harvatt et al., 2011; Thomas et al., 2015). Another common barrier is in regards to who is seen as responsible for the risk as well as an overall large amount of negative feelings. Thomas et al. (2015) who study perception of sea level change risks further find that people tend to feel detached from the topic. In their case study people saw the risk as something that would happen to people elsewhere, and something they had no responsibility for. This leads Thomas et al. (2015) to recommend communication have emphasis on urgency.

Covi & Kain (2016) conducted a study which could be interesting for comparison. Their research focuses on sea level rise risk communication between different groups in California. The risk discussed is to some extent comparable to the sea level rise risk studied in Tromsø. However the context and consequences of the sea level rise are notably different. Covi & Kain (2016) also place emphasis on the importance of emotion in effective risk communication, as the aim of the communication is not only conveying accurate information and better understanding stakeholder's perspectives, but to increase awareness and encourage taking action. Their findings categorise the audience by mostly demographic factors (Age, gender, political views, ethnicity…) when evaluating sea level rise communication.

2.2.2 Risk communication and community engagement

An increasingly significant concept and tool within climate change risk communication is that of community engagement and participation. Although not a direct requirement for risk communication, it can both serve as a powerful tool as well as an intended outcome of said communication. To communicate information about a risk effectively, making use of engaging tools and participatory projects can increase understanding, recall, and stimulate further discussions between parties (Meenar & Kitson, 2020). This is reflected in section 2.1 which makes note of the amount of studies investigating VR as a tool within participatory planning.

Jude et al., (2015) intriguingly do an extended project regarding the communication of coastal changes through more realistic visualisations. Specifically they note GIS output to have a barrier for people who are not as familiar with reading maps, hindered by the highly technical output. They find the need for clearer communication to audiences of different backgrounds and levels of understanding. Furthermore, they note the difficulty in communicating uncertainties as a part of informing stakeholders of the expected coastal changes.

Aside from the contents of the contents of visual information, the execution of the risk communication is further relevant to engagement. It can for example take the form of an informative website, survey, or workshop as shown by Dufty et al., (2012) who evaluated community engagement with sea level consequences in coastal communities in Australia.

Through these methods they find the public expresses a strong desire to have more involvement in the adaptation process, even a fear of being excluded.

2.2.3 VR in sea level risk communication

As stated prior, VR has been studied for its potential for community engagement. As such, it is likely to have potential in increasing engagement within risk communication as stated to be relevant in the previous section. Research regarding VR for engagement in sea level rise risks however is far more specific and hence scant. Nonetheless there are a couple notable studies which have an overlap in concepts to the aim of this thesis.

Dhunnoo et al. (2023) write an article most akin to this project regarding risk communication. With the intent to study creating climate change awareness to communities, the paper creates an interactive VR model showing a recreation of a flood that occurred in 1974. The model is presented to a number of *expert interviews*. Dhunnoo et al. (2023) justify the project due to the difficulty in creating awareness of risks far away temporally, as well as to test 3D visuals against the more common 2D visual communication. Although there are notable differences in the execution of the paper in comparison to the aim of this project, the outcome of the study would prove an interesting comparison to the results from this Tromsø case study.

Another highly relevant project is that of Calil et al., (2021) who study VR as a tool for environmental education regarding sea level rise within North America. They make note of the lack in both ocean and general environmental literacy, where VR can be a tool to address this. Furthermore they note the impact of direct experiences with hazards (e.g. hurricane Irma) decreasing denial or scepticism around climate change causing increased disasters and hazards. Their findings note significant potential for VR in education, being shocking, immersive, and overall being efficient in triggering discussion, reflection and engagement. Calil et al. (2021) also make note of the lack in comparisons of VR as a communication tool to other existing tools.

3 Theoretical framework

Beyond the established works and findings highlighted in the literature review, this chapter aims to establish relevant theoretical perspectives to form a framework that can ground the method and discussion. By exploring theories on different communication means in urban planning and beyond, the concepts are to inform how to approach data gathering and analysis. For risk communication theory in particular there is a long academic record of developing theories and perspectives.

3.1 Risk

Risk, risk perception and risk communication have a significant and intertwined presence in research. The concepts have become especially more prevalent within academia in the past half century, providing foundations for a number of perspectives (Covello, 2021). The following section will lay out the development of the first of these terms; the meaning of *risk* and how it can be approached in this study.

3.1.1 What is risk?

First and foremost, the term *Risk* requires further insight. Risk, in this project, is seen through a social sciences lens. As such, the concept of risk is considered to be a social construct, with no established strict definition. Risk in its simplest form has frequently been described as the product of probability and consequence. In earlier discussion of risk, it has been described as a quantitative factor to be evaluated by various engineers (Sommer et al., 2020). Often it was studied in relation to health, safety and the environment, however over time the scope has broadened significantly (Covello, 2021). It has become more acknowledged that more factors beyond calculating probability and consequence go into determining various risks. Furthermore, what we consider as prominent risks develop over time. Relatively, the risk of climate change is a new one due to intense human-caused pollution and land use. With the concept being so dynamic and changing over time, so does the academic understanding develop. It is considered to be dependent on people's perceptions as well as the risk's context, as it is now more frequently described alongside its uncertainties, and to be studied qualitatively.

3.1.2 Risk evaluation model by Sommer et al.

Sommer et al. (2020) have, in their book *emergency training and learning,* merged a number of existing risk models into an overarching model on understanding risk. This model is intended for understanding a risk and evaluating it. This thesis paper is not aiming to evaluate the urgency or mitigation of the risk in question, but the communication means. Nonetheless the model can aid in setting up a framework of understanding risk to study how different stakeholders evaluate the risk, and hence how VR could highlight these different elements.

The model combines 3 prior risk models, including the 3-factor model and 2-factor model. The 3-factor model describes risk as the relation between a threat to a given value, and said value's vulnerability to the threat (Figure 3.1). The 2-factor model is the previously mentioned definition of risk being the product of probability and consequence. The more likely the risk is of occuring, and the more negatively impactful the consequence the higher the risk is (Figure 3.1). These two models are merged, after defining the following included factors: value, threat, vulnerability, probability and consequence.

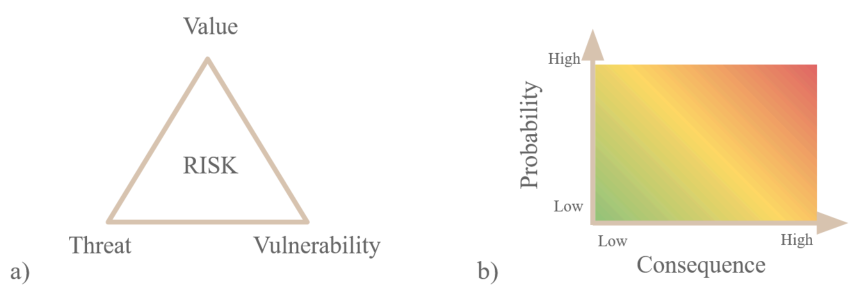


Figure 3.1 -Translated from norwegian, (a) three-factor risk model and (b) two-factor risk model (Sommer et al., 2020)

Value relates to resources which if exposed to an unwanted force would lead to a negative consequence to the owner, manager or stakeholder of the resource. The value can be health related, environmental, monetary etc. Value is a dynamic factor, changing over time and between individuals. When at risk, a value is under a *threat* which places the value in harm's way. Threats also change over time. *Vulnerability* is the lack of ability to hinder an unwanted scenario (i.e. the threat impacting the value). A system can range between being vulnerable, robust or invulnerable. This factor can be actively changed, for example simulated emergency training can be a tool to evaluate a system's vulnerability and how well a value is protected against a threat.

These three factors are described as relatively more concrete, and more measurable than the 2-factor model. Value, threat and vulnerability can be given rough measurements (eg. low, medium or high value to a target group) however probability and consequence are more difficult to measure, holding more uncertainties. Hence, Sommer et al. (2020) bring in the factors of *knowledge* and *control.* The probability of a risk is decided based on our collectively available background knowledge, and hence to evaluate a risk it is important to consider how much is collectively known and unknown. The stated probability of a risk is a knowledge-based probability. When something concrete can be said about the knowledge available, then one can also evaluate what the uncertainties are related to the risk. Sommer et al. (2020) define strong, weak and medium background knowledge based on a few criteria. Additionally, they define control based on how accessible it is to change the risk in a system. For example, are there effective risk mitigation or adaptation measures available and are they easily implemented? Can they impact the value of a resource, the presence of the threat or the vulnerability of a system? The above briefly summarise the factors included in the final model they present (Figure 3.2).

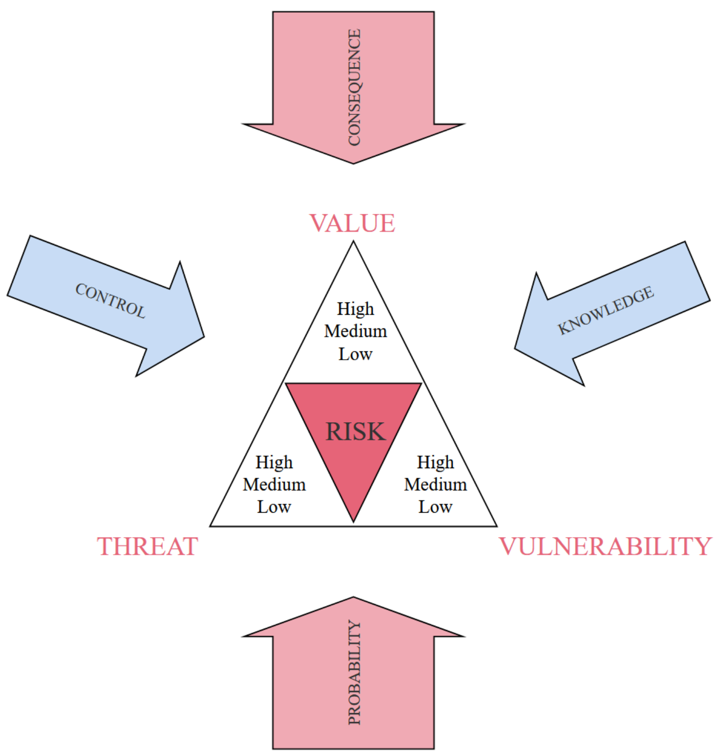


Figure 3.2 - Sommer et al. (2020) model for understanding risk (translated from norwegian)

Sommer et al. (2020) emphasise the factors included are not to be studied quantitatively, rather that their model is a checklist of factors to consider and to investigate under a qualitative nature. As stated, the intent of this thesis is not to evaluate the scale and nature of a risk, but the communication of said risk. This model is seen as a tool to investigate how some of these factors will differ between stakeholders, and whether the communication through VR impacts these factors.

3.2 Risk communication

Having covered a framework for evaluating a risk, the next section will describe relevant theories to risk communication, as well as delve further into what it is.

3.2.1 Risk mental modelling protocol

As it is a social construct, what a risk means will also vary between individuals. This can depend on their experiences, proximity to said risk, exposure, culture, awareness and more. People will have different perspectives, leading to diverse risk perceptions. Fischhoff et al. (1993) investigate a large number of risk perception and communication works, summarising their approaches and methods in their paper. Amongst their findings is the use of mental models to map out peoples risk perceptions. People have their own intuitive theories on a risk's sources, accumulation, and impact. Technical errors, or 'bugs' in these mental models can then lead to people forming misconceptions. In order to capture a person's mental model, a few approaches are noted which involve encouraging participants to share as much of their knowledge regarding a risk as possible. Subsequently, the researcher should prompt the participant to share their perspectives on mitigation, location, effects of exposure and so on. The researcher, throughout the process must not confirm or dispel their knowledge, be it misinformation or not.

The above is a protocol to ensure clarity on the user's perspective, which is seen relevant to reaching the aim of this project. Despite a risk perception mental model never being able to represent an individual's 'true' mental process, it provides insights as to what is important to said individual. A mental model as created in Fischhoff et al. (1993) collected works is outside of this project's scope, nonetheless part of the protocol is expected to be applicable in the method to determine the participant's risk perceptions.

3.2.2 Risk communication theory

Based on the book chapter by Vincent Covello (2021) which provides an overview of different aspects of risk communication, the theory is built on four foundational theories; Trust determination theory, Negative dominance theory, Mental Noise Theory and Risk perception theory. The following section will summarise the basis of these fundamentals.

The first point, *trust determination theory* states that trust is the most crucial factor to risk communication. The more a person has trust in the source of the information the more weight the communication will hold. Trust is built up on a few elements; If the messenger showcases empathy, care, honesty about shortcomings, competency in the field and some other factors, trust increases and the impact of risk communication does as well. Especially when a group is previously upset regarding a risk, trust needs work and time to be built up to foster efficient risk communication. Upset actors will inherently distrust the messenger more than otherwise.

Second, *mental noise theory* finds that individuals under higher stress process less risk information. The 'noise' of the stress reduces tendencies to take in, digest and remember the information relevant to a certain risk. This is more so relevant to adjusting risk communication methods to the stress level of the recipient, rather than considering the stress-inducing potential of a communication means.

Third, *negative dominance theory* states that negative information holds more weight to people under stress than positive information. This insinuates that stakeholders under some level of stress regarding the risk should not be given excessive negative communications, as they are innately under further emphasis already through negative dominance. Elaborating on this specific fundamental theory, it is an example of the importance of interdisciplinarity of risk communication. The concept of *negativity bias* originates in psychology, referring to an imbalance in how people process negative and positive occurrences. Rozin & Royzman (2001) elaborate on negativity bias by suggesting there are four ways it can manifest, with one being *negative dominance*, where "*combinations of negative and positive entities yield evaluations that are more negative than the algebraic sum of individual subjective valences would predict*". For example, if it takes 5 positive events to balance out one negative event, that is an example of negativity dominance. Alternatively, if losing 1000 NOK is worse than winning 1000 NOK, despite the two occurrences having the same monetary value, the former outweighs the latter in terms of the intensity of how we respond. Hence, it will take more positive events total to outweigh the negative, which carries over to risk communication. Risks are inherently negative, and overwhelming negative information will then overshadow positive, or hopeful information.

Lastly, the fourth fundamental consideration has to do with *risk perception*, and the subjective, personal nature of how individuals see risks. Relating to its difficult definition and acknowledging there is no objective risk in social science means that a number of personal factors will form how a person perceives risk, and hence how to approach communication. This can form what risks or elements should be brought to a person's attention. What risks may need more or less emphasis in a discussion, or are misinformed in relation to the scientific consensus at the time. Covello (2021) summarises 20 factors said to impact risk perception, interlinked with the previous 3 theoretical concepts. Figure 3.3 shows a summary of said concepts from his book.

Factor	Conditions associated with higher perceived risks, increased concerns, greater fears	Conditions associated with lower perceived risks, decreased concerns, and greater fears
Trust	Lack of trust in responsible persons	Trust in responsible persons
Voluntariness	Involuntary/coerced/imposed	Voluntary/chosen
Scope/catastrophic potential	High catastrophic potential	Low catastrophic potential
Familiarity	Unfamiliar/exotic	Familiar/routine
Understanding/visibility	Invisible/mechanisms or process not understood	Visible/mechanisms or process understood
Uncertainty	Effects and outcomes unknown or uncertain	Effects and outcomes known
Controllability (personal)	Effects and outcomes uncontrollable by the person	Effects and outcomes controllable by the person
Effects on children	Children specifically at risk	Children not specifically at risk
Effects manifestation	Delayed effects	Immediate effects
Effects on future generations	Significant threat to future generations	Little or no threat to future generations
Victim identity/specificity	Identifiable and/or specific person or victims	Nameless, faceless, or statistical victims
Pleasurable/dreaded	Outcomes and effects not pleasurable/dreaded	Outcomes and effects pleasurable/not dreaded
Awareness/media attention	Much awareness/media attention	Little awareness/media attention
Fairness/equity	Inequitable distribution of risks and benefits	Equitable distribution of risks and benefits
Benefits	Unclear benefits	Clear benefits
Reversibility	Effects and outcome irreversible	Effects and outcomes reversible
Personal stake	Direct and significant perceived personal risk or threat	Little or no perceived significant personal risk or threat
Nature of evidence	Evidence from human studies	Evidence from laboratory studies
Morality	Immoral/callous/unethical	Moral/ethical
Origin	Caused by human actions or failures	Caused by acts of nature or God

Figure 3.3 - Risk perception factors as summarised by Covello (2021)

3.2.3 Reflecting on risk communication

For long, the correct communication of risk was perceived as a requirement to inform the public of the scientific status quo so they subsequently make the right, informed decisions. The approach to public engagement in various social sciences has since changed to be more two-sided, as opposed to one (usually governmental) party informing the other (Mabon, 2020).

In different disciplines, the public was viewed as a recipient of information in regards to risk communication. However, as Mabon (2020) develops in their study on accessible climate information services, there has been a growth in interest on how risks are perceived by differing public groups and how they can be responded to. This has led to a growth in two-sided dialogues, with scientific knowledge and subsequent risk communication being perceived as a product of the dialogues. Not only is there knowledge to gain and communicate to the public, but the public's risk perceptions and experiences are knowledge sources in themselves.

This is further emphasised in the book chapter by Covello (2021), who outlines a few principles in risk communication, including listening to the audience and not to make assumptions on what the recipient knows or wants. Listening to the audience is informative to the messenger, who gets the opportunity for feedback and to evaluate the factors of perceptions as mentioned before. What are the audience's risk related stress levels? What source does the audience have trust in?

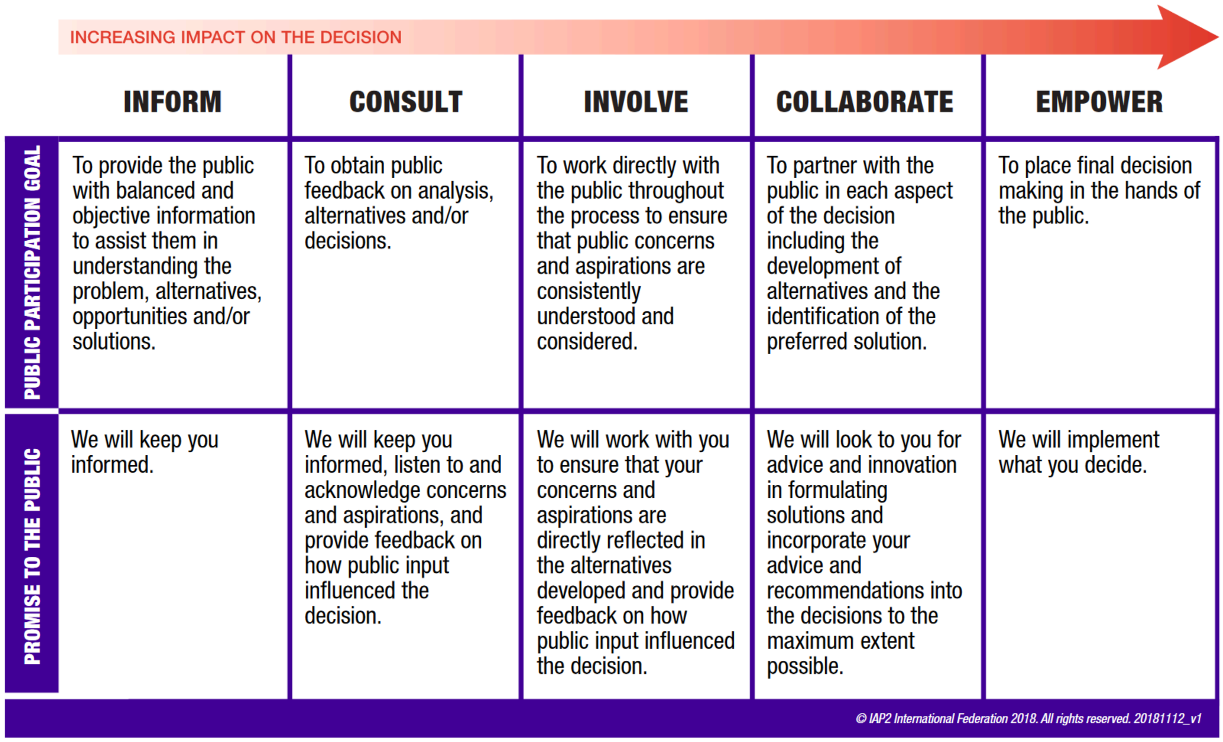
Furthermore, Sommer et al. (2020) make mention of a *crisis effect*, where after the experience of a risk happening (e.g. a terror attack or natural disaster) there is a window of opportunity where the risk is given more attention. This window can be used to direct more resources to controlling the risk, through lowering vulnerability, minimising the threat or minimising consequences. If the risk communication of VR is more impactful than a 2D communication by simulating the experience of this risk, could it also change the users perspective on the probability or consequence? Could it impact the sense of urgency or other factors mentioned, recreating elements of this crisis effect window? On the other hand, if VR simulations induce more negative information, would the effect be worth inducing due to negative dominance theory? Accurate information is important in risk communication, but if they are communicated in a more stressful manner it could hypothetically create a more skewed risk perception amongst groups.

This is all speculation and intended to exemplify the relevance of the above models and theories to the chosen method. In order to create a cohesive overview some of the factors are summarised in a theoretical framework for further use in the method chapter. The factors are taken from the risk understanding model as well as the risk perception factors from risk communication theory. Deciding which factors are most relevant to the research is difficult to determine, as *control* for example does not seem relevant due to the stakeholder's nonexistent impact on controlling the global sea level rise. However, they might have some control over the built environment's adaptation, and different risk communication methods could potentially change the participants' perception on the amount of control we may have over a risk. As risk communication not only covers communicating the knowledge we have at hand of risk, but also needs to consider risk perception and the subjective / individual element to it, and foster a dialogue.

3.3 Participation in planning

As stated in the above discussion, risk communication increasingly involves a two sided discussion rather than one sided informing. Hence, actors are also to be increasingly involved, leading to the importance of planning participation.

Head et al., (2007) outline this shifting importance of community engagement and some of its trends. They make note of different types of engagement as well as its motivations. Specifically they highlight the three groups; *government, community* and *business.* Heads et al. (2007) raises the importance of considering where the engagement practice originates, whether it is one of these three groups who will have different interests. For example a governmental initiated community engagement project might be because the government would benefit from widening the range of responsibility, sharing the potential success or failure, increasing awareness and strengthening trust. A business may have interests in engagement projects to maintain their influence. Furthermore there is value in a business expressing certain beliefs in participation. Community groups may want to initiate or participate in engaging projects due to the possibility of voicing disadvantaged groups, everyday citizens and NGOs whose growth often rely on outsourced services. These are examples of motivations as to why to initiate or participate in engagement practices, however the influence of any group may vary. Evaluating the efficiency of a participation process is furthermore very complex, as it is highly contextual. As such, it is important to consider the terms and method behind projects with participatory elements.



INCREASING IMPACT ON THE DECISION

	INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
PUBLIC PARTICIPATION GOAL	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
PROMISE TO THE PUBLIC	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

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Figure. 3.4 - IAP2 Spectrum of public participation (IAP2, 2018)

Without consideration of the context, a framework of level of public engagement was created by IAP2 (International Association for Public Participation). IAP2 (2018) hosts a platform with a large range of collected works regarding public participation. Based on their extended work they provide a *spectrum of public participation* (Figure 3.4) presenting different levels of participation from least to most impacting on the final decision making. Head et al. (2007) gives examples of what these levels could mean. For example, at the least impactful is *informing*, which could take the form of an online web page. The level above inform is *consult*, an example of which could be the use of focus groups or surveys. *Involve* could represent more in depth workshops or deliberative polling. *Collaborate* could make use of citizen committees and participatory decision making. *Empower* would mean putting full power of the decision making into the public's hands, e.g. through citizen's juries or ballots.

This thesis does not specifically seek to study VR as a participation tool. Nonetheless, engagement is a relevant aspect to risk communication practices. For a two-way dialogue to take place, some form of engagement of the other groups is required.

4 Project scope

The previous chapters have summarised and discussed much information across context, state of the art and theory related to the main concepts that build up the research aim. Much of these previous works span diverse risk cases, stakeholders and uses of VR that are beyond that of this paper. Nonetheless, they have been considered for their relevant aspects that will be used in executing the remainder of this thesis. Hence, the purpose of this chapter is to clarify the scope based on these previous sections. In particular, due to the many fluid definitions, the concepts are to be clearly defined.

4.1 Defining VR

Most significantly for this project, the communication tool needs to be clearly defined. As stated prior, there is no singular strict definition for VR. There are a multitude of methods to execute a VR simulation, in terms of hardware, software and functions included. Due to this, people with varying levels of involvement with VR are likely to have different expectations or experiences with how to define it. As this project centres around investigating this visual communication medium, there needs to be a consistent understanding of what is being investigated.

Firstly, the simulation will be exported to and experienced through the use of a HMD. Specifically, through the use of a *Meta Quest 3.* The Quest 3 is a relatively new but widely used HMD, leading to a multitude of online resources and discussions to learn from throughout this project. The Quest, as most modern VR HMDs, is accompanied by 2 handheld controllers used to interact with interfaces. Although these will be relevant in the creation of the simulation, their usage will be limited during the execution. As stated in the prior section (2.1.2), the level of interaction can have a notable impact on various communication elements. However, within the scope of this case, there are not many interaction elements that could significantly contribute to sea-related risk communication. Furthermore, with the resources available it is too costly to execute. Hence, the simulation will remain at a low level of interaction, allowing perspectives from different positions and a standard 360 view.

4.2 Defining the model

Furthermore, consider the level of detail (LOD) as explained by Biljecki et al., (2016). LOD is used to describe the geometrical complexity of spatial models, in particular that of buildings. LOD is a specification used across multiple disciplines as a somewhat standardised concept. LODs apply across architecture, urban planning and other spatial projects. See figure 4.1 for a visual explanation of the different LODs in building models. The previously mentioned web-based communication of sea level risks by Kartverket (*Havnivå i kart, n.d.)* would be an example of a LOD0.1. It provides an interactive two dimensional map with minimal details except the 2D outline of the buildings. Considering the available data, the VR sim to be produced will be at LOD2.0 or higher.

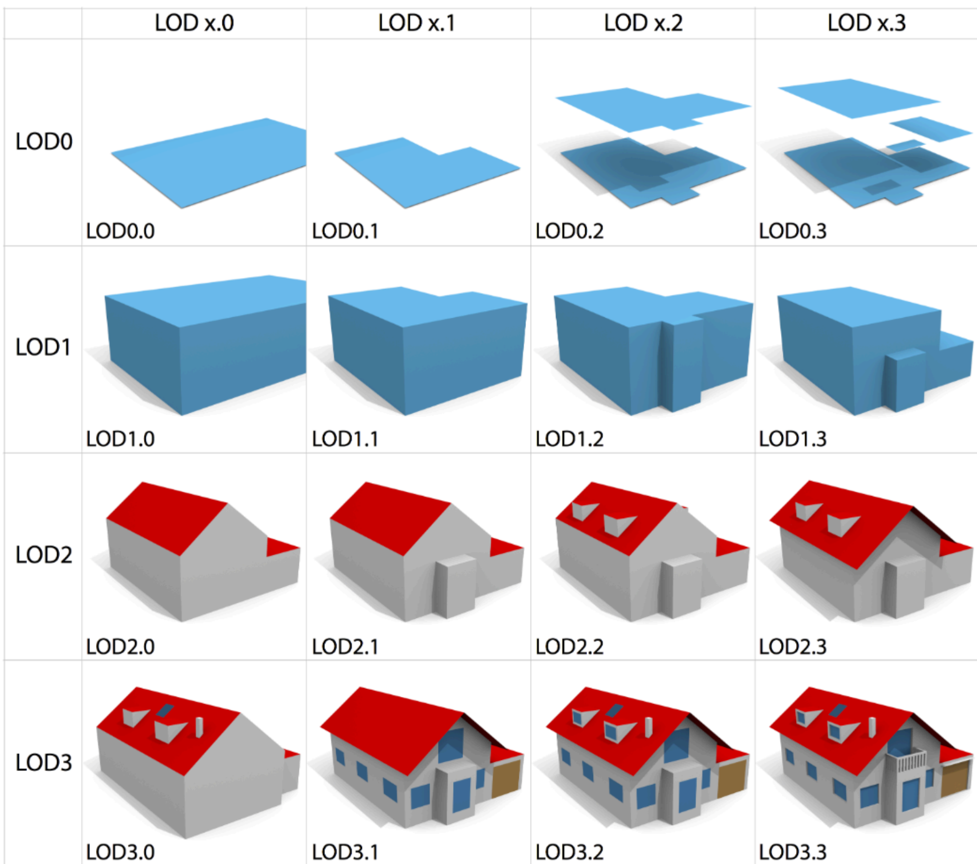

Figure 4.1 - LOD0 - LOD3 visualised by Biljecki et al. (2016)

The LOD is a relevant consideration especially in this project, as the noticeable difference between the existing sea level risk communication and the tested VR risk communication spans different dimensions. LOD0 does not include the height in its visual communications. It is a flat plane. LOD1 and above includes the third z-axis, perpendicular to the ground axes. As the risk communication in question is regarding a rising sea level and the consequent storm surges, the rise itself is inherently perpendicular to the ground axes. This is relevant to the question of whether an immersive 3D visualisation (through VR) has a different impact compared to the current 2D communications.

Furthermore, the question of what LOD is most efficient for what purpose is an interesting one. Intuitively it might seem that the higher the resemblance the model has to reality the more immersive the experience would be. However this has the potential to both significantly increase costs as well as distracting from other elements. Models do not require highly realistic details for a user to recognize the area, and within visualisation detail can lead to emphasis. To what extent should detail be included to make the model as recognizable as desired? What LOD is most efficient for what purpose? There are informal discussions around these questions and expert opinions, however it also represents a research gap. Considering this, this project will not place additional effort into researching the most applicable LOD for risk communication, and stick to one LOD aimed at keeping details minimal but recognizable so as to emphasise the risk. Furthermore, higher LOD data would make the project more costly, as LOD2 data of the chosen case area is already available. In summary, the VR sim will be a low-interaction, immersive 3D visualisation at LOD 2 or higher.

The model will include basic spatial elements such as the buildings, roads, terrain and the sea. In order to ensure it is recognizable, landmark elements should be highlighted (i.e. recognizable buildings) as well as some smaller scale elements such as benches and boats in the port.

4.3 Defining the risk

Within research there may not be a singular, strict definition, but the discussed works can provide a basis for defining the concept within the scope of this project. As such, this thesis considers risk as the possibility of a negative consequence to values from future storm surges. This definition acknowledges the differences in the meaning of risk between people, i.e. their differing risk perceptions. Risk is defined as personal and subjective, and cannot be measured quantitatively. Rather risk is built up of different elements to be taken under qualitative consideration. The specific risk for this thesis is the risk of future sea level rise and subsequent intensified storm surges considering climate change persisting. The exact threat to be considered in this risk will be defined next.

4.4 Delimiting sea level predictions in Tromsø

There is no one set prediction on the sea level rise and future storm surge risks in Norway. How emissions and climate change will develop the coming century is split into different scenarios. The widely used RCP (Representative Concentration Pathway) scenarios based on the IPCC reports provide models of possible outcomes to base predictions on. Furthermore, Norway is made up of a large landmass, many sections of which are still rising up as they bounce back from being relieved of glacier pressure. This means some parts of Norway are rising fast enough to offset a significant section of the sea level rise. Tromsø's landmass for example is expected to rise 26cm by 2100 (DSB, 2016). Lastly, the storm surge impact as well as its prevalence is determined by location and climatic factors. In northern Norway the impacts of storm surges differ from southern regions as it depends more on the tide. During low tide a storm surge has very limited impact with regards to the sea level rise, it is only during high tide there are significant consequences. These factors lead to the question: what are the different predictions for Tromsø, and what scenario predictions should be considered for this project?

Data for this project is taken from a few sources. The first notable source is the Norwegian Centre for Climate Services' (NCCS) report *Sea Level Change for Norway* commissioned by Miljødirektoratet (2015). This report communicates sea level predictions under the RCP2.6, RCP4.5 and RCP8.5 scenarios from the IPCC reports. RCP2.6 is a low emission scenario, RCP4.5 involves some reduction in emissions and RCP8.5 is a worst case scenario where there are no reductions (known as the *business as usual* prediction), causing a threefold increase in emissions by 2100. Sea level rise statistics in this report is offset by a region's landmass rise. Furthermore, this report uses return periods of high water levels to communicate storm surge risks. A 20 return height will refer to a sea level height occurring once every 20 years, or with a 5% chance of occurring during any year. Three increments of measurement are used: 20 year, 200 year and 1000 year return heights (low, medium and high risk). The NCCS reports predictions up to the year 2100 and no further.

Direktoratet for Samfunnssikkerhet og Beredskap (DSB) one year after published a guide on sea level rise and storm surge for municipal planning (2016). Based on the new numbers from NCCS' 2015 report as well as the general uncertainty on the functions of certain climate systems, the overall recommendation for planners is to plan according to the worst case scenario. This means planning in accordance with the RCP8.5 predictions. In regards to storm surge risk, it is recommended to work with the medium value of the three increments, namely the 200 years return height.

Kartverket, the Norwegian national mapping authority provides a website with these statistics for each region as well as an interactive 2D map of the entire country (*Havnivå i kart, n.d.; Se havnivå, tidevann og vannstand, n.d.*). These web functions are easily accessed and designed for clear communication of predictions to users. Therefore the Kartverket function will be used as a point of comparison for the VR simulation, as the current means of communicating sea level and storm surge risk. As such, the statistics for the VR simulation will adhere to the same guidelines by DSB for calculating the predictions for Tromsø.

This project will use the predictions of 2081-2100, averaging to 2090, based on the RCP8.5 scenario predictions. Storm surges will be visualised under a 200 year return height prediction, in which the Tromsø sea level rise is by 203 cm. Notably, the Kartverket water level website uses updated information on storm surge risks (as the NCCS and DSB data is now outdated). NN2000 (Normalnull 2000) represents the point zero of elevation in the national system. Tromsø's average water level today is 18 cm below NN2000, and under RCP8.5 is predicted (in the worst case) to rise 55 cm further by 2090 with corrections for landmass rise. Lastly, under current guidelines and knowledge, a storm surge of 200 yr return in 2090 is predicted to be **253 cm above NN2000, or 276 cm above the Tromsø average.**

After the completion of the simulation and method a new report commissioned by Miljødirektorated was published with updated predictions. With the new data, the worst case scenario rise in sea level in Tromsø would have been 77cm instead of the 55cm used in this project (Simpson et al., 2024).

4.5 Defining the stakeholder groups

As mentioned briefly in the introduction, this thesis builds on a previous project conducted by IMPETUS (*IMPETUS*, n.d.). In summary the project presented a similar VR output regarding sea level rise and storm surges in 2090 to politicians and to a design and architecture association in tromsø. This study will hence not study the same groups. Within the sub questions (section 1.3) the stakeholders chosen are municipal planners, local business owners and citizens. Within previous literature regarding risk communication and engagement practices, the focus tends to be on authorities (governmental), experts and the public (citizens). As this project takes a focus on stakeholders to a specific case study, experts in a field that do not hold a stake in the Torghuken project are not relevant. Nonetheless, municipal planners do hold their stake, represent an authority and have the added factor of being knowledgeable in their field. Citizens who to some extent visit the Torghuken area also hold stakes, and can serve to represent the public. Lastly, reflecting the 3 spheres of society by Steiner, who distinguishes the political, economic and cultural spheres in his social theory, the stakeholder group of local business owners are considered (Steiner, 1996). This group is distinguished by holding a great economic stake in the case, and being an integral section of Tromsø's wider economy. The three chosen stakeholder groups are further

To clarify the three groups, municipal planners represent workers within the municipality with a degree of authority or focus over the spatial planning in Tromsø. Local business owners will be actors who own or operate businesses within the case study area. Citizen visitors will be people who live within Tromsø, and who to some degree visit or use the case study area but do not necessarily have to live or operate in proximity to it. The citizen groups can be long or short term residents, nationals or internationals.

5 Method

The method chapter details the process behind the creation of the simulation, the interviews and the subsequent data collection.

5.1 VR simulation details

Before any interviews or stakeholder data collection can take place, the VR simulation as detailed in the chapter 4 project scope needs to be completed. This section will detail the data sources and creation process of the simulation prior to the stakeholder contact.

5.1.1 Input

To create the simulation, a few layers need to be brought together (model of current environment, proposal and predicted sea level rise). Existing models of the current environment exist in Tromsø, however at different detail levels and costs. Table 5.1 presents the final input sources used, after exploring multiple options. All sources are freely available, with the exception of Geodata's data which was accessed with a temporary licence requested for this project. As for the programs used, Arcgis Pro and FME were accessed through a student licence. The other two programs used, Blender and Unity are freely accessible. These two were the most essential in creating the simulation, as they were used to model the layers, merge the layers, have access to VR and GIS assets and have a large user base and resources to learn from.

Model Layer	**Data Source**	**Extracted from:**
Terrain	Kartverket	(*Høydedata*, n.d.)
Building models	GeoData	(*3D Clip&Ship*, n.d.)
Sea level & storm surge rise	Kartverket	(*Se havnivå, tidevann og vannstand*, n.d.)
Torghuken Proposal model	Tromsø Havn	Provided by Tromsø Havn
Current Torghuken piers, Tromsø Bridge & Benches	Case site photos	Visiting the site

Table 5.1 - Model layer's data sources overview

5.1.2 Process details

With a case study and subsequent site chosen for the simulation, the first part of the process was to collect information about the place. This was done through visiting the site and from a few positions next to the water taking photos for reference (for example Figure 5.1). These visuals would be from the same perspective as the simulation, showing what should be visible and highlighted. Additionally a quick visibility analysis using Kartverkets openly available DTM and DSM (*Høydedata*, n.d.) through Arcgis Pro provided a map highlighting the most visible areas from the simulation point.

Figure 5.1 - 2 example site reference photos

The freely available game engine Unity was used to merge all the necessary layers. Unity was chosen due to its accessibility, vast amount of users and hence resources to learn from as well as supporting the export to a Meta Quest HMD. This is done through a free asset, the *Meta XR all-in-one SDK,* providing building blocks for the camera, controllers and exporting to a Meta Quest product.

However, Unity is not the most flexible for editing all layers needed. Hence, the 3D modelling software *Blender* was used for some data. After the basemap the next important layer was the buildings. 3D data of buildings is freely available through for example openstreetmap, however does not originate from Norway and tends to be less detailed and/or accurate. The simulation will be experienced from eye-level, meaning the building models will appear equally tall as they are in reality through the HMD, justifying a higher LOD as well as accuracy. The simulation must be recognizable. Hence, Geodata's new *Clip & Ship* service was utilised. The service allows for easy access to Norwegian 3D data, including LOD2 buildings which were imported and edited in Blender. Blender furthermore allows for easy export to Unity, where all the layers were merged.

In order to create a recognizable simulation, I believed a few landmarks to be important. For example Kystens Hus with its particular shape and colour, the Tromsø bridge which was not in the Geodata clip & ship service, the Arctic cathedral at the other side of the water, etc. Therefore some of these recognizable elements which would make the area more recognizable to the user had to be modelled by hand and exported to Unity. Most notably there was no existing data which included the current Torghuken harbour, which is a crucial part to communicating the Tromsø Havn project. Modelling these was done in Blender using the photos taken at the beginning of the project as reference, hence their position is likely not as accurate as the rest of the buildings but sufficiently represents the real environment for the purposes of this project.

FME was used to convert file types and correct small details such as scale and coordinates of data so it would be imported into Unity and layered over one another more easily. For example a revit .ifj model of the proposed harbour was provided by Tromsø Havn, which was in conflict with the other file types and scales used, where FME becomes a useful tool.

Unity uses C# as a programming language, which allowed for allocating object movements to the VR controllers buttons. Hence, while in the simulation the user can switch between current and predicted water level, current and proposed harbours and different camera positions. With all controls coded and layers integrated, the simulation can be exported as an android application for the HMD to execute.

5.1.3 VR simulation product

With the multiple different sources for data, file types and programmes used the model is not on a technical level very accurate, but it is accessible, low cost and sufficiently representative. The most important part of the model that has to be technically accurate is the sea level rise, as this is the risk that is being communicated. An example snippet of current day and the predicted storm surge is shown in Figure 5.2.

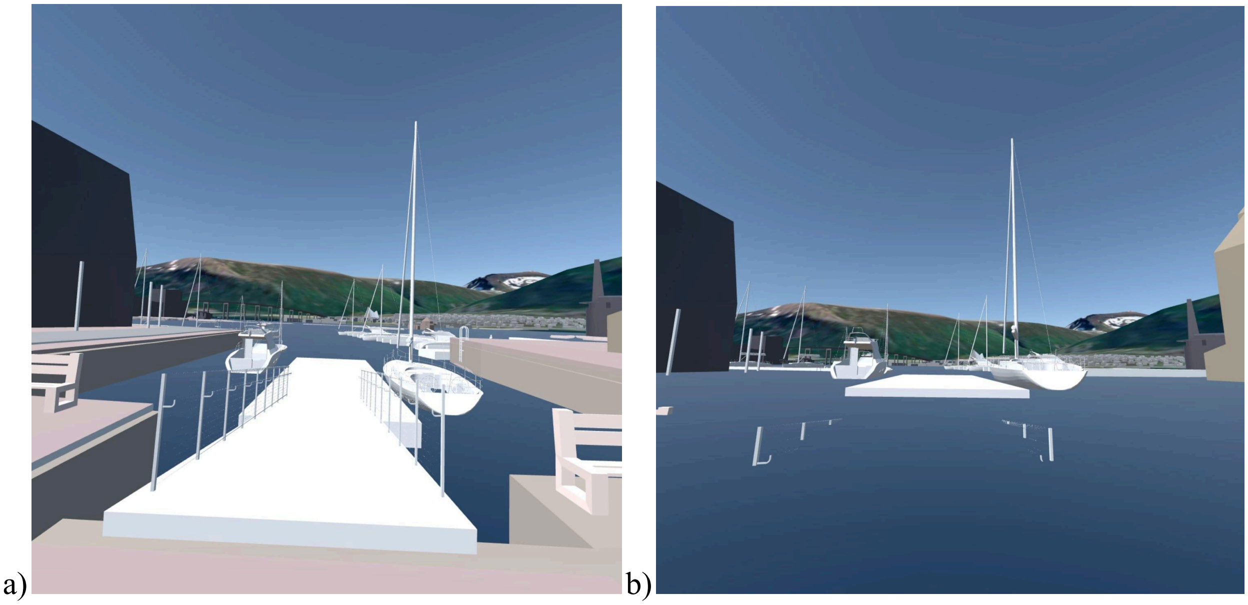

Figure 5.2 - VR model showing the current pier with a) current day water level and b) 2090 200 year storm surge prediction

5.2 Interviews

With the completion of the simulation, the data collection will be done through interviews with stakeholders of the Torghuken case. These stakeholders are split into 3 main groups: local business owners, municipal planners and citizen visitors. All stakeholders have to hold a stake in either the Torghuken case, the rising sea level consequences in Tromsø or preferrably, both.

5.2.1 Sampling

The interviewees are contacted through different means. The Tromsø municipality has a website with contacts, which can be reached out to to ask for possible interviewees. From this point municipal planners will be found through snowball sampling, asking each interviewee or contact whether they know anyone within the field who would be open to an interview. Local business owners will be contacted through the business websites, where the ones who accepted will also be asked for further contacts. Visitors are to be contacted within the case study area.

5.2.2 Coding

For the formation of an interview guide as well as later analysis, all interviews will be subject to coding. The data is qualitative, however coding will be used to create an overview of relevant points to the previous theoretical chapter. The process is intended to clarify the large output by certain concepts as well as to highlight which concepts are more prevalent and relevant to the interviewees. The coding process also allows for a deeper understanding of the interviews as they are transcribed and re-read multiple times. This is not to state that coding is the only approach to analysing the results, but a starting point to organise the output consistently as well as an initial method to analyse the findings against the theoretical chapter.

To ensure consistency all stakeholders were coded using the coding scheme shown in Figure 5.3. The coding was split into 2 main categories: the stakeholder's position and their risk communication experience. The stakeholder position is intended to help establish what the stakeholder's relevance is to the risk and case study. Hence, a few concepts from the theoretical frameworks discussed previously are included under this category. The interviews should establish what the stakeholder group's stakes are, or as worded in the model by Sommer et al. (2020), their *values*. Furthermore, the *consequences* to these mentioned values, as well as the stakeholder group's *awareness* regarding sea level rise and storm surges in Tromsø. Do they know of the risk, and if so how do they know of it? These three points are to clarify how the stakeholder group is positioned relative to the case and risk in question.

As for risk communication, it is split into risk understanding and risk perception with coding branches pulled from their respective theoretical discussions prior. Not all theoretical concepts are included. The risk understanding branch is intended to clarify how the interviewee understands the risk in question. Whether it is a reflection of the actual risk predictions or not, it is only to build an image of that individual's view. Therefore they will be asked to explain what is the *threat* exactly, how *vulnerable* they believe the existing system is against the threat, the *probability* of the threat occuring, how much *knowledge* we have collectively about this threat and how much *control* we have over the risk. If they are unaware of one of these elements, e.g. they have no idea what the probability of a threat might be, that will also be coded under this section. Whether they know or not, it is a relevant answer.

The risk perception branch is to bring in some elements from Covello's (2021) text, with the intention to expand some more on the individual interviewee's feelings towards the risk rather than their understanding. Based on the theory discussed, previous *experiences* with the risk can impact this. If they have experienced consequences to any of their values, whether in Torghuken or elsewhere they may perceive the risk differently. Their *trust* in their source of information (if they have a source of information). The *scope* of the risk, or how much 'catastrophic potential' they see in the risk, in relation to fear or negative perception. A risk does not have to seem catastrophic for it to have a perceived larger scope. The scope can also be derived from a fuller image of the interviewee's risk understanding, as they are closely tied together. Lastly, how much the interviewee personally *understands* the risk, or is *uncertain* about the risk can play into their perception. This once again ties into their risk understanding, as it depends how complete their understanding is from their perspective.

Both of these branches are tied together by risk communication, as they are seen as the elements to investigate whether they change through different means of communication. In short, the *impact* of VR on risk communication will be evaluated through whether risk understanding and risk perceptions differ before and after the VR simulation. The stakeholder's position, seen as setting up the context of the stakeholder group, will remain the same regardless of how a risk is communicated to them. Their understanding of the risk, and perceptions towards it may differ however, addressing the 3 sub questions.

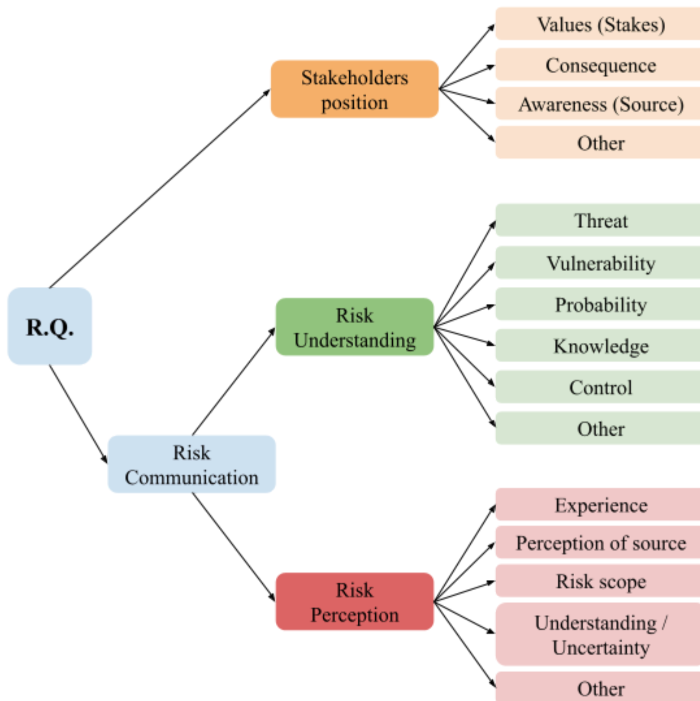

Figure 5.3 - Interviews coding scheme

The coding scheme presented is built on a compacted set of concepts discussed in the theoretical chapter. Far from all elements have been included, as Covello (2021) for example lists 20 total factors that could impact a person's perception towards a risk. This coding scheme has been made with consideration of the specific risk under the case study of future sea level rise and storm surges. Some of the factors have been merged or removed, for example the factor "effects on children" is not as relevant to flooding or storm surges in Torghuken, as it does not disproportionately impact age groups to a significant degree. Each branch has been given an extra code of "other" if during the interviews and coding process interesting points come up that do not fall under the other codes, allowing to highlight the points for later discussion.

5.2.3 Interview guide

After establishing a coding scheme, it was used as a basis to create the interview guide. The interviews were decided to be semi-structured interviews. The guide aids to cover the main points in the coding scheme, but the interview itself is intended to flow like a conversation. As stated prior in the theoretical chapter, risk communication is about two-sided communication (Mabon, 2020) rather than simply informing. Hence, the interview and VR communication should have to some extent a conversational element rather than just informing the stakeholder of the predicted risks.

In short, the interview guide is in 3 parts. Initially the interview should set up some context about the stakeholders position and establish their perspective and understanding of said risk. If the interviewee is unfamiliar with Kartverket's *Se Havnivå i Kart* (n.d.) web-service, this will also be presented and discussed. The interviewee's previous source of risk information will also be a point of comparison for VR as a source of risk communication. Hence if they do not have a source, Kartverket's web-service will be the comparison point. Second, the VR simulation will be presented, with an ongoing conversation throughout of what the interviewee is seeing and how they perceive it. The third and last section discusses all prior, any changes in perception or understanding as well as comparing the VR communication to other sources of risk communication. The interview concludes with asking for any additional information the participant wishes to share as well as asking for further contacts to interview. The full interview guide can be found in Appendix 3.

5.3 Ethical considerations

As the data collection involves interviewing stakeholders directly, this thesis takes ethical considerations on the collection and storing of said data. This is done through the use of *Sikt*, the Norwegian agency for shared services in education and research (*Sikt*, n.d.). Sikt provides data protection services and evaluation, and has accepted this thesis' evaluation form for data collection.

The ethical considerations all relate to the interviewees. They were provided with an information letter prior to the interviews alongside a consent form to sign (See Appendix 1-2). They were informed of their anonymization throughout the thesis, their right to retract consent, how their data will be stored and some further details about the project. The data collected was their perspectives relative to VR and risk communication, not including any identifiable information. Interviewees were recorded for the coding process, where the recording was stored on external hardware. Only the student had access to all the data, which will be deleted upon the completion of the thesis.

6 Results

6.1 Interview process output

A total of 9 interviews were conducted, with 3 interviewees from each stakeholder group. All interviewees are anonymised and will be referred to as shown in table 6.1. For both local business owners (LB) and municipal planners (MP) interviewees were contacted as planned; through their respective websites and subsequent snowball sampling. Not all contacts responded or agreed, however some were still fast to give alternative contacts. Roughly half of the LB and MP approached participated.

Citizen visitors (C) were more complicated as people on the site were not open to spontaneous interviews. Rather, acquaintances on site were asked for contacts. It was not possible to do unplanned interviews due to the time consuming nature, as people on site were often tourists or were only passing through with a destination to reach without the time to talk (or simply not interested). Therefore, all interviews had to be planned beforehand. As such the interviewees are not contacts of the interviewer, nonetheless they may not be as random as intended.

Stakeholder group	Interviewees (as anonymised codes)
Local business owners	LB1, LB2, LB3
Municipal planner	MP1, MP2, MP3
Citizen visitors	C1, C2, C3

Table 6.1 - Overview of anonymized interviewees codes.

Interviews were conducted in the interviewee's preferred language, 8 of which were in Norwegian and 1 in english. All has been translated to english by the interviewer, which may on one hand lead to misunderstandings across languages. On the other hand, conducting languages according to the interviewee's preference is expected to allow them to communicate more clearly, hence this inconsistency is considered unproblematic.

The interviews took place at the interviewee's convenience, usually at their working place. Slight discomfort was occasionally communicated at conducting the interviews in public places due to the use of a VR HMD in the presence of other unknown people. The duration of the interviews varied between 30 to 60 minutes depending on how much the participants had to share.

6.2 Coding Process

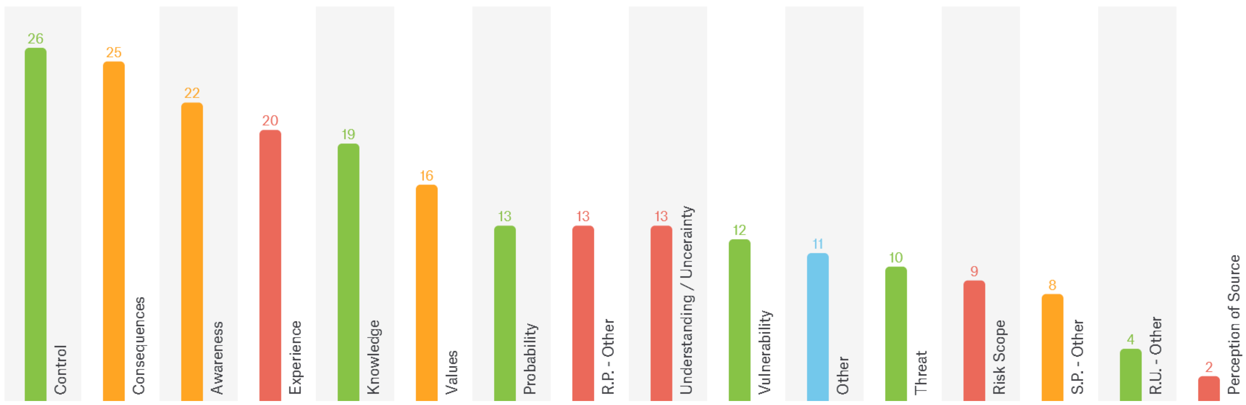

Figure 6.1 - Code distribution overview (Orange = stakeholder positioning, Green = risk understanding, Red = risk perception, Blue = other)

The coding process allowed the creation of an inventory with a clear overview of responses and discussion points tied to specific themes. The organisation of which leads to a more efficient comparison of concepts across interviews. Figure 6.1 above presents the code distribution overview, noting how often a discussion/answer was coded with what concept from the Figure 5.3 coding scheme. This is with the intent to organise the themes and point out outliers and patterns.

For example, most notably the topic of how the interviewees perceived their source of information (in relation to trust) never naturally came up in discussion throughout the interviews. When asked directly on their perception, the interviewees often did not really have an answer. The two codes are of interviewees indirectly expressing trust in the VR simulation for representing the future accurately despite being predictions. Hence, this was a less prevalent and significant concept than originally expected.

Concepts relating to level of control and consequences were significant and consistent discussion points throughout all interviews. In hindsight, this was in part due to no distinction being made between personal consequences relating to the stakeholder's position and general consequences of the risk which lead to different discussion points. Hence these codes are more prevalent.

Lastly, each of the three main branches included an "other" code for any interesting point relating to stakeholder position, risk understanding and risk perception to be considered for discussion. A fourth "other" code is present for any points not related to one of the three branches, consisting mainly of direct responses of participants when seeing or discussing the VR simulation. The discussion points attached to these codes as well as the ones mentioned above will be elaborated on in the upcoming chapter

6.3 Stakeholder Coding Output Comparisons

Before further analysis, the three main coding branches will be described to summarise the output. The answers relevant to the stakeholder's position, the risk understanding and risk perception will be briefly reviewed and compared to provide a basis for discussing how the communication means impacts different groups.

6.3.1 Comparing Stakeholder Positioning

Despite the 9 participants being diverse, there are notable elements that group them. What they value, what they recognize as a consequence and what their level of awareness was were the 3 main categories grouped amongst interviewee discussions.

6.3.1.1 LB 1-3

The most common value expressed by LB 1-3 in relation to the risk was understandably their physical property located by the sea.

As such, the consequences recognized involved being some negative side effect to their valuables. This would include salt water intrusion, damage to the buildings, loss of functions within the properties or to some degree not being able to operate the business. A secondary value expressed was access to resources, where the risk might consequently diminish this access or deter tourism and visitors. A last consequence brought up (but with less frequency and worry) is the potential cost of adapting their business/property to the risk.

How much awareness LB1-3 had varied much between the three. LB1 had never before considered sea level rise and storm surge risks to their work, whereas LB2 had much more extensively looked into it being able to point to specific sources. LB3 on the other hand expressed an awareness that the sea level would rise a little, but had not any concern of consequences and with the least interest in seeking out more information. This, amongst other factors presumably led the LB stakeholder group to have the most diverse reactions to seeing the VR simulation.

6.3.1.2 C 1-3

Between C1-3 the most prominent value was the cityscape. None of the three noted being frequently present in the case study area, though all were familiar with it. As such they did not hold a significant personal stake in the inner harbour beyond the lessening of the cityscape available to them.

They were quicker to apply the risk to the whole city island, imagining scenarios where the island would shrink and the city experiences loss of cultural heritage and accessibility. Worst case scenario they note losing certain areas to a rising sea and for example not being able to go to work. C1 specifically notes a concern about a potential consequence regarding costs, as a smaller city would mean a more expensive housing market compared to an already difficult housing situation.

C1-3 communicated similar levels of awareness regarding the risk prior to the interview, contrasting the diverse responses of LB1-3. Awareness was generally limited regarding the specific risk within Tromsø, however all three were aware of many other local climate change consequences as well as sea level rise in other locations.

6.3.1.3 MP 1-3

MP1-3 would rarely communicate personal values and consequences. The most personal value under threat noted was in relation to their responsibility as a worker within the municipality.

Otherwise MP1-3 would discuss multiple consequences to the city, including infrastructure damage, pollution into the sea and pollution of the city image or loss of accessibility. The MP group was also the only group to communicate a worst case consequence possibly being a loss of health or even life.

Awareness of the risk can vary slightly between interviewees depending on how much they focused on climate adaptation in their work, but all 3 recognized sea level rise as a risk and could name their sources of information. Due to their often involved work with climate adaptation and related risks within the municipality, a significant extent of awareness is essentially a given.

MP1-3 were the most consistent stakeholder group in terms of their values, consequences and awareness, as well as the most overall distinct from the other two stakeholder groups which had some more overlaps within their risk perceptions.

6.3.2 Comparing Risk Understanding

6.3.2.1 LB 1-3

LB1-3 in terms of their understanding of the risk is once again the more diverse group. How much knowledge they believed to be currently available around the risk varied. Nonetheless there was a somewhat consistent point expressed amongst the group where the knowledge regarding sea level rise risks in Tromsø might not be complete, but there are experts the businesses can consult. Interviewees noted that sea level risks have been present and dealt with in other locations, hence there must be people who know how to take measures against it for Tromsø as well.

Tied into the stakeholder's position, LB2 and LB3 especially understood they had low vulnerability to the risk. This is mostly due to confidence in being able to control the consequences.

All communicated that the risk poses a threat to their values as currently there is minimal to no measures against water damages, however the interviewees are confident this vulnerability can be controlled before the risk grows. Although they express lack of control at the overall risk (controlling sea level rise) they were more confident in controlling the threat to their personal values. Interviewees suggested ideas such as adapting the properties, working together with the municipality or as LB3 expressed in the worst case to move their business away from the risk area (although this was not an expected outcome).

6.3.2.2 C 1-3

Citizens also expressed uncertainty at the amount of knowledge currently present about the risk, stating belief that they believe experts are well informed on the risks but otherwise think knowledge is limited amongst inhabitants. C2 in particular brought up their concerns about common experiences with people who do not see climate change as being a risk or of consequence. This further plays into a different understanding of control.

C1-3 expressed different values than LB1-3 as stated in the prior section. These values are more in relation to the wider city and is not something the interviewees feel they have control over. Neither do they see their personal or wider consequences as something they can control. Hence, they also experience the existing system of Tromsø to be more vulnerable.

6.3.2.3 MP 1-3

MP1-3 was again the most distinct from the other stakeholders in their answers. They could more precisely point out what aspects they saw to be missing in the current knowledge base around the risk. For example, pointing out certain analyses or reports that are important to addressing the risk within a location specific context that are yet to be executed.

They mostly expressed a current vulnerability to the risk and a need to divert more resources to addressing the vulnerable system.

Control over this vulnerability was also experienced quite differently. As workers within the municipality, especially with a focus on climate adaptation, this group initially seemed to be the one which would have the highest sense of control of the three. However, individual control remains low as they express dependency on other systems and the wider state to prioritise and direct funding to certain issues. MP1-2 expects more control and attention diverted towards the consequences with time, but never a 100% invulnerable system. MP3 expressed similar ideas while stating some more confidence in the current level of knowledge, control and invulnerability of the system. MP 1-3 were also the most confident in the probability of the risk, expecting it to come to pass.

6.3.3 Comparing Risk Perception

6.3.3.1 LB 1-3

LB1-3 could not name specific prior experiences in relation to water-risks that could impact their risk perception in relation to the case. The LB interviewees have generally spent longer times living in the municipality than many of the other interviewees, and when asked about general climate change experiences the answers were also minimal. Interviewees could note personally experiencing changes in the sea ecosystem and the tree line having risen.

Furthermore, LB1-3 all express some degree of uncertainty in regards to their own position relevant to the risk. Uncertainties in how the risk will play out, potentially affect them or how to address it.

Yet overall LB1-3 expressed the least worry and least negative perception towards the risk, with confidence that potential negative outcomes would be handled, as it has been handled elsewhere.

6.3.3.2 C 1-3

C1-3 were overall the most negative in their risk perception. This group had a diverse background in relation to time spent in the municipality, however could point to more personal experiences in relation to sea related risks than LB1-3 (experienced both in Tromsø and other locations).

They generally did not see the risk to have a currently significant scope, but that it would grow to be a risk with major uncertainties that they perceived very negatively.

This group generally provided the least concrete ideas in relation to the expectations of the risk, expressing more uncertainty than certainty in their own knowledge.

6.3.3.3 MP 1-3

MP1-3 mentioned a number of experiences in relation to water and the sea, mostly in contexts outside of Tromsø. Furthermore they placed much emphasis on the importance of experience, with one interviewee stating it is to some degree unfortunate that the municipality has not experienced more consequences as these events are what push for action against the future risk.

This group expressed more certainty in the potentials of the risk, its scope and that the current actions taken against the risk are not in line with the scope that the risk will grow into. MP1-3 do acknowledge they cannot know what the risk will be eventually, and that there are uncertainties in how and who will tackle certain aspects of the risk, but express certainty it is a growing risk in need of attention. This group did not perceive the risk with as much uncertainty as C1-3, but nonetheless expressed more negative perceptions than LB1-3.

6.4 Process Limitations

The process experienced a few limitations. The most notable one will be, as mentioned prior, that 3 individuals cannot represent a whole stakeholder group. Being a qualitative method, the process allows for a more in depth discussion with participants but cannot fully present groups that are not unanimous to begin with. The citizens stakeholder group especially is expected to be an extremely broad group.

The interviews themselves also varied much per interviewee. Some had much more to share than others. In part this could be due to how the interview guide developed over time. The same interview guide was provided for all three stakeholder groups as they are to be compared, however as one interviewee brought up new points, they impact the upcoming interviews as their perspectives are to be compared. This also means that the early interviews had a few less questions. For example, the factor of having children and how it could impact risk perception (see section 7.2.2). Questions about the impact of children were only raised to interviewees after C1 was the first to bring it up without prompting. All interviews prior to C1 did not get asked about having children as a potential impacting factor.

Using VR as a tool itself has limitations as well, as it can only be used by one person at a time and has to be in person. This hinders the physical accessibility of using VR, as well as accessibility for people who are unfamiliar with it. For example some struggled getting the HMD on properly at first, however since interaction level was very low for this simulation this was a minor limitation. It was also noticed that when the interviews took place somewhere visible or in public some interviewees showed embarrassment at wearing the HMD and not being able to see their surroundings. There seems to be some degree of discomfort around the idea of being seen in public with an HMD in an informal setting, with C2 adding a comment that they were happy no one they knew was around.

As based on the findings in 3.1.3 and 3.1.5, the interviews were intended to not give the interviewee too much information beforehand, as well as to let it be a two sided communication rather than a one sided information session. Nonetheless with the consent letter and prior conversation leading up to the interview some of the interviewees had influenced answers, such as C3 who admitted they were not sure if they would have answered the same if they had not heard the mention of flood risks prior.

Furthermore, making it a two way discussion was not always as accessible. As stated by Mabon (2020) risk communication for long has been a one sided informing process. Recently it is developing into a two sided dialogue which considers the audience's opinion and experiences as they are closer to the risk. This was intended to be implemented into the interviews, however it became evident throughout that the process was not set up to allow for deeper engagement. This was due to the fact that the interviews were for research purposes, and despite using a case were not directly involved with the case project. Hence, the dialogue element was present as the interviews were conversations, nonetheless due to the aim it was not fully authentic, and complicated to evaluate. In addition, it was likely the overall execution of a single interview with only 2 people present that limited further engagement. Another approach to creating more of a discussion rather than an informing communication is to execute the communication with the inclusion of more participants. A method that allows multiple participants to discuss amongst themselves instead of a one on one interview may allow for more insightful and engaging results (Bartels et al., 2013).

The method chosen to answer the research question gives a large amount of qualitative data to work with, however the interviews remain singular and have no follow-ups. Therefore the interviews only collect data about the immediate reaction of stakeholder groups to the communication, and cannot take into account the long term impacts, whether it changes memorability and perceptions, or whether it is a short lived impact.

Lastly, the interviews were conducted in the language of choice of the interviewee, hence there were language differences and translations as a part of the results process. There is always likelihood for misunderstandings or human error in both the transcription and discussion due to the interpretive element of the process.

7 Discussion

The 9 total interviews are information-rich and have multiple points where participants both differ and agree. Hence, to answer the research question, the main points that make a stakeholder group react differently to risks and risk communication within the scope of the case is to be elaborated on in the upcoming sections. However, as stated, the sample sizes are too small to truly represent the stakeholder groups. As came to light throughout the process there are many additional elements to consider during the communications of risk as well as factors deciding how people respond to it. Having 3 interviewees per group is not representative of the full group and the participants are not as easily put into the 3 clear groups as initially expected. Hence this chapter will also delve into some of these factors that overlap between the theoretical framework of chapter 3, the literature review of chapter 2 and the interview output beyond the stakeholder differences.

7.1 Impact of VR on stakeholders

Initially, the discussion will cover the main reactions to the communication of risk information with the three different stakeholder groups. Using the results section and coding categories as a basis to compare how they may change and differ before and after the simulation, as well as the interviewee's direct responses to VR as communication.

When presenting the VR simulation and asking the interviewees for their initial opinion upon viewing it, there were some common reactions that applied to all interviewees. Very consistently participants were some degree of surprised, stating it was scary to see, lightly distressing or more extreme than expected. Reactions were notably more negative towards experiencing the simulation in comparison to seeing the same information in the 2D map providing the same numbers. How much of a negative perception this provided to the risk varied amongst interviewees. Most participants had little to no prior experience with using VR, aside from MP1-3 who had seen these predictions visualised before.

7.1.1 Local Business Owners

LB1-3 were the most surprising stakeholder group in terms of their reactions. Having conducted a literature review of similar studies led to some expectations. This group was expected to be most impacted by viewing the simulation due to their closeness to the case study area. The simulation would present their place of work or business to be partially under water by the 2090 prediction. Out of the 3 groups their values and consequences are the most closely tied and impactful. Furthermore, as found by Dhunoo et al (2023) who reached out to multiple people working in the area of their VR flooding simulation faced many rejections of those who did not wish to participate, or preferred to not think about climate change consequences. With this in mind LB1-3 were thought to be the most difficult group to contact as well as the one to have the most negative reaction. The interviews proved the opposite.

All 3 LB interviewees reacted to seeing the simulation by initially saying something to the effect of calling it dramatic or scary. This was a short-lasting response directly after or during the viewing of the VR simulation. LB1 stood out the most as following the expectations. They made note of having never considered this risk prior, and especially after seeing the simulation and discussing the risk, would look into the risk further and consult expert opinions. LB 2 and LB 3 on the other hand expressed far less worry or negative reactions, but with two different outlooks. LB2 communicated extensive awareness and knowledge about the risk, having given it much research and could quickly point out that the storm surges would be short lasting, how the risk is not an immediate but temporally distant concern, and that there are realistic measures to be taken against the potential consequences. They could put forth multiple ideas of how to adapt their values to lower their vulnerabilities. With a distinct sense of control and certainty LB 2 showed little to no worry about the risk, despite stating the VR simulation was more dramatic than expected.

LB3, much like LB1 had not considered the risk in question before. Nonetheless, LB 3 expressed minimal concern and worry, despite also making mention of the simulation looking more extreme than they were expecting. Their reasoning for not worrying or for retaining a neutral perspective of the risk is due to not being a very worrisome person by nature. Furthermore LB3 took a different position from most interviewees by expressing that a changing environment and climate does not inherently need to be a problem, but rather could be part of a natural cycle. This could potentially reflect with Berger & Wyss (2021) findings regarding scepticism around the scientific climate change consensus, which was likewise found by Dhunoo et al (2023) during their flood perception interviews. LB 3 did not express denial, rather scepticism at how accurate the consensus and general knowledge is around climate and sea related risks, as well as whether it is a risk. Hence LB3s reasoning for not considering the risk further, or seeing it as a risk is notably different from all other interviewees.

Furthermore, the discussion with LB 3 could be connected to one of the four main elements of risk communication summarised by Covello (2021): trust determination theory. Although the interviewee did not express distrust to any specific source of information, they expressed a degree of uncertainty or distrust to the existing consensus. Like most interviewees, LB3 could not point directly to their sources of information.

The local business owners' reactions to VR as a form of communication is the most difficult to summarise, as this group varied the most internally in their background (awareness, sense of control, sense of certainty) and reaction (from finding it worrisome to mostly unbothered). However when compared to the other two stakeholder groups, the most notable difference is that this stakeholder group was overall least concerned with the risk. Despite being to some degree surprised by the VR simulation, all 3 interviewees had some reason not to be too worried. LB1 quickly came with thoughts of potentially consulting experts, and thinking of ideas to control any consequences. LB2 expressed knowledge, confidence and control over the situation, thinking it will be solved. LB 3 was simply not as concerned, not having any of their values in direct threat and being more sceptical about the scope of the risk. The local business owners have control over their values and consequences, and resources available to tackle the risk, potentially leading the VR risk communication to be relatively less impactful.

7.1.2 Citizen Visitors

C1-3 showed more consistency in their responses to the VR simulation. The overall stakeholder group of citizens who visit the case study area within Tromsø is numerically the largest, covering most inhabitants of the city. Because of this the group likely is the most diverse, with backgrounds as either local, national or international, with varied occupations, experiences and views. As long as they live and operate in the city, whether for a long time or short, they fall under this group. Nonetheless the three interviewees representing this group were relatively more consistent in reactions and responses than LB1-3.

This stakeholder group had the overall shortest interviews, generally providing more concise answers. This is partially due to this stakeholder group sharing less direct values to the risk, specifically the case study area, as the area was only a place to visit shortly or pass through for C1-3. Moreover, none had very specific knowledge or expectations about the risk, except for that they expected the sea level to rise as it is doing in other areas on earth. With this awareness, but limited knowledge C1-3 reaction of surprise at the simulation followed expectations. The expressions of surprise and negative reaction to the information from the simulation continued for longer than with LB 2 and LB 3. C1-3 generally stated that viewing the VR simulation made them think of more potential consequences to themselves and the city than they could think of before seeing the simulation, or even with just seeing the Kartverket web service (*Se Havnivå i Kart*, n.d.).

However, lack of specific knowledge and expectations about the risk does not justify the VR simulation having a stronger impact on C1-3 when compared to LB1-3, as both LB 1 and LB 3 communicated similar lackings. Notably, though their personal consequences were more indirect as a result of the potential risk (e.g. losing accessibility, losing cultural heritage, rising housing prices) they had significantly less control over their relevant values. If the VR simulation communicated to them that Tromsø is more vulnerable to this threat than they expected, they cannot implement any protective measures by themselves. When asked about taking measures, all three interviewees could mention some measures such as temporary walls to hold back water during storm surges, however they have no significant control over whether that will be implemented or not. When asked about personal measures they can take, C1 thought they had no control beyond voting for politicians who would prioritise the risk. C2 mentions living more sustainably to reduce personal emissions, and having more people do so to reduce the effects of climate change. Interestingly C2 also states a somewhat disappointment in specifically older age groups who in C2's experience do not see climate change consequences or sea related risks as a problem and hence take no personal measures to live more sustainably.

Another element which may lead to their overall most negative perception could relate to their knowledge and awareness, as C1-3 had the most differing reactions to the two methods of communication presented; the 2D web service and the 3D VR simulation. This can be connected to something LB 2 stated prior, where they noted the 2D web service was already very informative to them due to their experience in reading and using maps. Hence, LB2 argues they are able to understand the consequences and impacts of seeing the 2D map more easily than someone with less experience reading maps. Technically the web service and VR simulation are two visual representations of the same information. But based on the responses from C1-3 the reaction to the VR simulation is far more impactful and visceral. Going by LB2's reasoning, even with such a visual communication as a map showing impacted areas, a VR simulation still provides less of a hurdle of understanding what consequences and impact a risk will have. This is further supported by the findings of Calil et al. (2021) and Jude et al. (2015) who note a lacking in environmental literacy and the barrier of reading maps to differing groups.

In summary, the citizen visitors stakeholder group had the overall most impacted reaction to the VR simulation as it most changed their risk understanding from their prior expectations, and changed their risk perception to become notably more negative about the risk and its consequences.

7.1.3 Municipal Planners

Municipal planners were easily the least impacted by using VR as a risk communication tool. This fairly straightforwardly came down to a few main factors. Firstly, the interviewees had prior experience with using VR, seeing sea levels in VR, and compared to the other stakeholder groups had extensive experience and knowledge about sea level rise risks and storm surge risks. Seeing the VR simulation had minimal impact on their risk understanding and risk perception, with no significant new information being brought up (e.g. new potential values, threats, consequences etc. mentioned after seeing the simulation).

This steadfast understanding and perception does not mean their perception was more positive however. Notably MP1 and MP2 especially were far more negative about the potential consequences and sense of control than LB1-3, stating they do not believe the risk has enough attention and that they are unlikely to ever gain 100% control over such a risk.

Furthermore, despite this VR simulation having a minimal impact on MP1-3 risk understanding and risk perception, it was not without other impacts. MP1-3 acknowledges using VR previously, and having experienced VR to be a powerful tool for various groups of people. For municipal planners they acknowledge VR as mostly to be a tool for competency-building events, as well as to be a reminder to the workers at the municipality. They are well familiar with the information the visualisations are representing, nonetheless they express the VR experience to be a more immersive and intense means of communication. They consistently state the tool to be fairly useful for other groups (i.e. business owners, citizens, politicians), and potentially useful in some occasions for municipal planners.

It should be considered that the three planners interviewed were already very familiar with the risk in question and very involved with general climate change impacts in Tromsø. This is not going to be the focus of all workers within the municipality, or planners / municipal workers as a stakeholder group. Workers within the stakeholder group may have focused on other spatial, environmental or societal elements and have less focus on climate change risks, where the impact of VR may differ.

Nonetheless, from these three participants it can be summarised that the impact of VR as opposed to other communication methods is the least significant out of the three. Despite not being fully representative of the stakeholder group, the reasoning for the limited change in risk understanding and perception with the use of VR can be connected to a few factors (knowledge, understanding, experience).

7.2 Further relevant factor considerations

After having discussed the most significant factors that based on the results impacted the stakeholder groups differently, this section will briefly cover some other factors that came up throughout the process. Not all elements were as directly tied to a specific stakeholder group within this paper, but showed relevance to the impact of VR on an audience in risk communication.

7.2.1 Negative dominance theory

A prevalent discussion point with stakeholders was their overall feeling regarding the risk before and after the simulation. Very consistently participants felt more negatively about the scope of the risk and its consequences afterwards. In overall feeling the municipal planners were already very aware of the risk and its consequences, and could express feeling quite negative prior to the simulation. Citizen visitors and local business owners were more intense in expressing surprise and worry after viewing the simulation, especially citizens. When some struggled to think of how the consequences could be minimised, or expressed increased uncertainty over potential lack of control over the risk, the reactions reflect what was described in Covello's (2021) summary of risk communication as negative dominance theory, and further a limitation within the communication.

Unlike the 2D map representation or other means of risk communication, the VR simulation provided a shock value as it was more extreme than participants had expected. The immersive communication combined with defying expectations leads to an overall more negative understanding and perception. Furthermore, the VR simulation shows two extremes; the current day normal level, and a 2090 200 years storm surge under an RCP 8.5 scenario. Showing one after the other creates a stark contrast, and as pointed out by MP1 and MP2, shows none of the inbetween stages. This negativity and especially lack of control as described by C1-3 can lead to an unfavourable outcome depending on the aim of the communication.

A relevant question to risk communication then becomes what the desired outcome is. Is it to inform the audience of a prediction and raise awareness? Under this aim the VR simulation was effective, especially for Local Businesses and Citizens, being surprising, immersive and memorable. However if a part of the aim is to encourage the audience to take action towards a risk, or change their behaviour the VR simulation was limited. Showing two extremes, which was mostly received as negative information creating a more negative perspective it outweighs hopeful, positive thoughts. As suggested by MP1-2, the simulation could have presented possible physical measures, or information with positive, hopeful associations that might lead to discussion points on how the audience can take actions or participate in and support such measures.

7.2.2 Impacts on children

Another relevant element is the impact of risks on children. This was reflected in Covello's (2021) summary on risk communication theory, stating that when a risk has adverse effects on children or future generations it is connected with greater perceived concerns and worry amongst people. This was initially not included in the interview guide and coding due to the assumption that a sea level rise and storm surge in 2090 would affect all age groups, nonetheless it was brought up without prompting by C1. Specifically they state that the risk presented in the VR simulation will be more prevalent for their current children, rather than adversely impacting younger age groups. The impact on children hence is an aspect which brings the relevance of the risk closer, as the simulation specifically shows a situation so distant. Hence, the impact of risk communication may differ depending on whether the recipient of the communication has children themselves or is involved with future generations.

Due to this interaction, the question was further brought up to the next interviewees, despite not being asked of the interviews conducted prior to C1. C2 elaborates by stating they do not believe having or not having children significantly impacts people's risk perception, due to personally knowing multiple people with children who according to C2 deny the impacts of climate change. Nonetheless, C2 does mention a worry that their children will not be able to go fishing the same way that C2 used to as the climate continues to change. Considering this, being a parent may increase the impact of VR communication if the participant has existing concerns about (or simply does not deny) the risk in question.

7.2.3 VR as a replacement for experience & temporal distance

Both Covello (2021) and MP1-3 emphasise the impact of prior experiences with risk shaping people's risk perception and understanding. From all interviews it is clear this is something that is missing in Tromsø inhabitants and stakeholders, where storm surge and sea level change experiences are minimal and not particularly memorable. MP1 even states this is to some extent unfortunate because only experiences and larger events drive the change needed to increase control over the consequences.

To some degree VR can serve as a replacement for a 'missing' experience. A rising sea level and storm surge is not a preferable event, yet without experiencing the consequences bringing a potential risk to people's attention, awareness lowers and it does not become prioritised. When asked to compare seeing the VR simulation to the 2D interactive map, interviewees would fairly consistently call the simulation more impactful, dramatic and in some discussions phrase it as "closer to reality". Interviewees fairly quickly recognized their environment, and expressed greater emotional responses to seeing the water rise next to them compared to on the web service.

Although VR is no replacement for reality, as stated by LB1 it becomes more real than 2D or verbal communication through the immersive presentation. As experiencing the risk would be undesirable, VR can to some degree aid in replacing a "lack" in experience by simulating it in a cost effective manner. This does not particularly apply to specific stakeholder groups in this project, as all have limited experience with the risk in question, however could be an applicable consideration for other case studies where variations in experiences are greater amongst groups.

7.2.4 Trust determination and uncertainties

A factor which prevalently was brought up in risk communication research and summarised by Covello (2021) as one of the four main elements in risk communication is Trust. The extent to which the audience trusts the source of information or the informant, which can be impacted by for example empathy, honesty about shortcomings and transparency. In an attempt to evaluate the impact of this potential factor, it was brought into the interview guide and coding scheme. However it became a minimally present conversation point. Interviewees could rarely point to specific sources of information, and generally did not express distrust towards the information.

It became relevant in two areas. First, LB3 who was the only interviewee to express a degree of distrust towards the existing knowledge base around climate change. LB3 stated they were sceptical about our collective knowledge regarding climate change consequences. As such, they were the only one to unpromptedly express a degree of distrust. Secondly, the degree to which participants had trust in the VR simulation is relevant to this theory. What was presented was never questioned and taken by most as factual, or as something that would happen. As was stated by Portman et al., (2015) an essential element in these climate change visualisations is for it to be based on accurate data. The model presented was based on specific predictions, but not an accurate prediction as there will always be other possible scenarios, and the future is unforeseeable.

LB3 expressed some scepticism, and LB2 expressed an understanding that the model presented was of an uncertain prediction. MP1-3 were all aware that the specific RCP8.5 prediction was shared and that it is one of multiple possible outcomes. C1-3 (and LB1) however, who were all least aware of this risk and subsequently most surprised by the VR simulation output, spoke of the data as if it was something that would happen and not as one of multiple possible outcomes. For this group, the uncertainties of the prediction coming to pass were not communicated through the VR simulation. This was also shown to be a barrier for Jude et al. (2015) who nonetheless explored visualising the uncertainties through a coloured zone, animations or otherwise. They note this as a challenge in need of further attention, to investigate how further output impacts the audience's understanding of the uncertainties. As this notably was not included in this project’s VR model, C1-3 in particular may have formed a more inaccurate view of the risk as it was not as tailored to this stakeholder group and they expressed consistent trust in the model.

Lastly, the cause of this trust in the communicated information can be compared to the findings from chapter 3. In relation to Covello’s (2021) description of trust determination theory, it may have been caused in part due to the personal conveying of the information as a human element to the communication that strengthens trust. In this case, the interviewer was a fellow resident of Tromsø holding similar stakes in the risk, likely impacting the trust. The extent to which the VR as a tool impacted trust is difficult to determine from this project’s output. When asked directly about their level of trust, the participants were often confused and struggled to answer it in an insightful manner, leaving this element of VR’s impact incomplete in this context and potentially due for further study.

7.2.5 LOD and Interaction

As stated by Meenar & Kitson (2020), simulations with more interactive features tend to increase memory and engagement. Dhunnoo et al., (2023) further evidenced that interactions with the living environment could draw up more emotional responses. As explained in chapter 4, the level of interaction was minimised due to time and knowledge constraints. When asking interviewees about how they would recognize the model faster or what changes they think would be conducive for stronger communication, interaction and LOD was occasionally raised as feedback points. For example including more facades, options to walk around or choose viewpoints themselves rather than asking the interviewer to trigger the changes for them. Following the findings from the literature review, this likely would have increased a degree of immersion and engagement, as well as potentially bringing the tool closer to simulating experiences as discussed in 7.2.4.

However, it should also be considered that this again might not always be a benefit. It quickly increases the cost of setting up the simulation, as well as is unlikely to provide increased engagement for all people. The interviewees with no prior experience with VR were satisfied with the simulation being shown and explained to them rather than taking control over it. C2, prior to the simulation also expressed fears of feeling unwell or fatigued during the simulation.

Some audiences may face a bigger hurdle if on top of experiencing a new VR technology they also have to navigate the controls in order to move about and interact with the environment. Depending on the set up of the controls and the length of the user wearing the HMD they may experience nausea or fatigue, a common side effect of VR simulations (Wohlgenannt et al., 2020). If interaction is a mandatory element it can overall hinder the accessibility of the tool. Hence the level of interaction, LOD and time spent experiencing the simulation should be adapted to who the audience is, what the aim is and the cost of the set up.

7.2.6 VR and Maps in Stakeholder Engagement and Communication

Throughout chapter 7 comparisons have been made between the interviewee's reactions to the VR simulation and the 2D interactive map. The VR has been described as generally more shocking, immersive, and engaging. But how does it hold up against Chapter 3 as a stakeholder engagement tool? Based on the *IAP2's* (2018) spectrum of public participation the set up and execution of the 2D map inherently falls under the category of *informing,* as the audience cannot provide input into relevant decision making. There might well be other engagement devices in place for sea level rise planning, however this thesis focuses on the 2D map and the VR output as risk communication specifically.

The execution of this thesis has not studied the implications within a specific planning project. A case was used to base the risk communication research in, but it was not executed as a participatory process. Rather it is a hypothetical scenario evaluating the impact the tools had on risk understanding and risk perception. Hence, this paper is significantly limited in evaluating VR as a public engagement tool alone within a planning project, especially considering the general difficulty of evaluating community engagement (Head, 2007). However a few relevant points come to light. Besides the fact that community engagement has been studied significantly in relation to VR, engagement has its relevant elements to risk communication.

As was mentioned in the chapter 2 literature review, VR can for example serve as a tool that lower barriers to engagement. Environmental literacy was found to be low, to which the output of a VR simulation is easier to digest that maps, especially for groups who are not used to reading maps (Jude et al., 2015; Poortvliet et al., 2020). This was further reflected in the interview findings, where all who communicated less experience with maps / awareness around the risk found the VR more impactful and easily understood (mainly C1-3). MP1-3 for example who all had more experience could point to understanding the same information being represented when comparing it to the 2D map.

Furthermore, a significant point in community engagement is the consideration of *control* and *responsibility. IAP2's* (2018) spectrum represents different levels of public control over a decision, not so as to say one is a superior choice to pursue but that the different levels can be appropriate for different projects. As noted they all have advantages and disadvantages. In the case of these interviews, *control* and *responsibility* were very common discussion points. Certain interviewees would feel a smaller sense of control throughout the interview, and a VR product that nurtures a sense of lacking control could impact engagement initiatives. As discussed prior the VR simulation could be adjusted for this, i.e. showing potential solutions or actions the audience could become involved in. Nonetheless, in this case all interviewees expressed different perspectives on who is responsible to control the risk. When asked directly who they believe should be responsible for tackling the risk consequences, C1-3 pointed to a local authority. LB1-3 would point to protecting some of their own assets, however they also pointed to local and national authorities. MP1-3 made the point that they themselves have limited control due to what needs to be prioritised and where funds are delegated to, thus depending on a higher authority.

In the case of this thesis, VR generally gave a sense of less control and more fear. Furthermore, it is difficult to apply to one of IAP2's (2018) levels as it was not directly part of any decision making, but evaluating its risk communication. If the VR simulation was modelled to communicate with the intention of facilitating a discussion around responsibility or control, it may be more applicable to engagement practices that prioritise the public's influence on decision making. Lastly, when considering the spectrum of public participation, VR has the potential to be a tool used within different levels in particular due to the nature of its execution. Currently it mostly is required to be in-person, hence is frequently implemented in workshops or focus-groups. Both the set-up and execution is costly. If VR equipment becomes more common, it may be that VR is also more appropriate in relation to these costs in an *informing*-level public engagement process.

7.2.7 Communication and informing

Throughout the execution of this thesis there has been an ongoing tension regarding the term *communication*. As discussed under chapter 3.2, risk communication has undergone a shift from *informing* to a *conversation* (Mabon, 2020). Bringing in diverse perspectives is becoming increasingly important to tackling a risk, as it broadens the understanding of its implications regarding the risk from more perspectives. This is in contrast with a more outdated approach where the experts or relevant authority are perceived as all-knowing and need to inform the public. As such, despite not being in collaboration with the Tromsø Havn project the interviews were also intended to be a dialogue, taking in knowledge and perspectives from the participants. This falls under occasional tension with the informing aspect. Aside from the intended two-sided conversation, there are different levels of environmental literacy as well as misconceptions that need to be taken into consideration (Berger & Wyss, 2021).

In a risk communication project the aim may be to raise awareness and address misconceptions, which can easily fall into being simply informing. This has been slightly imbalanced in this project, considering the communication *to* the stakeholders of the risk, as well as communicating *with* them their perceptions and understanding.

8 Conclusion

In short, the answer to the question of *does VR differently impact risk communication between urban planning stakeholders,* is yes. *Impact* in this research question is measured as difference in risk understanding and perception before and after experiencing the VR simulation as a communication tool. In line with previous research, VR overall impacted risk communication differently in comparison to verbal communication or interactive 2D maps. Furthermore, addressing the sub questions, this impact varied per individual and per stakeholder group. The tool has its limitations and benefits, and may be more or less appropriate to implement depending on both the aim of the communication, what the risk in question is and who takes part in the communication.

Some of the most significant and prevalent factors that were discussed during the interviews can be summarised as; Control, Understanding, Consequences and values. The local business owners might have had the greatest stakes in the area, but expressed less worry and change in risk perception due to their overall control and options over the consequences. Citizens expressed most worry and were most impacted, having overall the least control over the risk, as well as the largest sense of uncertainty having lower awareness. The municipal planners however, having extensively worked with the risk and having significant understanding about it were minimally impacted by the use of VR in risk communication, beyond the suggestion that VR can serve as a strong reminder for municipal workers or in competence building.

In determining these factors and setting up the method, the works from Sommer et al., (2020) and Covello (2021) have provided a very useful theoretical framework. These two works formed the bulk of the coding scheme and discussion. Some theories explored were not implemented to the same degree, notably creating a mental model of risk perception was not as appropriate to the execution of this thesis (Fischhoff et al., 1993). Similarly, the IAP2 (2018) framework despite its insight could not be fully explored. Although all theory explored could be connected to the findings to some degree, the scope of the research did not allow for all aspects to be fully represented, leaving notable room for further study to explore these elements under a more appropriate method. For example, many of Covello's (2021) factors of risk perception were irrelevant to the risk of this specific case study, and levels of trust in information sources were not well explored. Fostering a study regarding more diverse risks, and exploring the degrees and causes of (dis)trust could contribute to the body of literature around VR and risk communication tools.

As noted, costs of VR equipment and set up have significantly decreased rapidly, increasing accessibility. That is not to state that it still has its barriers. Most notably the requirement of being physically present to experience the simulation, hindering large scale accessibility in comparison to a web based solution available to all online. Furthermore this set up hinders deeper discussions, as this was not executed as a simultaneous experience for multiple stakeholders but only with one person at a time. As VR grows more accessible, more quantitative studies could potentially add further interesting insights in this growing field. The VR simulation within this thesis was furthermore created by a student without significant expertise, hence there are likely more cost effective approaches to developing the product.

Aside from overcoming the accessibility barrier, this thesis has been limited in the study of stakeholders. The three groups are broad, and despite the high amount of information that can be gathered through interviews, the discussion has raised more questions regarding different groups. For example within citizens and the surprising impact of children lead to questioning risk communication across age groups. Likewise, with local business owners, there are going to be significant differences between businesses who own the physical building and those who rent venues. The stakeholder groups, all relevant actors who might be affected or hold the power to affect the risk, are too diverse to fully explore in this project and are hence a significant point of further study.

Despite the limitations within this project, the findings do show that VR has a stronger impact on certain stakeholder groups than the 2D web services. With notable variety per group, the simulation surprised participants and changed risk perception and understanding. With the complexities of studying these elements, the changing risks, and the speed at which technologies develop, there remains much more to investigate to further narrow down how appropriate VR is as a tool within diverse risk communication cases.

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10 Appendix

Appendix 1.A - Information letter (English)

Are you interested in taking part in the research project

***"VR as a planning support system in risk communication"*?**

Purpose of the project
You are invited to participate in a research project where the main purpose is to *research emerging communication tools, namely Virtual Reality (VR), in urban planning. The project takes a specific focus on the potential of VR simulations in the communication of risks between different relevant actors. The research question, subject to minor changes, is as follows:*
"Does VR differently impact risk communication between urban planning stakeholders?"
The project is based around **the inner harbour Torghuken case, as developed by Tromsø Havn**.
The project is a master thesis for the programme Nordic Urban Planning Studies, for 30 ECTS spanning the spring semester of 2024 (January - June).

Which institution is responsible for the research project?
UiT - Norges Arktiske Universitet / Institutt for Samfunnsvitenskap.

Why are you being asked to participate?
Participants are asked due to their position being relevant to either future water-related risks in Tromsø, to the aforementioned Torghuken case, or to both.

What does participation involve for you?
The project methodology involves semi-structured interviews of approximately 1 hour. Participants will be asked to view a Virtual Reality simulation as a part of the interview process. The simulation will be shown through a head mounted device (meta quest 3), with questions being asked prior, during and after the simulation. The following data will be collected:

- *Electronic audio recording of the interview for transcription*
- *Hand written notes throughout the interview regarding the answers given*

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you choose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data
We will only use your personal data for the purpose(s) specified here and we will process your personal data in accordance with data protection legislation (the GDPR).

- *The Thesis is conducted by UiT student Wytske Kuipers. It is supervised by UiT professor Torill Nyseth and UiT Associate Professor Arild Buanes. Only the student Wytske Kuipers will have access to the data.*
- *Name and contacts will be coded throughout the project. The raw data and respective coding system will be stored separately on an external hard drive.*

Participants may be recognizable in the publication. Participants will be referred to by their position relative to the water related risks or the case study. As the study is about stakeholder communication, the stakeholder position will be disclosed (i.e. through their occupation, as a local business owner, a municipal planner, a visitor).

What will happen to your personal data at the end of the research project?
The planned end date of the project is *1st of July 2024. Upon its completion, and (if the participant wishes) the forwarding of a copy of the final product to the participants, all data will be physically discarded or deleted.*

Your rights
So long as you can be identified in the collected data, you have the right to:
- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent.

Based on an agreement with *UiT - Norges Arktiske Universitet / Institutt for Samfunnsvitenskap*, The Data Protection Services of Sikt – Norwegian Agency for Shared Services in Education and Research has assessed that the processing of personal data in this project meets requirements in data protection legislation.

Where can I find out more?
If you have questions about the project, or want to exercise your rights, contact:
- *UiT - Norges Arktiske Universitet / Institutt for Samfunnsvitenskap* via *Torill Nyseth through Torill.Nyseth@uit.no or Arild Buanes through Arild.Buanes@uit.no*
- Our Data Protection Officer: *Annikken Steinbakk, email: personvernombud@uit.no, phone: 00 47 776 46 153*

If you have questions about how data protection has been assessed in this project by Sikt, contact:
- email: (personverntjenester@sikt.no) or by telephone: +47 73 98 40 40.

Yours sincerely,

Torill Nyseth & Arild Buanes
(supervisors)

Wytske Kuipers
(student)

Appendix 1.B - Information letter (Norwegian)

Vil du delta i forskningsprosjektet
"*VR as a planning support system in risk communication*"?

Formålet med prosjektet
Dette er et spørsmål til deg om du vil delta i et forskningsprosjekt hvor formålet er å studere nye kommunikasjonsmetoder i byplanlegging, spesifikt Virtual Reality (VR). Prosjektet fokuserer på muligheten for VR simuleringer i risikokommunikasjon mellom forskjellige byplanlegging aktører. Forskningsspørsmålet (som kan forandres litt i fremtiden) er:

- *"Does VR differently impact risk communication between urban planning stakeholders?"*
- *Oversatt til norsk: "Påvirker VR risikokommunikasjon på forskjellige måter mellom aktører?"*

Forskningsprosjektet er basert på et pågående prosjekt av Tromsø Havn, som skal fornye byens Indre Havn ved Torghuken.
Forskningsprosjekter er en masteroppgave på 30 ECTs, som del av masteren Nordic Urban Planning Studies i vårsemesteret 2024 (Januari - Juni)

Hvorfor får du spørsmål om å delta?
Du får denne forespørselen fordi du er en relevant aktør til prosjektet ved Torghuken, til fremtidige havstigning risiko i Tromsø eller begge.

Hvem er ansvarlig for forskningsprosjektet?
UiT - Norges Arktiske Universitet / Institutt for Samfunnsvitenskap er ansvarlig for personopplysningene som behandles i prosjektet.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg. Du kan på et hvilket som helst tidspunkt trekke tilbake dette samtykket uten at det må begrunnes.

Hva innebærer det for deg å delta?
Deltakelse i forskningsprosjektet innebærer et intervju på cirka 1 time. Deltakere blir spurt om å bruke VR briller (meta quest 3) for å se en simulasjon av Torghuken som del av intervjuprosessen. Disse opplysningene vil bli samlet inn:

- Et elektronisk lydopptak av intervjuet for omskrivelse
- Håndskrevne notater gjennom intervjuet av svarene gitt av deltakeren.
- Deltakerens relevans i tilknytning til Torghuken eller havnivåstigning
- Deltakerens perspektiv om fremtidig havnivå risiko

Navn og kontaktinformasjon til deltakerne vil bare bli samlet inn for å kontakte deltakere for intervju. Deltakere blir anonymisert i prosjektet. Kontaktinformasjon blir ikke brukt.

Kort om personvern
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler personopplysningene konfidensielt og i samsvar med personvernregelverket.

Utdypende om personvern – hvordan vi oppbevarer og bruker dine opplysninger

- *Masteroppgaven tilhører UiT student Wytske Kuipers. Veiledere er UiT Professor Torill Nyseth og UiT Førsteamanuensis Arild Buanes. Bare studenten Wytske Kuipers har tilgang til alle personopplysninger.*
- *Navn og kontaktinformasjon av deltakere blir gitt koder i prosjektet. Kodesystemet og den rå data blir lagret på en ekstern harddisk.*

Sitater som ønskes bruk i oppgaven vil bli forelagt den siterte for sitatsjekk.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra UiT - Norges Arktiske Universitet / Institutt for Samfunnsvitenskap har personverntjenestene ved Sikt – Kunnskapssektorens tjenesteleverandør, vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- å be om innsyn i hvilke opplysninger vi behandler om deg, og få utlevert en kopi av opplysningene,
- å få rettet opplysninger om deg som er feil eller misvisende,
- å få slettet personopplysninger om deg,
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Vi vil gi deg en begrunnelse hvis vi mener at du ikke kan identifiseres, eller at rettighetene ikke kan utøves.

Hva skjer med personopplysningene dine når forskningsprosjektet avsluttes?
Prosjektet vil etter planen avsluttes 1. juli 2024.
Hvis deltakeren er interessert, blir prosjektet videresendt til dem etter avsluttningen.
Alle fysiske og elektroniske opplysninger vil deretter slettes.

Spørsmål
Hvis du har spørsmål eller vil utøve dine rettigheter, ta kontakt med:

- UiT - Norges Arktiske Universitet / Institutt for Samfunnsvitenskap gjennom Torill Nyseth, Torill.Nyseth@uit.no eller Arild Buanes, Arild.Buanes@uit.no
- Vårt personvernombud: Annikken Steinbakk, email: personvernombud@uit.no, phone: 00 47 776 46 153

Hvis du har spørsmål knyttet til Sikt's vurdering av prosjektet, kan du ta kontakt på e-post: personverntjenester@sikt.no, eller på telefon: 73 98 40 40.

Med vennlig hilsen,

Torill Nyseth & Arild Buanes
(veiledere)

Wytske Kuipers
(student)

Appendix 2.A - Consent form (English)

Consent form

I have received and understood information about the project *VR as a planning support system in risk communication* and have been given the opportunity to ask questions. I give consent:

- □ to participate in *an interview*

I give consent for my personal data to be processed until the end of the project.

(Signed by participant)

Appendix 2.B - Consent form (Norwegian)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *VR i risikokommunikasjon*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- □ å delta i et intervju

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

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(underskrevet av deltaker)

Appendix 3.A - Interview guide (English)

PRE-RECORDING

1. Introductions & introducing the project
2. Ask interviewee to read through information letter if they have not already done so
3. Request interviewee to sign consent form

- START RECORDING -

PART 1: INITIAL QUESTIONS

1. What is your relation to the Torghuken case area? (as a planner, case proximity, visitor etc.)
2. What do you see as important climate change related risks in Tromsø?
    a. What do you know about the sea level change in Tromsø?
    b. What do you know about storm surges in Tromsø?
3. What risk is most relevant/prevalent to you?
    a. Have you experienced the previously discussed risks?
    b. What consequences would these risks bring to your position (as a stakeholder)?
    c. Have you considered measures to control the consequences of this risk?
4. Where do you get information about sea level / storm surge risks from?
    a. Do you trust this source?
5. Ask about familiarity with Kartverkets Havnivå i Kart web-service
    a. If interviewee is unfamiliar, show the service and ask if they find it relevant to their personal situation

PART 2: VR SIMULATION

Present the VR simulation in the following order:

1. Show simulation of current day environment
    a. Do you recognize the location?
2. Show simulation of proposed harbour
    a. Explain the visual change
3. Show predicted storm surge impacts
    a. Explain the water level change and reasoning behind it

PART 3: DISCUSSION

1. *What did you think of seeing this simulation?*
2. *How did the simulation compare to your expectations of future sea level risks?*
3. If applicable, *How do you think this simulation compares to your prior source of water-risk information?*
    a. If the above is not applicable, *how does it compare to seeing the "Havnivå i kart" web-service?*
    b. *Do the tools communicate risk differently to you? If so, how?*
    c. *Do you see the scope of the risk differently?*
        i. *The potential consequences to your stakes(values)?*

ii. *Perceived control over the risk?*

4. ***Do you feel more positive or negative about the future risks now?***
5. *Do you think a VR simulation could impact other stakeholders? If so, how? (citizens, planners, local business owners)*

PART 4: CLOSING

1. *Do you have any additional experiences/information you would like to share?*
2. *Is there any additional information you recommend the interviewer to investigate?*
3. *Do you have further contact suggestions you believe the interviewer could request an interview from?*

- STOP RECORDING -

POST RECORDING

- Ask whether the interviewee would want a copy of the final work when complete.
- Clarify contact information in case of further questions.

Appendix 3.B - Interview guide (Norwegian)

FØR-OPPTAK

1. Introduksjon til prosjektet
2. Spør om deltakeren har lest gjennom samtykkeskjemaet
3. Spør deltakeren til å signere samtykkeskjemaet

- START OPPTAK -

DEL 1: BASIS SPØRSMÅL

1. Hvordan er du relatert til Torghuken (indre havn) området? (Planlegger, i nærheten, etc.)
2. Hva tror du er de største klimarelatert risiko i Tromsø?
    a. Hva vet du om havnivåstigning i Tromsø?
    b. Hva vet du om stormflo risiko i Tromsø?
3. Hvilken risiko er mest relevant til deg og din posisjon?
    a. Har du erfaring med havnivå / stormflo risiko? (Eller annen risiko som vi har snakket om)
    b. Hvilke konsekvenser har disse risikoene til din posisjon?
    c. Har du tenkt på hvordan du kan kontrollere denne risikoen / disse konsekvensene?
4. Hvor har du fått din informasjon om havnivåstigning / stormflo?
    a. Stoler du kildene?
5. Kjenner du til Kartverket's Havnivå I kart web-service?
    a. Er web-servicen relevant til deg og din posisjon?

DEL 2: VR SIMULATION

Vis VR simulasjonen:

1. Vis simulasjonen av torghuken i dag
    a. Kjenner du igjen hvor du står?
2. Vis simulasjonen av fremtidige torghuken
    a. Fortell om tromsø Havn
3. Vis 2090 havnivå og 200 års stormflo
    a. Forklar hva de ser på

DEL 3: DISKUSJON

1. *Hva syns du av å se den simulasjonen?*
2. *Hvordan var simulasjonen i forhold til dine forventninger av havnivåstigning og stormflo?*
3. *Hvordan var simulasjonen i forhold til din forrige kilde til havnivå / stormflo risiko informasjon?*
    a. *Hvordan var simulasjonen i forhold til kartverket's web service?*
    b. *Kommuniserer disse kildene risikoen på forskjellige måter? Hvordan?*
    c. *Ser du annerledes på risikoene og deres konsekvenser?*
        i. *Hvor farlig kan det være til deg og din posisjon?*
        ii. *Hvor mye kontroll kan du ha over konsekvensene dine?*
4. ***Føler du deg mer positiv eller negativt over risikoene etter simulasjonen***

5. *Tror du at en VR simulasjon kan ha en innflytelse over risikokommunikasjon mellom andre stakeholders? Hvordan?*

DEL 4: SLUTT SPØRSMÅL

1. *Har du noen flere erfaringer / informasjon du vil dele?*
2. *Er det noen informasjon du anbefaler jeg kan utforske videre?*
3. *Har du noen flere kontakter du anbefaler jeg kan spørre om en intervju?*

- SLUTT OPPTAK -

ETTER OPPTAK

- Spør om deltakeren vil ha en kopi av masteroppgaven når den er ferdig
- Gjenta kontaktinformasjonen i tilfelle de har videre spørsmål