HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Adaptation to extreme floods in urban land use planning

Case Helsinki

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Onerva Aula
Supervisors Janne I. Hukkinen &
Johan Munck af Rosenschöld

HELSINGIN YLIOPISTO

Tiedekunta - Fakultet – Faculty Faculty of Biological and Environmental Sciences		
Tekijä - Författare – Author Onerva Aula		
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Tiivistelmä - Referat – Abstract

This study aims to understand how cities adapt to environmentally induced hazards, like floods. Extreme floods are interesting firstly, because climate change is predicted to increase flooding in several places globally in the future, and secondly, because even a small risk could be realised in the right conditions.

The methods are a case study of flood adaptation in Helsinki, qualitative content analysis, interviews, and a scenario. Land use planning is chosen as the context of the case study, because densification challenges flood preparedness. The material consists of the zoning plan of Helsinki, its flood risk management related appendixes and interviews with city experts.

The qualitative content analysis aims to answer the first research question: How does land use planning consider extreme floods in Helsinki? The scenario, in turn, aims to answer the second research question: In what ways might an extreme flood challenge the current land use planning in Helsinki? The interviews are mainly used to support the other methods.

The results lead to one main argument, for which I present several justifications. The argument is that the flood risk management and land use planning in Helsinki, the urban structure of which is densifying, do not sufficiently consider the risk related to extreme floods, even though climate change is increasing the likelihood of such. In the end, I present some policy recommendations to change this.

Avainsanat - Nyckelord – Keywords
Adaptation, scenarios, case study, extreme floods, Helsinki, environmental policy

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Tekijä - Författare - Author Onerva Aula		
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Tiivistelmä - Referat – Abstract

Tämä tutkielma pyrkii ymmärtämään, miten kaupungit sopeutuvat ympäristölähtöisiin kriiseihin, kuten tulviin. Äärimmäiset tulvat ovat kiinnostavia ensinnäkin, koska ilmastonmuutoksen ennustetaan lisäävän tulvimista useissa paikoissa maailmanlaajuisesti tulevaisuudessa, ja toiseksi, koska pienikin riski voi toteutua oikeissa olosuhteissa.

Tutkimuksen metodeita ovat tapaustutkimus Helsingin tulvasopeutumisesta, kvalitatiivinen sisällönanalyysi, haastattelut ja skenaario. Maankäytön suunnittelu on valittu tapaustutkimuksen kontekstiksi, koska tiivistäminen haastaa tulviin varautumista. Materiaali koostuu Helsingin yleiskaavasta, sen tulvariskinhallinta-aiheisista liitteistä sekä kaupungin asiantuntijoiden haastatteluista.

Kvalitatiivinen sisällönanalyysi pyrkii vastaamaan ensimmäiseen tutkimuskysymykseen: Miten maankäytön suunnittelu ottaa äärimmäiset tulvat huomioon Helsingissä? Skenaario puolestaan pyrkii vastaamaan toiseen tutkimuskysymykseen: Millä tavoin äärimmäinen tulva saattaa haastaa Helsingin nykyistä maankäytön suunnittelua? Haastatteluja käytetään lähinnä muiden metodien tukena.

Tulokset johtavat yhteen pääväitteeseen, jota perustelen usein tavoin. Väite on, että kaupunkirakenteeltaan tiivistyvän Helsingin tulvariskienhallinnassa ja maankäytössä ei ole riittävästi huomioitu äärimmäisen kovien tulvien riskiä, vaikka ilmastonmuutos kasvattaa sellaisten todennäköisyyttä. Lopussa esitän politiikkasuosituksia asian muuttamiseksi.

Avainsanat - Nyckelord – Keywords
Sopeutuminen, skenaario, tapaustutkimus, äärimmäiset tulvat, Helsinki, ympäristöpolitiikka

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Glossary

Adaptation
Adjustments in ecological-social-economic systems that aim to reduce the risks related to the harmful impacts of real or anticipated climatic stimuli (IPCC 2001; Smit et al. 1999), like flood risk management.

City plan (*asemakaava* in Finnish)
City plans are a level of zoning that follow the zoning plan level (Kaupunkisuunnittelu-virasto 2016).

Coastal flood
A coastal flood means a temporary water covering of the ground due to a rise of the sea level (Parjanne et al. 2018).

Extreme flood / rare flood
A flood that is estimated to happen once in a hundred years on average or because of a 1/100a rainstorm (Parjanne et al. 2018) and is potentially significant (Casti et al. 2011).

Flood risk
A flood risk is a combination of the likelihood and the consequences of a flood. The consequences depend on the degree of danger and vulnerability. (Parjanne et al. 2018.)

Flood risk management
Legal efforts (Jaakonaho et al. 2015) to decrease flood risks and to react to and recover from their impacts (Pilli-Sihvola et al. 2018).

Fluvial flood
A fluvial flood means a temporary water covering of the ground due to a temporary rise of the water level in a water body (Parjanne et al. 2018).

Frequency rate
Frequency rates depict how often a certain water level is exceeded or a certain flow or rainfall occurs within a certain timespan, and it indicates the magnitude of a flood (Kahma et al. 2014; Parjanne et al. 2018; Suomen Kuntaliitto 2012). A frequency rate of 1/250a means that a flood of a certain size is estimated to happen every 250 years on average.

Pluvial flood
A fluvial flood means a temporary water covering of the ground due to accumulation of urban runoff (Parjanne et al. 2018).

Residual risk
Residual risk means those harmful impacts that can or cannot be prevented for technical or economic reasons and is considered acceptable (Parjanne & Huokuna 2014).

Vulnerability
The sensitivity of individuals, society and infrastructure to a potentially harmful or damaging phenomenon (Pilli-Sihvola et al. 2018).

Zoning plan (*yleiskaava* in Finnish)
Zoning plans are long-term land use plans that guide the development of the urban structure (Kaupunkisuunnitteluvirasto 2016).

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1 Introduction

Cases of extreme floods and rainstorms have been gaining visibility in Europe and worldwide. Disastrous events have demonstrated some of the possible consequences of exceeding the limits of flood risk management. Flood adaptation is an especially timely topic after the disastrous floods in Germany in 2021, which created startling devastation and even deaths (Cornwall 2021).

Extreme floods are interesting for at least two reasons. First, even a small risk could happen in the right conditions. In certain preparedness and scenario literature, extremes, uncertainties and small risks with high impact are taken seriously (e.g. Bruun et al. 2002; Buurman & Babovic 2016; Cornish 2003; Glenn et al. 2003; Lehtonen & Peltonen 2006; Mendonça et al. 2004; Petersen 1999). Second, this thesis leans on transformational adaptation approach, which has gained favour among adaptation literature (Munck af Rosenschöld & Rozema 2019). It is future oriented (Eakin et al. 2016) and finds extreme floods relevant, because the future is predicted to hold an increase in flooding due to climate change in several places globally (IPCC 2021).

This thesis investigates flood adaptation in Helsinki as a case of how cities adapt to environmentally induced crises. Climate change is predicted to increase flooding even to extreme levels in Helsinki (Aaltonen et al. 2008; Kahma et al. 2014; Mäkelä et al. 2016; Parjanne et al. 2018; Ruosteenoja et al. 2016; Veijalainen et al. 2012). I will examine how land use planning in Helsinki considers extreme floods in its flood risk management, and in what ways might an extreme flood challenge the current land use plans.[1] I conduct a qualitative content analysis to flood risk management strategies, analyse preliminary interviews with city experts and make a scenario. The findings imply that the land use planning in Helsinki may lack sufficient consideration of extreme floods. Despite, Helsinki densifies its urban structure, which may increase flood risks (Hamin & Gurran 2009) even further and challenge flood adaptation. In the end, I make some policy recommendations on how to consider extreme floods.

[1] This study is being conducted as a part of the LONGRISK project, which fo-cuses on decision support to manage the long-term growth of environmentally induced, complex and far-reaching multi-hazard risks in urban area.

2 Flood risks in Helsinki

Climate change takes varying forms regionally, and some climate change related risks are more relevant to certain regions than others (IPCC 2021). In many areas, climate change has been noticed to intensify precipitation and to increase sea levels extremely high (IPCC 2014; IPCC 2021). The city of Helsinki in southern Finland is one of these locations (Kahma et al. 2014; Ruosteenoja et al. 2016; Veijalainen et al. 2012). In Helsinki, climate change induces coastal, pluvial and fluvial floods (Pilli-Sihvola et al. 2018). A flood means a temporary water covering of the ground. Coastal floods are caused by a rise of the sea level, whereas fluvial floods are due to accumulation of urban runoff and pluvial floods due to a temporary rise of the water level in a water body. (Parjanne et al. 2018.)

In this chapter, I introduce relevant information about the increasing flooding and flood risks in Helsinki. I have investigated earlier literature and key reports related to floods and flood risks in Helsinki. Many of the reports were found from official government, public environmental administration and city websites. In subsections 2.1. and 2.2., I clarify the significance of coastal, pluvial and fluvial floods, introduce the concept of frequency rates and explain how densification and climate change contribute to flooding. In 2.3., I introduce the concept of flood risks and explain why they are rising. Ultimately in 2.4., I present the research questions based on the emerged knowledge gaps.

2.1 Coastal floods

The sea level is predicted to rise in Helsinki. Johansson et al. (2004) predict the mean sea level rise to be about 10-20 cm in the Gulf of Finland until the 2090's, while in a newer study, Johansson et al. (2014) predict about a 30 cm rise with an uncertainty range from –20 cm to +90 cm. Regardless of the exact numbers, some degree of sea level rise is likely due to the melting of glaciers (Parjanne et al. 2018). Even the post-glacial rebound effect, the slow on-going land uplift due to the removal of the pressure of ice sheets during the last ice age, will not be enough to stop it in the long term (Johansson et al. 2004; Johansson 2014). An increased sea level, in turn, increases coastal flood levels. In addition to the gradually rising sea level, it is realistic to expect abrupt sea level rises during the next hundred years in Helsinki (Lehtonen & Luoma 2006). They can be caused by extreme weather events like storm surges (Lehtonen & Luoma 2006) or strong winds (Johansson et al. 2014), as well as air pressure differences or the characteristic sea level fluctuation of the Baltic Sea (Parjanne et al. 2018). Shortly, the sea level of Helsinki is predicted to gradually increase during this century and go through sudden short-term rises, which both contribute to coastal flooding.

Frequency rates are a common concept to depict how often a certain water level is exceeded or a certain flow or rainfall occurs within a certain timespan, and it indicates the magnitude of a flood (Kahma et al. 2014; Parjanne et al. 2018; Suomen Kuntaliitto 2012). A frequency rate of 1/250a means that a flood of a certain size is estimated to happen every 250 years on average, and it gives perspective to whether a flood is rare or common. Parjanne et al. (2018) usually consider a 1/100a flood or a rainstorm as rare. Because an extreme event is defined as an “unlikely but potentially significant” event (Casti et al. 2011), rare and extreme floods and rainstorms are synonymous in this thesis. Thus, 1/100a and rarer floods and rainstorms are called extreme.

Both rare and common coastal floods are becoming alarmingly more frequent at many places both globally and in Finland, as the following numbers prove. IPCC (2021) claims with high confidence that the current 1/100a floods are to occur at least 1/1a at more than half of all tide gauge locations globally by 2100. In some places in Finland, current 1/100a floods may become 1/20a floods by the end of the century (Parjanne et al. 2018). In Helsinki, 1/1000a floods may become 1/100a by 2100. As for water levels, it would mean the following. In 2011, a 1/1000a flood was estimated to be +231cm in water level, and in 2100, a 1/100a flood might be +257 cm (Kahma et al. 2014.) Coastal floods are especially meaningful for coastal cities like Helsinki. The estimations of how much more common extreme coastal floods are becoming in Helsinki are noteworthy and important justifications for choosing Helsinki as a case.

2.2 Pluvial and fluvial floods

One reason why pluvial floods, aka urban floods, are significant is that Helsinki densifies. About 600 000 inhabitants are expected to move into Helsinki region by 2050 (Kaupunkisuunnitteluvirasto 2016). Densification is practiced as an attempt to mitigate climate change, as it reduces car travel and building energy (Hamin & Gurran 2009), but it can be problematic for adaption to floods. That is, densification happens to the detriment of surface absorbing capacity (Parjanne et al. 2018) and thus intensifies flood risks (Hamin & Gurran 2009). The more non-absorbent surface, the quicker and heavier urban runoff. Urban runoff means rain or meltwater that accumulates on the ground, roofs or other similar surfaces in thickly built areas. (Suomen Kuntaliitto 2012.) Importantly, a big share of non-absorbent surface is one of the factors causing uncontrollable pluvial floods (Suomen Kuntaliitto 2012). Despite, pluvial flood risks are not often taken into account in planning (Parjanne et al. 2018).

In addition to the abovementioned impacts of densification, climate change is expected to increase precipitation (Ruosteenoja et al. 2016) and strengthen rainstorms in Finland, especially in the summertime (Aaltonen et al. 2008; Veijalainen et al. 2012), which may also worsen pluvial floods. To conclude, densification together with increasing precipitation and rainstorms will increase pluvial floods in Helsinki. The size of a pluvial flood is often described with the rainfall that causes it (Suomen Kuntaliitto 2012), and there are some frequency rate estimations for rainfall (Aaltonen et al. 2008). For example, extreme 1/100a rainstorms are estimated to become about 1/30a at the end of the century (Mäkelä et al. 2016).

In addition to coastal and pluvial floods, there are fluvial floods. In Helsinki, fluvial floods occur when the Vantaanjoki watershed surface rises and small streams flood. The most significant reasons for them are increased precipitation, rainstorms and snowmelt. (Pilli-Sihvola et al. 2018.) In the earlier literature and key reports examined, there seems to be no mention about how frequent extreme fluvial floods might become. In the apparent absence of exact frequency rates, only general comments can be made about the exact extent to which fluvial floods may increase in Helsinki. Generally speaking, Helsinki will experience less melt-water in the spring but more precipitation overall, more meltwater in the winter, more autumn rains and more summer rainstorms due to climate change (Aaltonen et al. 2008; Veijalainen et al. 2012), which may mean more fluvial flooding from summer to winter. The potential increase of both pluvial and fluvial flooding justifies choosing Helsinki as a case.

2.3 Flood risks

The occurrence of floods is not a problem as such. An area can experience multiple heavy floods but has no flood risks – for example if it is an uninhabited and unbuilt area. The size of a flood risk is determined by a combination of likelihood, degree of danger and vulnerability. Vulnerability means the sensitivity of individuals, society and infrastructure to a potentially harmful or damaging phenomenon (Parjanne et al. 2018; Pilli-Sihvola et al. 2018).

Due to the grown significance of data communications and traffic systems and dependence on electricity, societies have become even more vulnerable to the impacts of weather extremities like storms and floods (Maa- ja metsätalousministeriö 2014). Also, objects that are vulnerable to climate impacts, like buildings and critical infrastructure, concentrate in cities. Densification changes flood risks by centralising and increasing risk potential in cities. (Parjanne et al. 2018.) Due to the combination of densification and climate change, coastal, pluvial and fluvial flood risks are predicted to increase in Helsinki (Hamin & Gurran 2009; Pilli-Sihvola et al. 2018; Johansson et al. 2004; Johansson et al. 2014).

As flood risks are increasing in Helsinki, it is essential to consider how are they managed. Without additional measures, flood risks are estimated to begin escalating around 2050 and double or triple in Finland by the end of the century, and it is recommended to prepare for them beforehand (Parjanne et al. 2018). However, despite the amount of preparation, not all risks can be prepared for (Parjanne et al. 2018).

Some extreme events inevitably lie outside the limits of management. Yet, if it is already known that extreme coastal floods and extreme rainstorms may become significantly more common within a century (Kahma et al. 2014; Parjanne et al. 2018), is it considered in the flood risk management of today? The question seems especially relevant for land use planning, as it is a sector, which must anticipate climate change impacts in its decisions for decades onward (Maa- ja metsätalousministeriö 2014).

Land use planning has been chosen as the focus area of this study, because land use decisions are crucial in adaptation. Climate change, land use and societal operability seem to have a robust link among each other. Climate change affects most sectors in the city, and land use decisions relate to all societal factors, as they determine the physical dimensions of society and impact the vulnerability of locations. (Juhola 2016.)

There are indications that the building pressure offers a significant challenge for fitting land use and flood protection together in Finland (Peltonen et al. 2006). It seems problematic to densify, while extreme flooding is increasing. Are the predicted extreme floods sufficiently considered in the land use planning of today, or instead, might we notice in a few decades that extreme floods damage the infrastructure that is built today?

According to Aaltonen et al. (2008), if unacceptable extreme rainstorms are estimated to occur, their management is planned together with the emergency services department. However, must extreme rainstorms cause emergencies every time they occur? With increasing frequency of severe flooding, recovery from emergencies may become cumulatively more difficult. Instead, might there be some improvements to be made in the current flood risk management that are within the reach of land use planning?

2.4. Research questions

Now that we know this much about flood risks in Helsinki, the following research questions arise.

1. How does land use planning consider extreme floods in Helsinki?
2. In what ways might an extreme flood challenge the current land use planning in Helsinki?

3 Conceptual framework

Conceptual framework depicts what is known about a phenomenon, identifies knowledge gaps and contours the methodological basis of the study. Researcher constructs the conceptual framework by choosing what is important, aims to prove the relevancy of the research and shows how it attempts to fill knowledge gaps. (Varpio et al. 2020.) I have depicted some parts of the phenomenon already in the previous chapter, where I introduced the flood risks in Helsinki. Because many climate change impacts are regional (IPCC 2021), conducting a case study is justified.

I continue by contouring how will I answer the research questions. I will utilise the information presented so far and the concepts of adaptation and scenarios, which I will introduce next. The methods have been chosen accordingly: a case study, a qualitative content analysis to relevant land use documents, interviews with city experts and a flood scenario. The empirical material analysed via these methods helps to answer the research questions.

Flood risk management consists of adjustments that aim to reduce harmful climate related risks, and thus it falls under the domain of adaptation (IPCC 2001; Smit et al. 1999). I will familiarise with the concept of adaptation in 3.1. Understanding adaptation in general might help to understand the broader implications of the single case of Helsinki. In 3.2., I introduce scenarios, as scenario making is a method to imagine events that we might need to adapt to.

3.1 Adaptation

The role of climate change adaptation has been growing in relation to mitigating climate change. In this thesis, climate change adaptation is defined as adjustments in ecological-social-economic systems that aim to reduce the risks related to the harmful impacts of real or anticipated climatic stimuli (IPCC 2001; Smit et al. 1999). In addition to the long dominant mitigation strategies that aim to reduce greenhouse gas emissions and decelerate climate change (Klein & Schmidt-Thomé 2006), policymakers have begun to consider adapting to the local impacts of climate change (Aguiar et al. 2018; Lorenzoni et al. 2000). A major reason is that even if anthropogenic greenhouse gas emissions were drastically reduced, the changes they cause will last for long due to the inertia of the climate system. Hence, many impacts of climate change are inevitable regardless of the amount of mitigation. (IPCC 2014; IPCC 2021; Parry et al. 1998.) For example, the deep ocean has a lengthy reaction time, and the global sea level is predicted to rise for centuries (Church et al. 2013; IPCC 2001) or even millennia (IPCC 2021).

Urban areas are not only key actors in driving the environmental change by emitting most greenhouse gases and extensively exploiting natural resources but also ever more the targets of the impacts of change (Juhola 2016). Extreme weather events that can build up from for example a storm, a flood or a rainstorm (Tennberg & Vola 2014) are likely to test the cities the most, as cities hold characteristics that aggravate their impacts (Carter 2011). Therefore, it is worthwhile to investigate how cities adapt to environmentally induced crises. So far, I have explained why adaptation is growing and why it is important in cities. Next, I will go deeper into what kind of adaptation is there.

Defining what is a harmful climatic stimuli and what kind of adjustments to make in ecological-social-economic systems calls for an approach. There are various types of adaptation (IPCC 2014), and transformational-incremental duality is a common distinction in the adaptation literature (Termeer et al. 2016). The incremental adaptation approach focuses on keeping up the business-as-usual practices and adapting by technological fixes (Dewulf 2013). It is to react to perceived and experienced extreme weather events (Storbjörk & Hedrén 2011), and thus it seems to lack the acknowledgement of previously unseen events. A concrete example of the approach could be to build robust infrastructure against floods by utilising historical evidence. Dislike of incremental approach has caused calls for a transformational approach (Munck af Rosenschöld & Rozema 2019), which is future-oriented and embraces dynamism, uncertainties and resilience (Eakin et al. 2016). It could be simplified that incremental approach is to adapt by regarding the past while transformational approach is to adapt by regarding the future.

There are notable uncertainties related to which climate scenarios could actualise in the future, and even abrupt changes could take place (IPCC 2021; Church et al. 2013). The outcomes of the scenarios are very different. By the end of the century, the global mean surface temperature can increase from 1 °C to

5,7 °C. (IPCC 2021.) As the future is estimated to consist of increasing uncertainties and unpredictable and unprecedented extreme phenomena (IPCC 2021), preparing for the future according to history seems insufficient. Thus, this thesis leans towards the future-oriented transformational approach and focuses on the future, uncertainties and how to manage them.

Floods are an apt example of a climate change impact that contains considerable uncertainties. The predicted global sea level rise in the 21st century ranges between 0,28 m and 2 m (IPCC 2021). Moreover, flood severity could be surprisingly high and stronger than earlier. For instance, there are remarkable uncertainties related to the ice-sheet contribution to the global sea level rise. Collapsing ice sheets of the Antarctic and Greenland could cause a notable sea level rise, even dozens of centimetres. (Church et al. 2013.) Thus, transformational approach could prove particularly useful in adapting to floods. These findings will be utilised in the qualitative content analysis, where I will be looking for signs from relevant land use documents whether the flood risk management in Helsinki is extreme and future considerate, i.e., whether it represents transformational approach.

3.2. Envisioning and anticipating extreme floods through scenarios

To answer the second research question, "In what ways might an extreme flood challenge the current land use planning in Helsinki?", I utilise scenarios. Scenarios are a means to manage uncertainties (Buurman & Babovic 2016), and as depicted earlier, uncertainties are a major factor to acknowledge in climate change adaptation. Events unveil from an unpredictable sequence of preceding states (Gould 1989), and scenarios can be used to outline these potential sequences and to envision possible futures. Thus, choosing scenario making as a part of this study is in accordance with transformational adaptation approach, as both try to deeply involve with the future and its uncertainties.

One who wants to be precautious, takes extremes seriously. Taking note of the worst-case scenarios is important for preparedness and taking care of public safety (Lehtonen & Peltonen 2006). As scenarios of even the smallest likelihood could actualise in the right conditions, preparing according to the mere average scenarios may not be enough. Most planners and futurists agree that planning should not be done only according to the most likely outlook (Glenn et al. 2003). The traditional way of policy making centres on best estimations and scenarios but could result in suboptimal system performance. Nonetheless, system design, planning and engineering are normally prepared for the most expected changes. (Buurman and Babovic 2016.) So, despite their importance and usefulness, extreme scenarios might be insufficiently used.

As extreme scenarios are of special interest in this study, I investigated some earlier literature related to them. Bruun et al. (2002) divide scenarios into trend-based and event-based. Event-based scenarios depict the future in a non-linear way, present events that are external to observable trends, admit that the past does not always manage to foretell the future and concentrate on small events that “can influence not only other small events but even the pattern of change” (Bruun et al. 2002). Extreme events, unlikely events and weak signals, i.e. early warning signs of surprising and broadly impactful events (Cornish 2003; Mendonça et al. 2004) can be investigated by means of event-based scenarios. Based on this, they seem remarkably useful in anticipating the uncertain future – especially considering that the more the climate warms, the more the risks of sudden changes grow (IPCC 2014; IPCC 2021).

Despite the usefulness of event-based scenarios, most scenarios are trend-based. They assume that the past reflects the future, and they often have high, low and a few middle values. Hence, they lack some aspects that are essential for preparedness, like surprise. Although trend-based scenarios are the most used, it may not be sufficient to merely rely on them. As trend-based scenarios cannot deal with surprises, they should be reinforced with event-based scenarios (Bruun et al. 2002). Glenn et al. (2003) suggest a collection of scenarios to be used in planning. If the scenarios widely cover the future and if plans are made to correspond to them, the future can be met with some degree of confidence. The more one can anticipate, the better one has capability to manage change. (Glenn et al. 2003.) In this study, there is capacity to craft and reflect only one extreme event-based scenario. It aims to envision one possible future, and it could be utilised as groundwork for further scenario making. However, it seems worthwhile to manufacture many different ones.

So far, I have told that there are two important adaptation approaches: transformational and incremental, and two important scenario types: event-based and trend-based. Notable is that the transformational approach and event-based scenarios have resemblances. They both are in demand, and they take the future and uncertainties into account (Bruun et al. 2002; Glenn et al. 2003; Munck af Rosenchöld & Rozema 2019). Thus, they together seem like a functional basis for adaptation to extreme future floods, and a useful foundation for the methods of this study.

I will utilise the components of transformational adaptation approach and event-based scenarios as follows. I will look for mentions of future floods, extreme floods and uncertainties related to floods in relevant land use documents in the qualitative content analysis. The review of relevant earlier literature and key reports conducted in chapter 2 has also helped to formulate key words to look for in the analysis. Moreover, I will craft an event-based scenario to answer the second research question.

4 Materials and methods

4.1 Materials

4.1.1. Written material

Information to fill the needs of this study can be found in the field of zoning. Zoning is a meaningful part of land use planning, because it is responsible for how densification and the related flood risk management are being conducted. It outlines municipal area use, long-term land use and urban structure. (Kaupunkisuunnitteluvirasto 2016.) It oversees placing new buildings and other infrastructure, which influences the size of flood risks (Parjanne et al. 2018).

The zoning plan (*yleiskaava* in Finnish) is a long-term land use plan that guides the development of the urban structure for about ten years at a time (Kaupunkisuunnitteluvirasto 2016). Above the zoning plan, there is the Land Use and Building Act (132/1999), which assigns national area use goals (Valtioneuvosto 2017) that aim to ensure considering nationally significant matters in zoning, like climate change adaptation and flood management. The national area use goals tell to prepare for the impacts of weather extremities, floods and climate change.

The national area use goals include flood risk management goals and say that flood danger areas must be considered, and flood risks pursued to be prevented. However, they do not define how to execute the goals. Instead, the execution is left to the zoning plan level and its subsequent levels. The national level cannot implement upper-level adaptation strategies at the local level (Juhola 2016) and it can mainly influence municipalities by legislation and recommendations (Juhola et al. 2012). Advice on how to adapt in land use planning cannot be found in neither the national area use goals nor the national adaptation strategy (Maa- ja metsätalousministeriö 2014). Instead, Finland has strong local government (Juhola et al. 2012), and the city of Helsinki holds the monopoly over land use decisions (Juhola 2016). The zoning plan is also made by the city of Helsinki (Kaupunkisuunnitteluvirasto 2016).

Due to the generality and long execution time of the zoning plan, flood risk management can only be done in its following stages, like the city plans (*asemakaava* in Finnish) (Kaupunkisuunnitteluvirasto 2016). In fact, city plans are the most important stage for long-term preparing for climate change impacts (Kaupunkisuunnitteluvirasto 2015). However, going through all of them would excessively expand this thesis. The zoning plan is an apt and sufficient choice for this study, because it is narrow enough to inspect and it creates the frames and requirements for its following stages (Kaupunkisuunnitteluvirasto 2016).

The written material of this study consists of the following. The zoning plan is updated every ten years or so, and the newest zoning plan 2016 became valid in 2018 (Kaupunkisuunnitteluvirasto 2016). The zoning plan deals with flood preparedness specifically in its techno-economic report (Kaupunkisuunnitteluvirasto 2015), where it names ten reports to give some baselines for the following planning stages. Moreover, the separate zoning plan for Helsinki underground (Kivilaakso et al. 2009) is included, as underground construction matters for overall risk management (Lehtonen & Luoma 2006).

The ten abovementioned reports for further planning stages consist of a legal flood risk management plan for 2016-2021 (Jaakonaho et al. 2015), a common flood strategy (Kaupunkisuunnitteluvirasto 2008), a building elevation guide (Parjanne & Huokuna 2014), a flood situation guide (Helsingin kaupunki 2013), legal preliminary urban flood risk assessments (FCG 2011; SITOWISE 2018), an urban flood sensitive area assessment (FCG 2012), an urban runoff water program (Helsingin kaupunki 2018), a future oriented urban runoff management report (FCG 2007), a legal Vantaanjoki watershed flood risk management plan for 2016-2021 (Suomalainen et al. 2015) and a Vantaanjoki river action plan (Suhonen & Rantakokko 2006).

To conclude, the written material consists of 13 documents: the zoning plan of Helsinki, its techno-economic appendix and the ten flood risk management report appendixes in it and the underground zoning plan. In this thesis, they are called *the flood risk management strategies* and often referred to merely as strategies. See Appendix 1 for their reference list.

4.1.2. Interview material

In addition to the written material, I utilise interview material. Interviews are used to get research material that is then analysed and interpreted to solve a research problem (Hirsjärvi & Hurme 2000). Preliminary interviews, as the ones in this study, are informal and unstructured. They aim to find out which topics the discussants find significant and which should be explored more. (Bell 2010.) The preliminary informal discussions with city experts were executed as a part of the LONGRISK project. In this study, the interviews are mainly a confirmative source of information to support the findings from the written material.

The interviews were led by a colleague researcher, and I participated as a research assistant. A total of four (4) discussions were conducted via the video conferencing tool Teams. Each lasted for about an hour. Moreover, I interviewed one (1) expert from HSY via email about the measurements of the sewer system.

The interviews were held between March and May in 2021, and they were held in Finnish as all participants are native Finnish speakers.

The search for the city experts was done mainly by my colleague. Suitable contacts were found through the city webpage or by snowball sampling, which means that experts were asked to suggest other experts as resources (Lavrakas 2008). All were contacted directly by email. More people than the four discussants were contacted but no response was received. The interviewees are experts from HSY and the Urban Environment Division of the city of Helsinki. HSY stands for the Helsinki region environmental services, and it is responsible for the sewer system. The expertise of the discussants are land use, zoning, climate, urban environment, traffic and urban runoff.

The interviews were guided, which means that there were selected topics and a question to guide the interview, but the respondents were free to talk about the topics in their own pace (Bell 2010). The city experts of Helsinki were approached with the question “What environmentally induced crises keeps you awake at night?” that the rest of the conversation developed on. The aim was to lead the project forward by improving understanding of what kind of potential environmental crises there are that may not be that well under control. From the point of view of this study, the interviews were a confirmatory opportunity for me to ask questions related to flood risk management and densification, which had risen from the written material along the research.

4.2 Methods

The method used to answer the research questions is a qualitative case study analysis with a triangulation of data sources: the flood risk management strategies and the preliminary discussions and the email interview with the city experts. To answer the second research question, also a scenario is made.

4.2.1. Case study

A case must be a definite entirety, like an event, an individual, an entity, a decision, a program, an organisational change or an implementation process (Yin

2009). In this study, the case is flood adaptation in Helsinki, which is a case of how cities adapt to environmentally induced crises. Case studies (Eriksson & Koistinen 2014) are relevant when investigating adaptation, because adaptation to climate change is place and context specific (IPCC 2014). This study utilises contextual approach, which means that the case is desired to be understood as a part of its environment (Eriksson & Koistinen 2014), which I have defined to be land use planning.

A case study lacks a universal definition, but it could be described as a method that aims to define, analyse and solve a case (Eriksson & Koistinen 2014). The researcher is an active interpreter, who decides and justifies what is interesting in a case (Eriksson & Koistinen 2014). There are different types of case studies. This study is an illustrative one. Illustrative case studies offer information of the dominant nature and form of practices and depict matters that are reached in certain contexts (Ryan et al. 1992). This case, flood adaptation in the context of land use planning in Helsinki, may represent and illustrate aspects of the larger theme of how cities adapt to environmentally induced crises, but the case is wanted to be understood deeply without necessarily making generalisations of it. This is usually why case studies are chosen as a method. Case studies do not pursue one correct truth about a case, but rather assume that there are many versions of reality that depend on the situation and the actors. (Eriksson & Koistinen 2014.)

A case study is worth to choose as a method also for example, when how-questions are central, the researcher has little control over the phenomenon or there is little empirical research on the topic (Yin 2014). These characteristics make it suitable also for this study. Researchers face the same difficulties with case studies as with other approaches. Yet, a laborious analysis phase may provide a special challenge. (Eriksson & Koistinen 2014.) Each method has its benefits and drawbacks but combining many of them can provide more comprehensive information of the case and verify the results (Eriksson & Koistinen 2014). Utilising and combining different data sources is typical for case studies (Eriksson & Koistinen 2014), and their use is a classic evaluation meter for case studies (Laine et al. 2007).

4.2.2. Qualitative content analysis

Research material must be organised, analysed and interpreted (Eriksson & Koistinen 2014). It ought to be studied systematically and similarities or differences must be looked for (Saaranen-Kauppinen & Puusniekka 2006). In this study, qualitative content analysis and coding are used as tools to analyse the written material and to answer the research questions. Qualitative content analysis is a basic analysis method used in all traditions of qualitative research that enables objective and systematic analysis of different documents (Tuomi & Sarajärvi 2018). Coding means to give names to and mark relevant contents in the material (Eriksson & Koistinen 2014), which eases its handling (Saaranen-Kauppinen & Puusniekka 2006). Codes can emerge from the collected material or from earlier research or theory (Erikkson & Koistinen 2014).

Content analysis is divided into three categories: data-driven, theory-based and theory-guided (translated by author). Theory-guided analysis means that the units of analysis arise from the material, but earlier literature guides the analysis. (Tuomi & Sarajärvi 2018.) The analysis is not directly based on theory, but the connections can be seen (Saaranen-Kauppinen & Puusniekka 2006).

A theory-guided content analysis was conducted to the material in five phases. First, based on the earlier literature and the key reports introduced in the chapters 2 and 3, the following codes were created: coastal floods, pluvial floods, fluvial floods, future floods, future climate, flood size, flood risks, rare floods, extreme floods, densification, flood preparedness, regional climate change, uncertainties, scenarios, incremental adaptation and transformational adaptation. Second, the material was investigated. I read and skimmed the nearly 1000 pages of the strategies and highlighted essential parts that were even of slightest interest. Finding out that the zoning plan is valid for about ten years raised wonder about whether modifications to it could be made amidst the term if a flood crisis challenged the plan. Thus, the additional codes of modifiability and path dependency arose from the material. In addition, issues around management responsibilities emerged and formed another code.

Third, I formed themes. After the first familiarisation round with the material, I began classification, which is to look for combining or separating entireties

(Saaranen-Kauppinen & Puusniekka 2006). I simplified the codes into groups and bundled similar groups into one another. This ultimately formed the themes of climate change, flood adaptation, flood risks, coastal floods, pluvial floods and fluvial floods. Fourth, as in theory-guided analysis, the findings from the material were interpreted, explained and reinforced with theory (Saaranen-Kauppinen & Puusniekka 2006). The earlier literature and the key reports were revised, and early results were drafted in documents named after the themes. Fifth, I revised the highlighted parts of the material, and wrote down the most meaningful parts to be analysed further. Thus, the analysis was iterative.

4.2.3. Preliminary interviews

Next, I explain the method behind analysing the interview material. Because the preliminary interviews were informal and their main purpose was to find important topics to be explored more (Bell 2010) for the LONGRISK project, they were not recorded nor written down word-to-word. Yet, some written notes were taken to remember the content. The email interview was permitted to be used literally. After each interview, me and the other researcher discussed shortly what we considered as key findings.

The interviewees are anonymised in the notes. They are named with numbers: Interviewee 1, Interviewee 2 and so on. Anonymised interview notes are stored at the P drive of the University of Helsinki and are destroyed at the completion of the LONGRISK project. The interview material is only at the use of the researchers of LONGRISK.

The interview notes cannot be directly referred to as exact quotes, because the discussions were informal, and errors may have occurred in capturing the conversation and interpreting the notes afterwards. The discussions mainly aid me to confirm whether I am on the right track with my observations drawn from the written material and earlier literature. When relevant, they are brought up along the analysis.

4.2.4. Scenario

By creating an extreme event-based scenario, I answer the research question 2: "In what ways might an extreme flood endanger the current land use plans?" Scenario making is one of the few tools to envision the uncertain future (Buurman & Babovic 2016). Glenn et al. (2003) suggest defining a domain of interest when constructing scenarios. In this study, it is the intersection of land use, climate change and floods (see Figure 1).

The scenario does not follow the average acceleration speed of climate change but includes its rapidly progressing elements and cascading and compound issues. The scenario aims to fall out of the average, the likely and the foreseeable. The flood event is on purpose rarer and bigger than what the strategies prepare for. It aims to bring up aspects that may challenge land use planning. For a justifiable illustration, I utilise the written material, the preliminary interviews and the climate change and scenario related literature and the key reports that were introduced in the chapters 2 and 3. Moreover, I rely on the national and regional risk assessments (Sisäasiainministeriö 2019; Uudenmaan alueellisen riskiarvion työryhmä 2018). Thus, the events are completely plausible – not pure imagination or fiction.

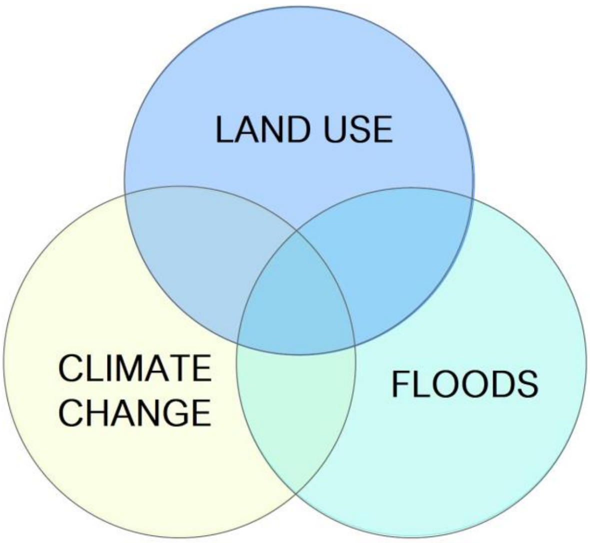

Figure 1. A cross domain graph/a VEN diagram of the domain of interest of the scenario.

5 Results

In the previous chapter, I have explained how I have organised and analysed the material. Next, I present the results of the analysis. In 5.1. and its subchapters, I explore how the flood risk management strategies consider extreme floods. Based on these discoveries, I craft a scenario in 5.2. Finally in 5.3., I examine how the scenario challenges the strategies and draw support from the interviews. Some discussion between earlier literature and results is presented in this chapter and more will follow in chapter 6.

5.1 Flood risk management

5.1.1 Defining significant flood risks

To recognise how land use planning considers extreme floods in Helsinki, one must first look at the legal procedure behind recognising significant flood risks in Finland. According to the flood risk law (Laki tulvariskien hallinnasta 620/2010), an area can be defined as a significant flood risk area after the pre-evaluation of flood risks. In the pre-evaluation, the significance of a flood risk, its likelihood, regional and local conditions and the potentially damaging consequences are assessed. A very rare 1/1000a flood must cause notable harmful consequences to the five criteria below (Jaakonaho et al. 2015; Suomalainen et al. 2015).

- Damaging impact on the health or safety of people
- Long-term interruption of a necessity service, like water or energy maintenance, data communications, road traffic or other similar
- Long-term interruption of economic activities that secure the vital functions of society
- Long-term or pervasive damaging impact on environment
- Unrepairable damaging impact to cultural heritage. (Laki tulvariskien hallinnasta 620/2010.)

Due to its growing population, zoning pressure, traffic communications that become cut in a flood situation and other vulnerable necessity services, the coastal area of Helsinki and Espoo has been named as one of the 22 significant flood risk areas of Finland (Jaakonaho et al. 2015; Laki tulvariskien hallinnasta 620/2010). Relatively, Helsinki does not have legally significant fluvial or pluvial flood risk areas. Yet, some legally significant fluvial flood risks are recognised (Jaakonaho et al. 2015; Laki tulvariskien hallinnasta 620/2010; Suomalainen et al. 2015) whereas pluvial flood risks are not (FCG 2011; SITOWISE 2018).

In addition to pluvial flood risks, conditional flood events are not considered legally significant. Conditional flood events are events like compounding floods, in other words a simultaneous combination of different types of floods, or floods that are caused by a dysfunction (FCG 2011; SITOWISE 2018). Despite the lack of legal recognition, objects that suffer from such floods can be named as special targets. Even though no legally significant pluvial flood risks are currently recognised, many pluvial flood risks are named as special targets (SITOWISE 2018). However, the significance of special targets remains obscure, as the strategies do not directly tell how they are managed. Kaupunkisuunnitteluvirasto (2015) tells that in the stages after the zoning plan, an urban runoff management plan is composed for zoning destinations that may experience significant urban runoff impacts. This probably concerns special targets, and it might mean that they are dealt with after the zoning plan level. Thus, the management of special targets and any other targets that are not covered in the strategies fall out of the scope of this study.

5.1.2. The significance of flood maps and management plans

Legally significant flood risks are managed in the land use planning in Helsinki as follows. Flood danger maps, flood risk maps and flood risk management plans are composed and revised every six years (Laki tulvariskien hallinnasta 620/2010). However, the plans are not binding and do not oblige any facet to execute them. Officials must consider the plans in their activities, but the strategies do not specify how. (Jaakonaho et al. 2015; Suomalainen et al. 2015.) This seems to somewhat deteriorate their practical meaning.

As legally significant coastal and fluvial floods have been recognised, they have flood maps and management plans. Instead, as no significant pluvial flood risks have been declared, there is no legal obligation for composing flood maps or a flood risk management plan for them. I wanted to verify that there are no such maps, and I investigated more of the earlier literature and the key reports that were introduced in chapter 2. They revealed that some pluvial flood maps exist, but they are not public, they have a large margin of error, and they are only directional and serve municipalities as a preliminary evaluation tool (Sane et al. 2021). Pluvial flood risks are more complicated to estimate than coastal and fluvial flood risks (Parjanne et al. 2018). This is a central result. Having no sufficient certainty about where pluvial floods could strike and what kind of impact they might have may result in issues in managing them.

Moreover, climate change impacts have not been considered in the coastal and fluvial flood maps (Pilli-Sihvola et al. 2018). As the flood risk management plans are based on the flood maps, they also mainly correspond to the current flood risks and climate (FCG 2011; Jaakonaho et al. 2015) - not to the flood risks that climate change is predicted to inflict. It might mean that the management is manufactured short-sightedly. However, there is currently a novel project called TIIMA where the aim is to update all flood maps, create pluvial flood maps, and produce flood maps that consider climate change, especially for areas where climate change will increase flooding (Suomen ympäristökeskus 2021), which seems beneficial for future land use planning.

Despite the knowledge gap related to pluvial flood maps, land use planning has been practicing densifying in its long-term decision making. Densification changes greatly the urban runoff flow and increases pluvial floods and the amount of potential flood risk objects (FCG 2011; SITOWISE 2018). Its consequences may be uncertain. The lack of quality pluvial flood maps together with densifying that increases pluvial floods poses an unquantified but plausible danger in managing pluvial flood risks.

To summarise, the practical significance of flood maps and management plans is questionable, as there does not seem to be obligations to follow them. Also, they are made according to current flood risks and climate, which might cause the management to be short-sighted. Moreover, the lack of pluvial flood maps together with densifying may cause challenges to flood risk management, and the importance of that lack cannot be enough emphasised. Long-term infrastructure is built even though there apparently is information missing about how increasing pluvial floods may impact the infrastructure.

5.1.3. Acceptable risks

Next, I investigate what the strategies consider as sufficient flood risk management. Flood risks can never be fully removed nearby water bodies. Instead, a small risk always remains. A residual risk means those harmful impacts that can or cannot be prevented for technical or economic reasons and is considered acceptable. (Parjanne & Huokuna 2014.)

The flood risk management plans aim to prepare for no bigger than 1/100a and 1/250a coastal and fluvial floods in their management goals (Jaakonaho et al. 2015; Suomalainen et al. 2015). Because floods that are rarer than 1/100a are defined as extreme floods (Parjanne et al. 2018), it can be said that the management plans aim to manage extreme coastal and fluvial floods. Some examples of the management goals are that 1/100a coastal floods must not be let to cause property damage and cultural heritage sights must be protected from 1/100a coastal floods and vital economic activities from 1/250a coastal and fluvial floods. Exhaustive reasoning for these definitions is missing, but supposedly the reasons are mainly economic or technical. There are some exceptions to these measures among the lowest building elevation recommendation that embrace extreme floods even more (see chapter 5.1.4).

As for pluvial floods, most of Helsinki has a runoff sewer system, which is commonly measured for about a 1/2a rain (FCG 2007). Interviewee 5 wrote (27.4.2021) that the measurements have been updated to 1/3a rains. Still, the runoff sewer system alone is insufficient for the predicted extreme rainstorms. FCG (2007) considers it to be reasonable that the sewers are not measured for extreme rains and that some rain situations cannot be fully managed. Instead, there are flood routes, where the runoff is led to. They are measured for distinctly rarer rainstorms than the separate sewer system or other urban runoff systems (Suomen Kuntaliitto 2012). Yet, their measurements were not found. Hence, it remains unclear whether the combination of the separate sewer system and the flood routes is sufficient to manage extreme pluvial floods.

To summarise, land use planning manages coastal and fluvial floods up to 1/250a and pluvial floods at least up to 1/3a but perhaps more. These numbers provide the limits of the flood risk management in land use planning. The remaining harmful impacts seem to be accepted as the residual risk. At this point, it is important to notice that extreme coastal and fluvial floods are aimed to be managed, but extreme pluvial floods are seemingly not. Considering that flooding is predicted to become more common and frequent in Helsinki (Kahma et al. 2014; Parjanne et al. 2018), the current management may not suffice in the future. So far, I have defined the limits of flood risk management in land use planning. Next, I explain how floods are managed within those limits.

5.1.4. Management of coastal and fluvial floods

The Centre for Economic Development, Transport and the Environment (the ELY centre) is responsible for the assessing and managing of coastal and fluvial flood risks (Suomalainen et al. 2015), and there are different responsible agents for pluvial floods. The national area usage goals tell not to locate new construction in flood danger areas, like the coastal area of Helsinki, unless their flood risk management is ensured. (Valtioneuvosto 2017.) Building on flood risk areas is usually possible with different technical means, says Kaupunkisuunnitteluvirasto (2015). Nonetheless, because all applicable areas are already built as efficiently as possible, even areas that suit poorly for building, like low-lying areas and areas with poor soil, are introduced for building without special actions according to FCG (2007). Therefore, there are contradicting statements about whether the necessary flood risk management is always sufficiently ensured as far as building is considered.

Land use planning tries to decrease the potential damages of floods and to prevent the flood risk from increasing (Suomalainen et al. 2015), which sounds like a rather deliberative and strategic approach. Its coastal and fluvial flood management actions relate to zoning, building orders, lowest building elevation recommendations, which means the recommended first floor elevation, and setting up protection for single electricity, gas, heat, data communications and water distribution structures (Jaakonaho et al. 2015).

The land use planning in Helsinki prepares for coastal and fluvial floods mainly by building sufficiently high from the water level (Jaakonaho et al. 2015) to avoid vulnerable infrastructure from getting wet (Parjanne & Huokuna 2014). The need for urban planning reaches further into the future than 2100 until which scientifically justifiable calculations are possible to be made. Thus, the recommendation is to build above the sea level of such floods that are 1/250a in 2100. (Parjanne & Huokuna 2014.) This seems to be the only management action that has been shaped according to estimations of the future. Yet, it is not transparent what climate scenario was used. In comparison, the lowest building elevation recommendation for fresh waters is based on current 1/100a floods (Parjanne & Huokuna 2014). Based on this observation, coastal floods seem to receive a special importance in Helsinki.

The lowest building elevation recommendations differ from the flood risk management plan goals by that they prepare for more extreme floods. The most vulnerable infrastructure, like hospitals and objects that are vital for the operability of the society, like big industrial and power plants, should be located so high that they do not get wet even with a 1/500a flood (Parjanne & Huokuna 2014). By contrast, insignificant, flood resilient or waterproof objects can be discretionarily located lower than the lowest building elevation recommendation (Kaupunkisuunnitteluvirasto 2008). However, sometimes having buildings locate below the recommendation is unintended. For instance, much old infrastructure and many old premises have been built below the current lowest building elevation recommendations in the vulnerable downtown (FCG 2007).

To summarise, there seems to be a fundamental contradiction in terms of whether the flood risk management is sufficiently ensured at the new building sites at the coastal flood danger area. Land use planning aims to strategically decrease flood damages and control flood risks. One of its most central coastal and fluvial flood management actions is the lowest building elevation recommendation, which varies depending on the quality of the location. Some of the recommendations embrace more extreme floods than the legal flood risk management plans and some even take the future climate into account, which seems to represent a relatively cautious and future-oriented approach.

5.1.5. Management of pluvial floods

Municipalities are responsible for the assessment and management of pluvial floods (Laki tulvariskien hallinnasta 620/2010; Parjanne & Huokuna 2014). There is not as clear a set of management actions for pluvial floods as there is for coastal and fluvial floods. Instead, the key finding is the distinction between the management in downtown and the rest of the city. The downtown has a mixed sewer system, while elsewhere the urban runoff is separated from the sewage, as Interviewee 1 explained. Downtown also has old infrastructure and older city plans with outdated flood management that do not correspond to the current strategies.

Flooding of the runoff sewer and the mixed sewer system in downtown are considered as one of the biggest urban runoff related problems in Helsinki. The Finnish administration locates mainly at the downtown, and in a heavy flood situation, the functioning of the critical systems, that matter to the operability of the Finnish society, may be disturbed. When the mixed sewer system in downtown floods, impure sewage ends up in the sea and the sewage may flood inside buildings. Urban runoff may enter and damage buildings, infrastructure, and property. (FCG 2007.)

The sensitivity to floods can be tempered by advancing the urban runoff systems and increasing the distribution of separate sewer systems into areas of mixed sewer system (FCG 2012; Tulvastrategia 2008). Additional runoff sewers have been built to support the mixed sewer system in the downtown, but more might be needed in the future (FCG 2007). In addition to the sewer system, flood damages can be prevented by decentralising pluvial floods through infiltration, delay mechanisms and flood routes (Aaltonen et al. 2008), but the strategies do not mention how big floods they can take. Because the quality of all technical fixes cannot be reviewed in this thesis, the focus is more on the general management measures. However, as mentioned before, pluvial flood risk management seems to lack a clear set of actions and measures.

To summarise, it is challenging to estimate how sufficient the pluvial flood risk management is in relation to extreme floods, because it lacks explicit measures. However, it can be at least said that a heavy flood in downtown can accumulate into disturbances in the operability of the whole Finnish society. The downtown is more vulnerable to floods than the rest of the city, because it has older infrastructure, older city planning and a mixed sewer system.

So far, I have explained how flood risks are defined, how significant the flood maps and the flood management plans are, what are the accepted limits of the flood risk management and how are floods managed within those limits. Next, I illustrate how might an extreme flood look alike in the light of the strategies.

5.2 Scenario

In August 2023, the sea level is exceptionally high due to the natural fluctuation of the Baltic Sea, and concurrent storm winds make it reach its record height. Yet, the sea level surprisingly rises even more, as a weathered ice boulder in the ice sheet of Greenland rapidly detaches. The sea level reaches about +2,60 meters, which signifies a flood rarer than 1/1000a. Soon, a rapidly developing and progressing thunder and rainstorm arrives from the south. Within three hours, Helsinki receives 20 % of its annual precipitation. The rain peak is estimated to be 1/1000a. The coast, streets and Vantaanjoki watershed flood. The wind speed is 35 m/s on average and its gusts even 42 m/s, which causes trees to fall on buildings, people, cables and roads.

Reacting in time is challenging, as a set of severe floods emerge fast, and the management responsibilities in such an exceptional situation are unclear. Warnings and the extreme weather forecast do not reach nearly enough citizens in time, and many rely on the help of the municipal forces. People jam the public safety answering point with their calls. As many places flood within a short notice, and resources to respond to all of them are finite, rapid prioritisations between locations are made. Reaction to floods in unpredicted sites is slow. Emergency services department, health services, sea rescue department and police are soon overburdened.

Sea water and rainwater cause havoc in the streets. The coastal flood is particularly long and lasts for twelve hours. Some necessity services are temporarily cut like heat, water and electricity distribution and phone and data communications. As the flood damages the data communications services, operative actions in the flood situation are disrupted and delayed. As there are critical governmental and business activities in downtown, regional disruptions turn into nationwide problems. A wide three-hour long power cut turns off the traffic control systems and traffic lights and stops commuter trains and trams completely. Together with the rough weather, it causes jams and accidents.

Infrastructure gets damaged. Water enters and damages basements and other underground premises like subway, pedestrian tunnels and underground parking lots and disrupts their use. Sea water hits especially the old residential areas built on low-lying areas, like downtown. Salty water damages cars, cargos and other belongings at the harbours.

As many runoff sewers in Helsinki are measured only for common rainstorms, they overflow soon. Because leading the sewage to the purification plant requires pumping and electricity, all the sewage had to be discharged into the sea during the power cut. Some of that sewage rose to the streets along the flooding sea water causing a health hazard.

Soon after the crisis, it is time for the decision makers to gather for budget revision negotiations for land use planning. There is disappointment in the flood risk management, as the devastation and expenses are major. The crisis has evoked concerns among people who are investing in the new seaside districts like Kruunuvuorenranta, Jätkäsaari and Kalasatama. They worry whether the flood crisis negatively influenced people’s interest in living by the sea, and whether densifying is a worthwhile direction. There is also a backlash from citizens. Many of those who live by the coast complain that they have not been aware of how serious the risks beyond management are.

There are some open questions dividing opinions among the decision makers. Should there be changes in the budgeting, the strategies and the ongoing land use projects? Will land use planning want invest in being able to manage these kinds of extreme floods or will it continue to consider such risks as acceptable residual risks? Moreover, what could land use planning do instantly to improve management?

5.3 Utilising the scenario in land use planning

The scenario above illustrates some of the ways how an extreme flood might look alike with the current flood risk management, and thus answers the second research question. Next, I examine how might such an extreme flood challenge the current land use planning. I examine the opportunities to utilise the scenario in land use planning, because making scenarios is not the end goal. Instead, they can be utilised in policy making. The scenario ended with open questions, and I will discuss them with the help of the written and interview material.

5.3.1. Potential overconfidence in management

When the city experts were approached with the question “What environmental crises keeps you awake at night?”, three interviewees gave comments that implied their confidence in that Helsinki can manage environmental hazards – especially with their city plans. Interviewee 4 said that the city plans are always techno-economically well composed, and thus the infrastructure rarely experiences big threats. Interviewee 1 was especially confident with new districts with novel city plans and that Helsinki can overall adapt to climate change. They acknowledged that extreme weather conditions increase, but added that in the conditions of Helsinki, the risks are not so enormous that they could not be controlled. Interviewee 3 said that Helsinki can ideally adapt to climate change by anticipating the upcoming crises and preventing them from happening with city planning solutions.

Both the interviewees and the strategies agree that the city plan level is important in flood risk management (Kaupunkisuunnitteluvirasto 2015; Kaupunkisuunnitteluvirasto 2016). However, there seems to be discrepancy between the interviews and the strategies. There is confidence that the management measurements are sufficient among the three abovementioned interviewees, while the strategies state that some floods are beyond management. Potential overconfidence in city planning may cause the flood risk management to be insufficient for upcoming extreme floods.

However, a wider sampling is required to confirm whether such confidence exists among city experts at large. Also, the statements of the interviewees are quite vague. Moreover, it remains unclear how aware the city experts are of different crisis scenarios. For example, the scenario presented in chapter 5.3. is beyond control in many ways. It is an example of an extreme flood, which does not gain legal significance, because a combination of coastal, pluvial, and fluvial floods and their synergistic impacts are considered conditional (FCG 2011; SITOWISE 2018), and 1/1000a floods are outside of the techno-economic limits of the flood risk management. Not being aware of possible scenarios might influence how the city experts view the management sufficiency and how willing they are to modify the strategies.

5.3.2. Hindrances in management

Next, I discuss what kind of obstacles there may be for changing the strategies or the on-going land use projects. First, executing a new type of flood risk management may take time. Interviewee 1 said that the land use department is not very reactive. Instead, crises may reveal problems and pressure to make strategic changes. Interviewee 4 stated that short-term emergencies do not yet cause the big aims in city planning to be changed, like enabling urban growth.

Second, even if there was clarity about what should be done to flood risk management, it may have to be compromised with other interests in zoning. Zoning is complex and has more aims than only responding to climate change, said Interviewee 3. The entirety must be considered, and prioritisations and compromises made. Zoning plans are thus not perfect plans, but they rather balance different interests and fit them together, they concluded. Techno-economic limits are likely key matters in defining if proposals pass or not. Juhola (2016) and Hamin and Gurran (2009) have pointed out the same about strategic land use planning, adaptation and competing goals.

Third, some of the strategies say to follow the IPCC reports for climate information and update accordingly (Jaakonaho et al. 2016; Parjanne & Huokuna 2014; Suhonen & Rantakokko 2006) but they do not say what kind of climate information might be the turning points to change the measures in the strategies. As depicted earlier, extreme floods are becoming more common in Helsinki, even tenfold (Aaltonen et al. 2008; Kahma et al. 2014; Mäkelä et al. 2016; Veijalainen et al. 2012), and some of the current management measurements may prove insufficient by 2100. It remains unclear, whether such estimations are found reasonable enough for changing the current management measurements. If not, it awakes wonder, what is then, or whether it has been predefined at all what kind of findings, events or milestones must first appear. If no referential points for changing management are predefined, it could lead into confusion and inertness at the moment when action is needed.

Fourth, there seems to be issues with management responsibilities. Adaptation can portray as a wicked problem of governance, when communicative aspects are considered (Dewulf 2013), which seems to fit this case. Interviewee 1 said that the flood risk management is under the influence of so many operations, that they are not sure if it is under the control of anyone – and if not, that deficiency may arise if something happens. Interviewee 3 said that Helsinki has inevitably the problem of a big organisation, meaning that because it has been cut up into parts, the interfaces cause fraction. Also, FCG (2007) brought up scattered responsibilities and said that responsibilities may have to be deliberated more frequently in the future if heavy rainstorms and flooding increase. Deficiencies in the division of responsibilities may challenge management. For example, the flood risk management facets may not know which responsibilities to take, which decisions to make or who should lead.

Fifth, even if there emerged a need to shortly change the strategies, it is unclear whether it would be possible due to time restrictions. The strategies do not clarify whether they can be changed in the middle of their periods of validity. The zoning plan is valid for about ten years and the flood risk management strategies for six. Not being able to change the strategies amid their term is potentially problematic. It could result in entire districts being built and flood risk management being conducted in an unfavourable way for years. If they cannot be changed amidst the term, it might take even years before the new and desired flood risk management can be implemented.

To somewhat summarise this chapter, I explored how the strategies consider extreme floods in 5.1. In 5.2., I illustrated some of the ways how an extreme flood might look alike with the current flood risk management. In 5.3., I examined the opportunities to utilise the scenario in land use planning and discussed some of the possible obstacles in changing the strategies or the on-going land use projects. Next, I intertwine the findings into the conceptual framework and earlier literature.

6 Discussion

So far, I have examined the flood risk management strategies in respect to extreme floods, investigated the interview material, envisioned a flood crisis scenario, and examined some potential issues in managing such. The scenario illustrates possible consequences of an extreme flood that is beyond the current management. For understandable techno-economic reasons and finiteness of resources, not every scenario can be prepared for. Some extreme event will inevitably remain outside the reach of management. However, it is reasonable to inspect what type of additional and realistic management could be taken up. Based on the analysis, there is room for land use planning to strategically improve its capacity to adapt to the plausible future flood hazards in Helsinki. In this chapter, I cover some policy recommendations and future research needs and evaluate this study.

6.1. Policy recommendations

Based on the results, land use planning could try establishing at least the following type of management of extreme floods. First, reassessing whether there are legally significant pluvial flood risks seems worthwhile. Helsinki is considered to have legally significant coastal and fluvial flood risks, but no pluvial flood risks (FCG 2011; Jaakonaho et al. 2015; SITOWISE 2018; Suomalainen et al. 2015). SITOWISE (2018) explains the lack of legally significant pluvial flood risks by saying that one damaged target does not yet equal a significant impact, because in a city of the size of Helsinki, societally meaningful services are provided by many actors. Still, the national and regional risk assessments (Sisäasiainministeriö 2019; Uudenmaan alueellisen riskiarvion työryhmä 2018) claim that damaging events like nationwide societal disturbances are possible due to pluvial flooding in downtown. Moreover, it must be noticed that due to the lack of quality pluvial flood maps, there may be vulnerable targets that still go unnoticed. Parjanne et al. (2018) also say that pluvial flood risks are often not considered in planning. Due to this discrepancy between the materials and considering that extreme rainstorms are increasing in Helsinki (Mäkelä et al. 2016), it seems questionable to assume that there are no legally significant pluvial flood risks.

Second, investing shortly in creating quality pluvial flood maps seems fundamental. They would help to assess whether there actually are legally significant pluvial flood risks and how to conduct densification securely. Densification together with increasing precipitation and rainstorms will increase pluvial floods in Helsinki, cause uncontrollable flooding and increase flood risk potential (Aaltonen et al. 2008; Parjanne et al. 2018; Ruosteenoja et al. 2016; Suomen Kuntaliitto 2012; Veijalainen et al. 2012). Building pressure challenges flood protection (Peltonen et al. 2006). If pluvial floods are not properly anticipated, it leaves the managing parties with uncertainty, which again may complicate flood risk management. Considering this, it seems rather odd that long-term infrastructure is being built without certainty about where pluvial floods could hit and thus what kind of impact they might have on the infrastructure. The current lack of quality pluvial flood maps questions whether densification is a secure long-term course in land use planning. The existing uncertainty seems to call for creating the pluvial flood maps in haste. The TIIMA project, which was mentioned earlier, finishes in 2023 and thus it is not ready before the next six-year long term (2022-2027) of the strategies begins. Thus, it becomes important whether the strategies can be modified in the middle of their term to correspond to the novel flood maps. This study could not tell whether there are opportunities to change the strategies. Not being able to modify the strategies during their term may cause harmful path dependencies.

Third, reconsidering whether to include future floods, like compounding floods, in the current flood risk management seems reasonable. Estimating whether the coastal, fluvial, and pluvial flood areas overlap and creating maps for compounding floods could be a start. Such a future-oriented outlook would represent the transformational adaptation approach (Eakin et al. 2016). As coastal, fluvial, and pluvial floods are estimated to become more common in Helsinki (Aaltonen et al. 2008; Kahma et al. 2014; Mäkelä et al. 2016; Veijalainen et al. 2012), their chances to occur simultaneously also increases. Thus, reassessing whether to include compounding floods in the flood risk management seems justified. Because there may be synergy between the impacts of compounding floods, they may cause surprising events. Even though the national and regional risk assessments address compounding floods to some extent, they are excluded from the current flood risk management in land use planning. If compounding floods are not soundly anticipated, it accumulates uncertainty and may complicate flood risk management.

Fourth, more transformational adaptation approach could be integrated into flood risk management by including different climate change scenarios. The current flood maps, which work as the basis of the flood risk management, are based on current climate (FCG 2011; Jaakonaho et al. 2015). Thus, the flood risk management goals are set according to the current flood risks and climate – not according to the potential flood risk that climate change may increase (FCG 2011; Jaakonaho et al. 2015). Only the lowest building elevation recommendation represents future-orientedness in its measurements (Parjanne & Huokuna 2014). The fact that most of the management is based on historical data and does not consider future floods may be interpreted to represent incremental adaptation approach, which is reacting to perceived and experienced extreme weather events (Storbjörk & Hedrén 2011). Preparing for increasing uncertainties according to history can be insufficient. Instead, literature supports the transformational approach and future-orientedness as a worthwhile direction for adaptation (Munck af Rosenschöld & Rozema 2019). Thus, flood maps for different future climate scenarios could be created, and some future-orientedness could be integrated into all the management measurements where there yet is none. The management measurements could correspond to future extreme floods and set the limits higher than the current 1/100a and 1/250a for coastal and fluvial floods and 1/3a for rainstorms. For example, the pluvial flood risk management measures could consequently be set for extreme floods, and the separate sewer systems could be distributed more widely, especially into the vulnerable downtown.

Fifth, to include even more of the future-oriented transformational adaptation approach in the flood risk management, a continuous scenario making practice could be begun. Scenario making is a useful tool to tackle uncertainties (Buurman & Babovic 2016), but this analysis could not find out whether such is already taking place. Glenn et al. (2003) recommend using a collection of scenarios in planning. If the scenarios cover a wide span of futures and plans are made to correspond to them, the future can be met more confidently. Scenarios become useful only when used to evaluate policy (Glenn et al. 2003). Scenarios not only represent the future, but also create it (Bruun et al. 2002), because as the decisionmakers choose what scenarios guide the policies and planning, the society is shaped accordingly. Management could aim to embrace the future but also acknowledge that estimations of the future change continuously. Management of extreme floods could be enhanced by outlining and predefining potential turning points that could trigger a change in policy. Inspired by the adaptation pathways by Buurman and Babovic (2016), management measurements tailored for each flood scenario could be exercised when the circumstances hit a trigger point, like widening the sewers, installing porous pavement, changing building materials, beginning a sewer system expansion project or reshaping the urban structure completely. Flexibility allows making changes along the emergence of new information, unexpected circumstances or changing planning criteria. Assimilating such a management policy could be one way to utilise scenario making. Moreover, if the pathways were roughly designed beforehand, finalising them may take less time, when action is needed. Such an anticipatory tactic could suit land use planning – considering that it generally makes decisions slowly. Such might ease making thorough and deliberate decisions fast, which seems to be a skill that land use planning is currently lacking. As the last policy recommendation, the issues with the management responsibilities could be clarified, because it might smooth out the management and making changes in policy.

6.2. Helsinki case in relation to earlier literature

Even with single case studies, it is good to consider the results in a broader scale (Eriksson & Koistinen 2014). The Helsinki case represents some aspects of how cities adapt to environmentally induced crises. Extremes are normally not prepared for in planning, engineering and policy making (Buurman & Babovic 2016). This seems to partially be the case in Helsinki, too. Land use planning aims to manage extreme coastal and fluvial floods (Jaakonaho et al. 2015; Suomalainen et al. 2015), but not extreme pluvial floods, according to Interviewee 5 and FCG (2007). Neither the increasing of extreme floods nor rainstorms is considered in most of the management. Some of the current extreme floods are aimed to be managed, but those management measures may fall short over time. Moreover, this case study confirms that building pressure offers a major challenge for fitting land use and flood protection together in Finland (Peltonen et al. 2006).

It could be very useful for the flood risk management in the land use planning in Helsinki to utilise transformational adaptation approach and scenario making, which both are future-oriented, embrace uncertainties (Bruun et al. 2002; Buurman & Babovic 2016; Glenn et al. 2003) and have gained favour among adaptation literature (Munck af Rosenschöld & Rozema 2019). There are plenty of uncertainties related to future floods (IPCC 2021; Church et al. 2013), which are increasing in Helsinki (Aaltonen et al. 2008; Kahma et al. 2014; Mäkelä et al. 2016; Veijalainen et al. 2012). However, most of the examined flood risk management does not seem to represent the transformational adaptation approach. Moreover, it remains unclear whether land use planning utilises scenarios.

6.3. Future research needs

The produced results and the identified knowledge gaps of this study may assist in broader research related to how cities adapt to environmentally induced crises and flood risk management in Helsinki or other urban areas. First, this analysis proved that zoning plan level may not alone reveal comprehensive enough information about the case. Instead, also the city plan level could be considered, because the strategies are being executed there. Land use planning may have capabilities to respond to future challenges that did not come up in the analysed zoning plan level strategies. Because no city plan level document could be fitted into this study, some relevant piece of information may have been excluded. One could expand the research into the city plan level, investigate the city plans and interview city plan managers, say, with the following questions: How does the land use planning in Helsinki prepare for extreme floods in its city plans? Has there been scenario work? Do the city plans consider that the planning criteria may change, for example as new climate change information emerges?

Second, pluvial flood risks and compounding floods are classified as special target, which are not included within the limits of flood risk management. This analysis could not reveal how the floods are managed, which fall outside those limits, and it could be investigated in another research. Third, the legal flood risk management plans are not binding but they must be considered (Jaakonaho et al. 2015; Suomalainen et al. 2015). Further research could clarify what practical impact such non-obligatoriness has on management; for instance, how much leeway it gives, and how much of the executed flood risk management corresponds to the plans as such. An existing adaptation strategy does not yet equal its implementation due to many challenges known as the barriers to adaptation (Juhola 2016). In this case, non-obligatoriness could be seen as such a barrier.

Fourth, it could be examined are the strategies locked in their periods of validity or whether they can be modified in the middle of their term, for example to correspond to novel flood maps. If there is no margin to change, there may be ten-year and six-year long path dependencies. It may cause that new infrastructure is built and outdated flood risk management conducted for years in an undesirable way, even if a need to change the ways arose. Fifth, the ELY centre is responsible for assessing and managing of coastal and fluvial flood risks (Suomalainen et al. 2015), while municipalities correspond to pluvial floods (Laki tulvariskien hallinnasta 620/2010; Parjanne & Huokuna 2014). As the responsible facets are different, their policies to evaluate and manage flood risks may differ, and further research could examine how and why.

Fifth, Helsinki is being densified regardless of the questionable amount of knowledge about how densification contributes to the increasing pluvial flooding and the lack of extreme pluvial flood management plans. As densification is a mitigation attempt (Hamin & Gurran 2009), and flood risk management classifies as adaptation (IPCC 2001; Smit et al. 1999), it seems like some mitigation goals may be run over adaptation goals in Helsinki. Strategic planning, like land use planning decisions must consider other factors besides adaptation (Juhola 2016), and there is not always guidance for solving conflicts between mitigation and adaptation in urban policy decisions. Once conflicts between competing goals are identified, strategic planning intends to resolve, overcome, or offset them. (Hamin & Gurran 2009.) Further research could examine what kind of competition or conflict there are between mitigation and adaptation in the flood risk management in Helsinki, and how could land use planning balance them.

Sixth, Dewulf (2013) has concluded from climate change adaptation literature that there is a "tension between framing climate change adaptation as a tame technical problem that can be solved by experts, and framing climate change as a wicked problem of governance, where uncertainties, institutions, and equity need to be taken into account”. The first framing can be seen as incremental approach and the second as transformational approach. Framing matters, because different frames lead to different policy responses (Dewulf 2013). Some of the interviewees expressed confidence in the management and the city plans, even though the strategies say that some floods are beyond management. This may refer to that the city experts consider flood adaptation mainly as a technically manageable problem, which represents incremental approach, but a wider sampling is needed to see how common such a view is.

Seventh, three city experts expressed confidence in the current flood adaptation in land use planning. However, it remains unclear how aware the city experts are of environmental crisis scenarios. It could be interesting to investigate if the city experts viewed the sufficiency of the current flood risk management differently after being exposed to extreme flood crisis scenarios.

Eight, there are results referring to framing adaptation as a wicked problem of governance. In Helsinki, even if the technical fixes in the city plan level themselves were trustworthy, their management may not be. Shortages in the fluency of flood risk management appeared in this study, and they could be investigated further in another study.

Last, there are a few knowledge gaps. I could not find an estimation about how frequent extreme fluvial floods might become in Helsinki, and the apparent absence of their frequency rates is a knowledge gap to be filled. Moreover, the measurements for flood routes were not found. Further research could delve into finding them and estimating whether they are sufficient to correspond to the increasing extreme pluvial floods.

6.4. Self-assessment

The aim of this study was to see how cities adapt to environmentally induced crises and specifically how extreme floods are being adapted to in the land use planning in Helsinki, and I consider the aim to be filled. Triangulation of data sources have been utilised to ensure a rich analysis of the case. Yet, there are areas of improvement and matters to acknowledge that may have affected the results.

At first, this thesis leans on estimations and they impact the results. Estimations about the frequencies of floods or the sizes of flood risks are mere estimations after all. Long observation periods aid to calculate, how often a certain water level is exceeded on average, but the evaluations include lots of uncertainties related to modelling and the length of the observation period (Parjanne & Huokuna 2014). As for assessing flood risks, the sea level scenarios and economic growth cause the most uncertainties (Parjanne et al. 2018). So, different estimations might have caused different results.

As for the critique of this study, I have gathered seven points. First, the city plan level had to be excluded from this study, even though it is an important part of executing flood risk management. However, focusing on the zoning plan level may have served the purpose of this study enough, as it has limited and guided the focus to stay on adaptation policy instead of lingering on technical details. This study has aimed to see adaptation as not a mere matter of technical solutions, but also as a matter of policy. Policy drives the decisions on adaptation and defines matters like what is a harmful climatic stimuli and what kind of adjustments to make in ecological-social-economic systems. Second, this study could have been enrichened by involving the concept of resilience. It may have had been useful for reflecting and assessing the success of adaptation, and it would have impacted the results.

Third, because the flood risk management is limited by techno-economic reasons, investigating the financial aspects could have brought more depth into the analysis but they had to be left out of this thesis due to their extent. Financial aspects impact decisions like whether to prepare for rare floods with expensive soil filling action beforehand or whether to fix the property damages afterwards. Fourth, because reading about a thousand pages of reports is plenty to skim and to code manually, some humane negligence of important notions may have occurred. Fifth, thanks to LONGRISK project, I got access to interviewing some city experts, but not all their backgrounds were in zoning or floods. I might have been able to gather more accurate results if I had conducted the interviews specifically with zoning plan experts.

Sixth, it must be noticed that in preliminary interviews, which are informal discussions, the role of the discussant may slide from an organisation representative to an individual. Hence, the results could have been reinforced with more formal interviews. Seventh, Glenn et al. (2003) suggest a set of scenarios for planning. I could have made a few shorter scenarios instead of one long one. This scenario depicts events and trends as they could develop, which makes it an exploratory or descriptive scenario (Glenn et al. 2003). In addition to that, it could be constructive to have one or more scenarios for comparison. For example, a normative scenario could depict how to obtain a desirable future with policy changes (Glenn et al. 2003).

7 Conclusions

In this thesis, I have investigated how cities adapt to environmentally induced hazards, like extreme floods in Helsinki. Extremes are usually not prepared for in planning, engineering and policy making (Buurman & Babovic 2016), and this study argues that the predicted extreme floods are not sufficiently considered in the land use planning in Helsinki, either. It aims to manage extreme coastal and fluvial floods (Jaakonaho et al. 2015; Suomalainen et al. 2015), but not extreme pluvial floods (Interviewee 5; FCG (2007) and mostly not future extreme floods, either (FCG 2011; Jaakonaho et al. 2015; Pilli-Sihvola et al).

Building pressure offers a major challenge for fitting land use and flood protection together in Finland (Peltonen et al. 2006). The analysis implies that there is room for land use planning to improve its adaptation to plausible future flood hazards in Helsinki. Despite the favour that the transformational adaptation approach has gained among adaptation literature (Munck af Rosenschöld & Rozema 2019), most of the investigated flood risk management does not seem to represent it, because it lacks consideration of the climate and the uncertainties of the future.

Knowledge gaps related to pluvial, compounding and future flood maps accumulate uncertainty. Long-term infrastructure is built regardless of the contingency related to the impact of such floods. Lack of future-orientedness might prove problematic, especially as decisions in land use planning echo for decades onwards (Maa- ja metsätalousministeriö 2014). Most of my policy recommendations address how to include more future-orientedness and means to manage uncertainties in the flood risk management in land use planning.

Further research could delve deeper into what kind of long-term decisions should be made in land use planning among the future-related uncertainties and challenges that this study has found. Future research could also include the city plan level in the case study, address possible tension between climate change mitigation and adaptation, and investigate how the framing of adaptation among city experts influences policy making and how the non-obligatoriness of the legal management plans impacts management.

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References

Aaltonen, J., Hohti, H., Jylhä, K., Karvonen, T., Kilpeläinen, T., Koistinen, J., Kotro, J., Kuitunen, T., Ollila, M., Parvio, A., Pulkkinen, S., Silander, J., Tiihonen, T., Tuomenvirta, H., & Vajda, A. (2008). Rankkasateet ja taajamatulvat (RATU). (Suomen ympäristö 31/2008). Suomen ympäristökeskus, Helsinki.

Aguiar, F. C., Bentz, J., Silva, J. M. N., Fonseca, A. L., Swart, R., Santos, F. D. & Penha-Lopes, G. (2018). Adaptation to climate change at local level in Europe: An overview. Environmental Science & Policy 86, 38-63.

Bell, J. (2010). *Doing your research project: a guide for first-time researchers in education, health and social science* (5th ed.). Open University Press.

Bruun, H., Hukkinen, J. & Eklund, E. (2002). Scenarios for coping with contingency: The case of aquaculture in the Finnish Archipelago Sea. *Technological Forecasting and Social Change, 69*(2), 107-127.

Buurman, J. & Babovic, V. (2016). Adaptation Pathways and Real Options Analysis: An approach to deep uncertainty in climate change adaptation policies, *Policy & Society, 35*(2), 137-150.

Carter, J. G. (2011). Climate change adaptation in European cities. *Current Opinion in Environmental Sustainability, 3*(3), 193–198.

Casti, J., Ilmola, L., Rouvinen P. & Wilenius, M. (2011). Extreme events. Taloustieto Oy, Helsinki.

Church, J. A., Clark, P. U., Cazenave, A., Gregory, J. M., Jevrejeva, S., Levermann, A., Merrifield, M. A., Milne, G. A., Nerem, R. S., Nunn, P. D., Payne, A. J., Pfeffer, W. T., Stammer, D. & Unnikrishnan, A. S. (2013). Sea Level Change. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T. F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. & Midgley, P.M. (eds.)]. Cambridge University Press, Cambridge.

Cornish, E. (2003). The wild cards in our future. *The Futurist, 37*(4), 18–22.

Cornwall, W. (2021). Europe’s deadly floods leave scientists stunned. *Science, 373*(6553), 372–373.

Dewulf, A. (2013). Contrasting frames in policy debates on climate change adaptation. *Wiley Interdisciplinary Reviews. Climate Change*, *4*(4), 321–330.

Eakin, H., York, A., Aggarwal, R., Waters, S., Welch, J., Rubiños, C., Smith-Heisters, S., Bausch, C., & Anderies, J. M. (2016). Cognitive and institutional influences on farmers’ adaptive capacity: insights into barriers and opportunities for transformative change in central Arizona. *Regional Environmental Change, 16*(3), 801–814.

Eriksson, P., & Koistinen, K. (2014). *Monenlainen tapaustutkimus*. (Kuluttajatutkimuskeskuksen tutkimuksia ja selvityksiä 11/2014). Kuluttajatutkimuskeskus, Helsinki.

FCG. (2007). Helsingin hulevesien hallinta nyt ja tulevaisuuden näkökulmia. Helsingin kaupunki.

FCG. (2011). Hulevesitulvariskien alustava arviointi Helsingin kaupungissa - Arviointiselostus. FCG Finnish Consulting Group Oy.

FCG. (2012). Hulevesitulvariskialueiden ja hulevesitulvaherkkien alueiden selvittäminen Helsingin kaupungissa - Loppuraportti. Helsingin kaupunki, rakennusvirasto.

Glenn, J. C. & The Futures Group International. (2003). Scenarios. In: *Futures Research Methodology — Version 2.0* [J. C. Glenn, J. C. & Gordon, T. J. (eds.)]. American Council for the United Nations University, Washington DC.

Gould, S. J. (1989). *Wonderful Life: The Burgess Shale and the Nature of History.* W. W. Norton, New York.

Hamin, E. M., & Gurran, N. (2009). Urban form and climate change: Balancing adaptation and mitigation in the U.S. and Australia. *Habitat International*, *33*(3), 238–245.

Helsingin kaupunki. (2013). Helsingin kaupungin tulvaohje - Asukkaiden ja omaisuuden suojaaminen tulvavaara-alueilla Helsingissä.

Helsingin kaupunki. (2018). Helsingin kaupungin hulevesiohjelma. (Helsingin kaupungin kaupunkiympäristön julkaisuja 3/2018).

Hirsjärvi, S. & Hurme, H. (2000). *Tutkimushaastattelu: teemahaastattelun teoria ja käytäntö.* Yliopistopaino, Helsinki.

IPCC. (2001). *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* [Houghton, J. T., Ding, Y., Griggs, D. J., Noguer, M., van der Linden, P. J., Dai, X., Maskell, K. & Johnson, C. A. (eds.)]. Cambridge University Press, Cambridge.

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* [Core Writing Team, Pachauri, R. K. & Meyer, L. A. (eds.)]. IPCC, Geneva.

IPCC. (2021). Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Péan, C., Berger, S., Caud, N., Chen, Y, Goldfarb, L., Gomis, M. I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T. K., Waterfield, T., Yelekçi, O., Yu, R. & Zhou, B. (eds.)]. Cambridge University Press. In Press.

Jaakonaho, O., Jussila, T. & Rantakokko, K. (2015). Helsingin ja Espoon rannikkoalueen tulvariskien hallintasuunnitelma vuosille 2016-2021. (Raportteja 97/2015). Uudenmaan elinkeino-, liikenne- ja ympäristökeskus, Helsinki.

Johansson, M., Kahma, K., Boman, H. & Launiainen, J. (2004). Scenarios for sea level on the Finnish coast. *Boreal Environment Research 9*(2), 153-166.

Johansson, M. M., Pellikka, H., Kahma, K. K., & Ruosteenoja, K. (2014). Global sea level rise scenarios adapted to the Finnish coast. *Journal of Marine Systems, 129*, 35–46.

Juhola, S. (2016). Barriers to the implementation of climate change adaptation in land use planning: A multi-level governance problem? *International Journal of Climate Change Strategies and Management, 8*(3), 338–355.

Kahma, K., Pellikka, H., Leinonen, K., Leijala, U., & Johansson, M. (2014). Pitkän aikavälin tulvariskit ja alimmat suositeltavat rakentamiskorkeudet Suomen rannikolla. (Raportteja 6/2014). Ilmatieteen laitos, Helsinki.

Kaupunkisuunnitteluvirasto. (2008). Helsingin kaupungin tulvastrategia. (Helsingin kaupunkisuunnitteluviraston yleissuunnitteluosaston selvityksiä 1/2010).

Kaupunkisuunnitteluvirasto. (2015). Helsingin yleiskaava - Teknistaloudellinen suunnittelu. (Helsingin kaupunkisuunnitteluviraston yleissuunnitteluosaston selvityksiä 2015:3). Helsingin kaupunkisuunnitteluvirasto.

Kaupunkisuunnitteluvirasto. (2016.) Helsingin yleiskaava – Selostus – Kaupunkikaava – Helsingin uusi yleiskaava. (Helsingin kaupunkisuunnitteluviraston yleissuunnitteluosaston selvityksiä 2016:3). Helsingin kaupunkisuunnitteluvirasto.

Kivilaakso, E., Narvi, S., Neuvonen, M., Siivola, M. & Kolu, S. (2009). Helsingin maanalainen yleiskaava - Maanalaisen yleiskaavan selostus 17.12.2009. Helsingin kaupunkisuunnitteluvirasto.

Klein, J. & Schmidt-Thomé, P. (2006). Impacts and Coping Capacity as key elements in a Vulnerability assessment on Sea Level Change Scenarios. *Geological Survey of Finland, Special Paper 41,* 45–50.

Laki tulvariskien hallinnasta 620/2010. Decreed in Naantali 24.6.2010.

Laine, M., Bamberg, J., Jokinen, P. (2007). Tapaustutkimuksen taito. Gaudeamus, Helsinki.

Lavrakas, P. J. (2008). *Encyclopedia of survey research methods.* SAGE Publications, Thousand Oaks.

Lehtonen, S. & Peltonen, L. (2006). Risk communication and sea-level rise: bridging the gap between climate science and planning practice. *Geological Survey of Finland, Special Paper 41,* 61–69.

Lorenzoni, I., Jordan, A., Hulme, M., Turner, R. K. & O'Riordan, T. (2000). A coevolutionary approach to climate change impact assessment: Part I. Integrating socio-economic and climate change scenarios, *Global Environmental Change, 10(1)*, 57–68.

Maa- ja metsätalousministeriö. (2014). Kansallinen ilmastonmuutokseen sopeutumissuunnitelma 2022 - Valtioneuvoston periaatepäätös 20.11.2014. (Maa- ja metsätalousministeriön julkaisuja 5/2014).

Mendonça, S., Pina e Cunha, M., Kaivo-oja, J. & Ruff, F. (2004). Wild Cards, Weak Signals and Organizational Improvisation. *Futures, 36*(2), 201-218.

Munck af Rosenschöld, J. & Rozema, J. G. (2019). Moving from incremental to transformational change in climate adaptation policy? An institutionalist perspective. In *Research Handbook on Climate Change Adaptation Policy* (pp. 91–107). Edward Elgar Publishing.

Mäkelä, A., Lehtonen, I., Ruosteenoja, K., Jylhä, K., Tuomenvirta, H. & Drebs, A. (2016). Ilmastonmuutos pääkaupunkiseudulla. (Raportteja 8/2016). Ilmatieteen laitos, Helsinki.

Parjanne, A. & Huokuna, M. (toim.) (2014). Tulviin varautuminen rakentamisessa - Opas alimpien rakentamiskorkeuksien määrittämiseksi ranta-alueilla. (Ympäristöopas, 2014). Suomen ympäristökeskus, Ilmatieteen laitos, Ympäristöministeriö & Maa- ja metsätalousministeriö, Helsinki.

Parjanne, A., Silander, J., Tiitu, M. & Viinikka, A. (2018). Suomen tulvariskit nyt ja tulevaisuudessa - Varautuminen maankäytön, talouden ja ilmaston muutokseen. (Suomen ympäristökeskuksen raportteja 30/2018). Suomen ympäristökeskus, Helsinki.

Parry, M., Arnell, N., Hulme, M., Nicholls, R. & Livermore, M. (1998). Adapting to the inevitable. *Nature 395,* 741.

Peltonen, L., Haanpää, S., & Lehtonen, S. (2006). EXTREFLOOD - Tulvariskien hallinta yhdyskuntasuunnittelussa. (Suomen Ympäristö 22/2006). Ympäristöministeriö, Helsinki.

Petersen, J. L. (1999). *Out of the Blue-How to Anticipate Big Future Surprises.* Madison Books, Lanham.

Pilli-Sihvola, K., Haavisto, R., Leijala, U., Luhtala, S., Mäkelä, A., Ruuhela, R. & Votsis, A. (2018). Sään ja ilmastonmuutoksen aiheuttamat riskit Helsingissä. (Kaupunkiympäristön julkaisuja 2018:6). Helsingin kaupunki / kaupunkiympäristön toimiala.

Ribeiro, P. J. G., & Pena Jardim Gonçalves, L. A. (2019). Urban resilience: A conceptual framework. *Sustainable Cities and Society, 50,* 1-11.

Ruosteenoja, K., Jylhä, K., & Kämäräinen, M. (2016). Climate projections for Finland Under the RCP Forcing Scenarios. *Geophysica, 51*(1), 17–50.

Ryan, B., Scapens, R. W. & Theobald, M. (1992). *Research method and methodology in finance and accounting.* Academic Press, London.

Saaranen-Kauppinen, A. & Puusniekka, A. (2006). KvaliMOTV - Menetelmäopetuksen tietovaranto. Accessed online 27.7.2021. https://www.fsd.tuni.fi/menetelmaopetus/kvali/

Sane, M., Dahlberg, N. & Huokuna, M. (2021). Hulevesien tulvakartta auttaa kuntia riskien hallinnassa. *Vesitalous, 62*(2), 10-13.

Sisäasiainministeriö (2019). Kansallinen riskiarvio 2018. (Sisäasiainministeriön julkaisuja 2019:5). Sisäasiainministeriö, Helsinki.

SITOWISE. (2018). Hulevesitulvariskien alustava arviointi Helsingin kaupungissa, 2. kierros – Arviointiselostus. Helsingin kaupunki KYMP.

Smit, B., Burton, I., Klein, R. J. T. & Street, R. (1999). The Science of Adaptation: A Framework for Assessment. *Mitigation and Adaptation Strategies for Global Change 4*(3–4), 199-213.

Storbjörk, S., & Hedrén, J. (2011). Institutional capacity-building for targeting sea-level rise in the climate adaptation of Swedish coastal zone management: lessons from Coastby. *Ocean and Coastal Management, 54*(3), 265–273.

Suhonen & Rantakokko. (2006). Vantaanjoen tulvantorjunnan toimintasuunnitelma. (Uudenmaan ympäristökeskuksen raportteja 1/2006). Uudenmaan ympäristökeskus, Helsinki.

Suomalainen, M., Seppälä, R. & Jaakonaho, O. (2015). Vantaanjoen vesistöalueen tulvariskien hallintasuunnitelmavuosille 2016–2021. (Raportteja 92/2015). Hämeen elinkeino-, liikenne- ja ympäristökeskus, Hämeenlinna.

Suomen Kuntaliitto. (2012). Hulevesiopas. Suomen Kuntaliitto, Helsinki.

Suomen ympäristökeskus. (2021). Tietopohjaa ilmastoviisaaseen maankäyttöön (TIIMA). Accessed online 27.9.2021. Available: https://www.syke.fi/hankkeet/tiima

Tennberg, M. & Vola, J. (2014). Myrskyjä ei voi hallita: Haavoittuvuuden poliittinen talous. *Alue Ja Ympäristö, 43*(1), 73–84.

Termeer, C., Dewulf, A. & Biesbroek, G. R. (2017). Transformational change: governance interventions for climate change adaptation from a continuous change perspective. *Journal of Environmental Planning and Management*, *60*(4), 558–576.

The Land Use and Building Act (132/1999). Decreed in Helsinki 5.2.1999.

Tuomi, J. & Sarajärvi, A. (2018). *Laadullinen tutkimus ja sisällönanalyysi.* Kustannusosakeyhtiö Tammi, Helsinki.

Valtioneuvosto. (2017). Valtioneuvoston päätös valtakunnallisista alueidenkäyttötavoitteista 14.12.2017. Accessed online 6.7.2021. https://valtioneuvosto.fi/delegate/file/35630

Valtioneuvosto. (2017). Yhteiskunnan turvallisuusstrategia - Valtioneuvoston periaatepäätös. Turvallisuuskomitea, Helsinki.

Varpio, L., Paradis, E., Uijtdehaage, S., & Young, M. (2020). The Distinctions Between Theory, Theoretical Framework, and Conceptual Framework. *Academic Medicine*, *95*(7), 989–994.

Veijalainen, N., Jakkila, J., Nurmi, T., Vehviläinen, B., Marttunen, M. & Aaltonen, J. (2012.) Suomen vesivarat ja ilmastonmuutos – vaikutukset ja muutoksiin sopeutuminen – WaterAdapt-projektin loppuraportti. (Suomen ympäristö 16/2012). Suomen ympäristökeskus, Helsinki.

Uudenmaan alueellisen riskiarvion työryhmä. (2018). Uudenmaan alueellinen riskiarvio 2018.

Yin, R. K. (2014). *Case study research: design and methods* (5th edition). SAGE Publications, Thousand Oaks.

Appendices

The written material is listed below. It consists of the zoning plan, its techno-economic appendix and the underground zoning plan.

- Helsingin yleiskaava - Selostus (Kaupunkisuunnitteluvirasto 2016)
- Helsingin yleiskaava - Teknistaloudellinen suunnittelu (Kaupunkisuunnitteluvirasto 2015)
- Helsingin maanalainen yleiskaava - Maanalaisen yleiskaavan selostus 17.12.2009. (Kivilaakso et al. 2009)

The ten reports that provide baselines for the planning stages after the zoning plan are listed below in Appendix 1. The list is slightly modified from the original list in the techno-economic report. When one looks at the original list, one can see that reports 1 and 9 have yet only been drafts on the release year of the zoning plan. However, at the time of making this study, the real reports are released, and I decided to use them instead of the drafts. Moreover, a new version of the report 7 has been released and it says to have replaced the previous one. Thus, the original report 7 is left out and the new one is included. Also, an updated version of the report 5 has been released. However, there is no mention about whether the new version replaces the old, so I included both in the analysis and numbered the new version as 5B.

Appendix 1. The reports that the zoning plan of Helsinki offers as the baselines for preparing for floods (Kaupunkisuunnitteluvirasto 2015).

Sea floods	Urban floods	River floods
1. Helsingin ja Espoon rannikkoalueen tulvariskien hallintasuunnitelma vuosille 2016–2021 (Jaakonaho et al. 2015)	5. Hulevesitulvariskien alustava arviointi Helsingin kaupungissa (FCG 2011)	9. Vantaanjoen vesistöalueen tulvariskien hallintasuunnitelma vuosille 2016–2021 (Suomalainen et al. 2015)
2. Helsingin kaupungin tulvastrategia (Kaupunkisuunnitteluvirasto 2008)	5B. Hulevesitulvariskien alustava arviointi Helsingin kaupungissa (SITOWISE 2018)	10. Vantaanjoen tulvantorjunnan toimintasuunnitelma (Suhonen & Rantakokko 2006)
3. Tulviin varautuminen rakentamisessa - Opas alimpien rakentamiskorkeuksien määrittämiseksi ranta-alueilla (Parjanne & Huokuna 2014)	6. Hulevesitulvariskialueiden ja hulevesitulvaherkkien alueiden selvittäminen Helsingin kaupungissa (FCG 2012)	
4. Helsingin kaupungin tulvaohje - Asukkaiden ja omaisuuden suojaaminen tulvavaara-alueilla Helsingissä (Helsingin kaupunki 2013)	7. Helsingin kaupungin hulevesiohjelma (Helsingin kaupunki 2018)	
	8. Helsingin hulevesien hallinta nyt ja tulevaisuuden näkökulmia (FCG 2007)	