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Master Thesis

Title:	Are Dutch Social Housing Institutions Prepared for Flood Risk?
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1. Introduction

Since the publication of the first Intergovernmental Panel on Climate Change (IPCC) assessment in 1992, it has become clear that humanity has an increasing negative impact on global warming and our climate system (IPCC, 1992). Subsequent IPCC reports presented more compelling evidence, revealing alarming changes in climate events such as melting polar ice, sea level rise, and increasing extreme weather events. These reports not only underscore the urgency of addressing climate change but also provide detailed projections of the ongoing changes in our climate system throughout the 21st century. Findings are not merely theoretical; adverse effects of climate change are already evident in our day-to-day lives, where flood events are occurring more frequently and more severely.

For the Netherlands, a nation with a long history in water management, the Royal Dutch Meteorological Institute (KNMI) confirms the increased risk of flooding resulting from sea level rise and changing weather patterns in their 2023 Climate Scenarios (KNMI, 2023). Following the recent flooding in the province of Limburg in 2021, which resulted in total damages of approximately €433 million (Slager, 2023), flood risk mitigation and adaptation have become increasingly pertinent in the Netherlands. Especially in the real estate sector, where flood events have great consequences, including threats to residents, damaged properties, and strengthened depreciation (Pryce & Chen, 2011). Furthermore, previous academic findings suggest that increased flood risk, apart from direct and indirect damages to properties and inhabitants, can result in downward pressure on property values, increased mortgage delinquency, and environmental migration (Beltrán et al., 2019; Eichholtz et al., 2019; Holtermans et al., 2023, 2024; Mutlu et al., 2022; Pryce & Chen, 2011; Surminski et al., 2020).

In the Dutch real estate market, housing associations[1] are important providers in the development and operation of affordable housing, supplying approximately one-third of the total residential housing stock in the Netherlands (CBS, 2024). Given their substantial presence in terms of both total value and number of dwellings, housing associations may face considerable exposure to flood risk. Therefore, addressing flood risk may be an important topic on the agenda of the housing association. However, current academic findings suggest that

[1] In this study, the terms "social housing institutions", "housing associations", and "Dutch social housing" are used interchangeably.

Dutch housing associations exhibit limited awareness and are not well prepared to manage physical climate risks due to lacking policies, insufficient financial means, and a lack of cooperation (Boezeman & de Vries, 2019; Roders et al., 2012, 2013; Roders & Straub, 2015). While these studies may be somewhat dated, to my best knowledge, these are the only academic studies investigating the intersection of physical climate risks and social housing in the Netherlands. Thus, despite an extensive body of academic literature elaborating on the adverse effects of increased flood risk on the real estate sector, it remains unclear whether Dutch housing associations are aware of, worried about, and prepared for these (future) flood risks.

To address this gap in academic research, this study investigates the flood risk perception of housing associations in the Netherlands. More specifically, this study aims to measure the level of flood risk awareness, worry and preparedness, what key factors contribute to this level of flood risk perception and, ultimately, what these findings imply for the sector as a whole. By combining geospatial data with a survey-based research approach, I measure both the current estimated (objective) flood risk and the (subjective) flood risk perception of the housing association. Furthermore, I collect information on the characteristics of the housing association to investigate what other factors contribute to increased flood risk perception.

Using a large-scale sample consisting of 252 individual respondents, distributed across 139 unique housing associations in the Netherlands, I provide empirical evidence that past flood experience and the usage of the Climate Impact Atlas significantly contribute to a higher level of flood risk perception of Dutch housing associations, measured by the level of awareness, worry, preparedness, and overall flood risk perception. Furthermore, larger housing associations and those with a higher proportion of single-family homes in their portfolio show significantly higher levels of self-reported flood risk preparedness. While these findings highlight the importance of leveraging tools like the Climate Impact Atlas to analyse flood risk and increase awareness, worry, and preparedness, the results reveal that only 30% of the surveyed housing associations use the Climate Impact Atlas.

Additionally, I test whether increased levels of flood risk perception result in a higher likelihood of including physical climate risks in the portfolio strategy of the housing association. Using binary logistic regression analysis, I find that levels of worry and preparedness significantly increase the probability of incorporating physical climate risks in the portfolio strategy of the housing association. Specifically, a one standard deviation increase in the level of worry (preparedness) results in the housing association being 2.37 (2.46) times more likely to incorporate physical climate risks in their portfolio strategy. Despite the significant contribution of worry and preparedness to the likelihood of integrating physical climate risks into portfolio strategies, the survey reveals that less than 30% of the housing associations in the sample have already incorporated these risks into their strategies.

The remainder of this study is structured as follows: Section 2 provides an overview of the current academic findings on the intersection of flood risks and real estate, the Dutch social housing sector, and the concept of flood risk perception. Next, Section 3 discusses the survey design, covering question development, data and sample selection, and testing the reliability and validity of the survey. Section 4 elaborates on the initial results of the survey. Section 5 discusses the empirical research design of this study and elaborates on the variable construction, hypothesis development, and statistical techniques. Section 6 presents the results of the empirical analyses. Section 7 provides a discussion of these results and elaborates on the limitations and suggestions for future research. Finally, Section 8 concludes.

2. Literature review

The purpose of this section is to provide a comprehensive overview of the existing academic literature on flood risk, its intersections with real estate and social housing in the Netherlands, and the concept of risk perception. First, this section will discuss the general definition of physical climate risks. Secondly, this section will present the current academic findings on the effects of flood risks on real assets, covering its origin, damages, and consequences. Furthermore, a section on social housing in the Netherlands will shape the context of this thesis. Finally, this section will investigate the concept of (flood) risk perception and how risk perception can be measured.

2.1. Physical climate risks

According to the Task Force on Climate-related Financial Disclosures (TCFD) 2017 report, climate risks can be distinguished into two categories: transition risk and physical risk. While transition risk refers to the risks that arise from the mitigation and adaptation measures to prevent and revert climate change, physical climate risk refers to the direct adverse impacts and damages that arise from climate-related hazards, affecting natural and human systems (IPCC, 2014; TCFD, 2017). According to the IPCC 2014 report, these risks are primarily driven by changes in weather patterns and extreme events resulting from global warming. Evidence shows that the observed changes in climate events such as increased temperature extremes, changes in rainfall patterns, and sea level rise can be linked to human activity. The 2014 IPCC report highlights the consequences of continued emissions of greenhouse gasses, resulting in an increasing likelihood of extreme heat waves, wildfires, and floods. In the more recent Sixth Assessment IPCC report (2023), these events are even more prevalent and new compelling evidence is presented regarding observed adverse impacts of climate change on our world and society.

These physical climate risks can take the form of acute events, or they can represent chronic changes in climate patterns over longer periods (TCFD, 2017). Acute events include extreme storms like hurricanes and typhoons, extreme heat waves, heavy rainfall leading to flooding, and prolonged periods of drought. These events often result in immediate and visible impacts such as loss of lives, destruction of infrastructure, and economic losses. Chronic changes, on the other hand, occur gradually over time and include phenomena such as shifting rainfall patterns, rising average temperatures, melting ice caps, and ocean acidification (IPCC, 2023). Alternatively, Attoh et al. (2022) explain that climate risk can be seen as the product of its three components: hazards, vulnerability, and exposure. Hazards refer to specific weather events or phenomena, such as hurricanes or floods, which pose a threat. Vulnerability relates to the susceptibility of properties or communities to the impacts of these hazards, influenced by factors like building materials, infrastructure, and socioeconomic conditions. Exposure corresponds to the extent to which assets or communities are situated in areas prone to these hazards, indicating their potential risk level (Dutch Green Building Council, 2022; Gallo & Lepousez, 2020; MSCI, 2023).

For the real estate sector in particular, several physical climate risks are identified in the literature. In general, these risks materialise when properties and residents suffer tangible damage due to more severe weather events influenced by climate change (Carlin et al., 2023). In their report, Carlin et al. (2023) identify some of the most important physical climate risks for the real estate market, including Sea level rise (SLR) and coastal flooding, inland flooding, extreme storms, wildfires, soil subsidence, and heat and water stress. For the Dutch real estate market, these physical risks are organised into four themes: (1) heat, (2) drought, (3) nuisance floods (flash floods caused by extreme rainfall), and (4) flooding (AFM, 2023; Climate Adaptation Services, 2024b; Dutch Green Building Council, 2022; KNMI, 2023).

2.2. Flood risk and real estate

While those types of risks are all highly relevant, delving into every underlying climate risk is beyond the scope of this study. Henceforth, the focus will be specifically on the risks of flooding and its connection to real estate. An important note to make here is that my study will focus on all types of flood risk, including those stemming from extreme rainfall resulting in flash floods, as well as floods caused by overflowing rivers and rare dyke breaches. According to De Bruijn et al. (2015), flood risk can be seen as the product of flood hazard and vulnerability. Here, hazard refers to the potential to cause harm or damage, whereas vulnerability also takes into account the characteristics of an area, such as land use, population, and the buildings located in the area. Flood hazard depends on the probability and severity of the flooding, where severity is defined by flood depth, flow velocity, and rising rate (De Bruijn et al., 2015).

Floods are commonly categorised into coastal flooding, pluvial flooding, and fluvial flooding. Coastal flooding refers to flooding along the coastline, often resulting from high tides in combination with storm surges (ICLR, 2021). According to Tanaka et al. (2020), the flooding of inland areas, on the other hand, can be distinguished into pluvial and fluvial flooding, both being interconnected. Pluvial or "flash" flooding is caused by intense rainfall exceeding soil infiltration capacity, whereas fluvial or riverine flooding refers to the failure of natural drainage systems after prolonged periods of precipitation, such as overflowing rivers or even dyke breach (Tanaka et al., 2020). A combination of both pluvial and fluvial flooding, also referred to as a compound event, can create even more severe flood risks (Thieken et al., 2022). In the case of such an event, intense rainfall leading to surface flooding is followed by riverine flooding, even days after the first flood event.

Even though changing tides, storms, and heavy precipitation are all part of the natural ecosystem on our planet, findings from the IPCC suggest that ongoing global warming causes sea levels to rise, reshapes weather patterns, and amplifies extreme events. This includes a higher frequency and severity of (tropical) storms and prolonged periods of rainfall, resulting in an increased likelihood and intensity of both pluvial and fluvial flooding, as well as coastal flooding. (IPCC, 1992, 2014, 2023). Technically speaking, as global temperatures rise, more water evaporates into the air and warmer air has an increased capacity to hold water. This shifting evaporation-precipitation cycle can increase the frequency and severity of floods in some areas while contributing to drought conditions in others (Davies et al., 2021; Pryce & Chen, 2011). Furthermore, rising sea levels can result in the gradual inundation of low-lying areas, increased probability and severity of coastal flooding, land erosion, and groundwater inundation (Vitousek et al., 2017).

For both medium and high-emission level scenarios, flood risks are projected to increase with very high confidence (IPCC, 2023). For Europe, Steinhausen et al. (2022) find that climate change will continue to increase flood risks in the UK and Central Europe by seven (ten) fold in the medium (high) emission level scenario towards the end of the century. Scandinavia and the Mediterranean show a possible decrease in flood risks. The 2023 Climate Scenario's presented by the Royal Dutch Meteorological Institute (KNMI) confirms the increase in extreme precipitation and sea level rise resulting in a higher risk of flooding for the Netherlands (KNMI, 2023). Furthermore, findings suggest this increased risk is strongest in urban areas and along major rivers (Steinhausen et al., 2022). Pryce & Chen (2011) mention that, historically, the most urbanised regions are located close to rivers, resulting in a higher exposure to fluvial flooding. Additionally, urbanised areas exhibit lower infiltration and drainage capacity, thus increasing the risk of flash floods after intense rainfall.

2.2.1. Damages

Flood risk can result in either direct or indirect damages. Direct damages relate to the physical damage directly resulting from a natural disaster, whereas indirect damages follow after direct damages occur (Caloia & Jansen, 2021). For real estate, inland flooding initially results in (direct) property or infrastructure damage, followed by recovery efforts causing normal usage distress (indirect) (Carlin et al., 2023). In practice, direct damages could include damage to electrical systems such as elevators or central heating, structural damage, and damage to furniture. Indirect damages may result from temporary relocation costs of residents and business disruption.

To put these damages into a financial perspective, Jongman, Hochrainer-Stigler, et al. (2014) estimate that floods in Europe led to an average annual loss of €4.9 billion in the period between 2000 and 2012. Based on their analysis and model, the authors expect these annual losses to increase towards €23.5 billion by the year 2050. For the Netherlands, recent floods in the summer of 2021 caused total damages of approximately € 433 million (Slager, 2023). Although these losses are estimated as total economic losses and are not specifically tight to real estate, they do indicate that there is a substantial negative economic effect caused by floods. To connect these losses to actual damages of Dutch properties specifically, Slager (2018) estimates that 90% of total direct flood damages can be attributed to properties. Alternatively, a more recent study conducted by Deltares (2022) indicates that the maximum direct damage to dwellings due to floods in the Netherlands is estimated to be €1295 per square meter in 2022. Damage to the interior is estimated at a maximum of approximately € 82.000. Of course, these numbers are rough estimates and should be used with caution.

2.2.2. Consequences

Next to actual damages incurred, the anticipated potential damages of increased flood risk can result in adverse effects on property prices, insurance and lending, and even widespread environmental migration (Pryce & Chen, 2011). For example, Addoum et al. (2023), and Eichholtz et al. (2019) investigate the effect of Hurricane Sandy on property values in New York and Boston and find that increased flood risks have a significant downward pressure on properties located in these areas, even though both cities were not initially at risk of hurricanes. Holtermans et al. (2023) find similar results. Adding to these observations, Baldauf et al. (2020) find that beliefs about (future) flood risks affect the pricing of properties, emphasising that properties in a “believer” neighbourhood transact at a discount compared to “non-believer” neighbourhoods. Comparing the effects of coastal flooding versus inland flooding using a hedonic pricing model, Beltrán et al. (2019) find that properties fully flooded by inland flooding transact at prices 24.9 percent lower compared to non-flooded counterparts, whereas for coastal flooding this price effect is 21.1 percent.

For the Dutch market specifically, the risk of flooding does not seem sufficiently priced in (AFM, 2023). Mutlu et al. (2022) observed a 5.6%-10.9% flood risk discount in the Netherlands after the 1993-1995 floods in the province of Limburg. Although a discount was observable, the authors indicate a diminishing and eventually vanishing effect nine to twelve years after the flooding. In contrast to these findings indicating some flood risk discount on property prices, Niu et al. (2023) find no such discount in the Dutch housing market. In fact, after analysing the price differences between properties located within a dyke protected area and those outside, the authors conclude that prices of properties outside of dyke protection are, on average, 6.5% to

10.2% higher. Overall, although some findings in the literature are somewhat contradictory, most studies indicate a negative effect of flood risk on property values.

When it comes to mortgages and climate risks, Holtermans et al. (2024) investigate the effect of Hurricane Harvey and Sandy on commercial mortgage payments in the US and find that both events significantly increased delinquency rates. Consequently, this may lead to increased credit risks for capital providers (Caloia & Jansen, 2021). Additionally, Holtermans et al. (2024) find some evidence that potential flood risks are already taken into account during the underwriting process. For the effect of UK flood risks on residential mortgages, Surminski et al. (2020) anticipate an increase in Annual Average Loss (AAL) of 61% (130%) in the case of 2°C (4°C) warming. For the Dutch scenario, Jongman et al. (2014) emphasise that while properties in flood-prone areas exhibit lower prices, those areas in fact represent higher economic value and show higher growth in terms of building stock compared to non-flood areas. This could potentially lead to adverse effects on insurance schemes in the Netherlands, the authors conclude.

Next to direct and indirect effects on property level, increased occurrence of floods can have serious social consequences. Pryce & Chen (2011) emphasise that flood risks can lead to environmental migration, happening directly after a catastrophic event and occurring more gradually over time due to the depopulation of areas with a high risk of flooding. For the Dutch market, Niu et al. (2023) observe that better-informed homeowners are more likely to respond to flood risk information. Higher education level, lower income and risk aversion seem to increase the likelihood of homeowners leaving an area of high flood risk (Niu et al., 2023).

2.3. Social housing in the Netherlands

As discussed earlier, physical climate risks hold significant relevance for the real estate market. While the Dutch real estate sector has been briefly addressed already, this section delves deeper into the specific context of Dutch social housing, shaping the research area of this study. This part is twofold. Firstly, a concise overview of the Dutch social housing system will be provided. Secondly, this section will address the current state of climate adaptation within the Dutch social housing sector.

2.3.1. The Dutch social housing system

Social housing institutions have been fundamental to Dutch society since the introduction of the first housing act in 1901, which started the state involvement in housing provision and laid the groundwork for the current housing system in the Netherlands (Boezeman & de Vries, 2019). As of 2023, Dutch housing associations own around 2.3 million dwellings in the Netherlands with a total value of about € 140 billion, distributed across 276 active associations (Autoriteit Woningcorporaties, 2023; CBS, 2024; ILT, 2024c). The size of this portfolio has been stable over the past decade, compromising approximately thirty percent of the total Dutch housing market (CBS, 2024). The areas in which the housing associations operate are described in the Housing Market Policy[2] which divides the Dutch housing market into 19 Housing Market Regions[3]. These areas define where the housing association is allowed to operate but can be expanded by filing for an official exemption (Ministry of the Interior and Kingdom Relations, 2024).

As described in the 2015 Housing Act[4], the main responsibility of housing associations is to provide affordable housing for low-income households. In 2024, this translates into a minimal allocation of 85% of the total portfolio attributed to households under a certain income level (Rijksoverheid, 2024). To achieve this, housing associations engage in constructing new buildings, renovating existing ones, and managing their current portfolios. The Dutch Housing Act imposes several other important rules and regulations, including rent regulation, the separation of commercial and non-commercial activities to protect tenants, and governance standards to prevent board misconduct (Boezeman & de Vries, 2019).

According to Boezeman & de Vries (2019), the Dutch social housing system is shaped by several key institutions. First of all, the Ministry of the Interior holds responsibility for formulating policies and regulations governing the social housing sector. Secondly, the Authority Housing Associations (Aw)[5] serves as the regulatory body, ensuring that housing associations comply with regulations (ILT, 2024b). Furthermore, the Aw oversees the Social Housing Guarantee Fund[6] (WSW), which facilitates housing associations with favourable interest rates by providing guarantees to credit providers (ILT, 2024a). Other important actors

[2] Woningmarktbeleid
[3] Woningmarktregio's
[4] NL: Woningwet 2015
[5] NL: Autoriteit Woningcorporaties (Aw)
[6] NL: Waarborgfonds Sociale Woningbouw (WSW)

include "Woonbond", Aedes, and VNG[7], serving as representative associations for tenants, social housing providers, and municipalities, respectively (Boezeman & de Vries, 2019).

2.3.2. Climate risk mitigation and adaptation

In the Netherlands, nationwide climate adaptation strategies are described in the 2016 National Climate Adaptation Strategy. This report describes how the Netherlands can minimise the negative effects of climate change and exploit the positive opportunities (Ministry of Infrastructure and the Environment, 2016). Related to this initiative are the National Delta Program and the Delta Program Spatial Adaptation (DPRA), in which the latter shapes the strategy for climate-proofing the built and natural environment. (Kennisportaal Klimaatadaptatie, 2024; Nationaal Deltaprogramma, 2024). Furthermore, Climate Adaptation Services (CAS) has developed the Climate Impact Atlas for the Netherlands to visualise and identify physical climate risks. This tool consists of multiple geospatial maps showing the different climate risks for the Netherlands, spread over the four themes of nuisance floods, heat, drought, and flooding. By using this tool, individuals and organisations can visualise the physical climate risks that are most prevalent in the region where they live or operate, facilitating mitigation and adaptation to climate risks (Climate Adaptation Services, 2024a).

Although the risks related to climate change and the adaptation measures that should be implemented are already well documented in the Netherlands, this does not necessarily mean that Dutch housing associations are aware of the physical climate risks that their portfolios bear. Even if these organisations are aware of the risks, it does not imply that sufficient mitigation and adaptation policies have been implemented already (Boezeman & de Vries, 2019; Roders et al., 2012). In their research, Boezeman & de Vries (2019) investigate the current adaptation policies and practices of housing associations to find out whether climate adaptation is already being mainstreamed. Findings suggest limited awareness among housing associations, where current adaptation practices are primarily reactive responses to damages rather than proactive efforts aimed at climate-proofing the portfolio. This lack of mainstreaming climate adaptation can be due to constraints in terms of lacking policies, insufficient financial means, regulations, and a lack of cooperation (Boezeman & de Vries, 2019). This research builds further on previous findings of Roders et al. (2012, 2013) and Roders & Straub (2015), who investigate climate adaptation awareness among housing associations and evaluate the feasibility of

[7] NL: Vereniging van Nederlandse Gemeenten

implementing such adaptation policies. In the most recent study, Roders & Straub (2015) combine their previous findings and emphasise that the implementation of adaptation strategies is lacking due to budget constraints and low priority on the policy agenda. Although these studies may be somewhat dated, to my knowledge, these are the only studies specifically focused on the intersection between housing associations and physical climate risks in the Netherlands.

2.4. Measuring risk perception

As outlined in previous sections, academic evidence suggests that flood risks can pose significant challenges to Dutch housing associations. However, it is unclear whether housing associations in the Netherlands are aware of, worried about, and prepared for these flood risks. This perception of risk is described by Slovic (1987) as the judgements and responses of individuals when evaluating hazardous activities and technologies, aiding in risk analysis and policymaking. Clearly, psychological factors play a significant role in how physical climate risks are perceived by an individual and acted upon within the institutional context. Slovic & Peters (2006) explain that risk perception is how people naturally feel about danger, while risk analysis, as commonly referred to in risk management, is a more objective approach that uses logic and science to evaluate risks.

Climate risk assessments are often conducted based on this objective approach and defined in terms of analysing hazards, vulnerability, and exposure (Attoh et al., 2022; Gallo & Lepousez, 2020). Analysing these aspects helps us understand the characteristics of the risk, however, it does not explain to us how individuals and institutions perceive these risks and how they respond to them. In the case of climate change, understanding the latter is especially relevant due to the complexity, magnitude, timing and often invisibility of the climate change problem (van der Linden, 2015). Since climate change is something that happens on a global scale and occurs gradually and over a long period of time, it may be difficult to directly assess the risks that come with it. Therefore, individuals rely on their own judgement and beliefs about climate change, which may result in differences in how people perceive and act on climate risks (van der Linden, 2015). According to Lechowska (2018), it is this subjective assessment of risk that is crucial for effective flood risk management.

2.4.1. Measuring climate risk perception

Research on measuring risk perception is often conducted in the field of psychometrics, which refers to the quantitative measurement of psychological variables such as knowledge or attitudes that explain why people are extremely risk-averse to certain hazards but indifferent to others (Slovic, 1987). To measure the differences in climate risk perception, several methodologies have been developed in academic literature. These approaches have been discussed and put into a set of best practice approaches by Van der Linden (2015) in his study to develop the Climate Change Risk Perception Model (CCRPM). Sorted by explanatory power (R^2), Van der Linden (2015) provides an overview of which psychometric variables are included in some of the best models to explain differences in climate risk perception. These variables include personal experience, culture, political preferences, knowledge, beliefs, values, trust, and socio-demographics. Based on these findings, Van der Linden (2015) constructed a more systematic approach to measure climate risk perception: the CCRPM. This model, with an explanatory power of 68%, has been one of the most successful climate risk perception models to date (van Eck et al., 2020). The CCRPM was initially tested in the United Kingdom, however other studies using this model provide similar results for different geographical areas (van Eck et al., 2020).

2.4.2. Measuring flood risk perception

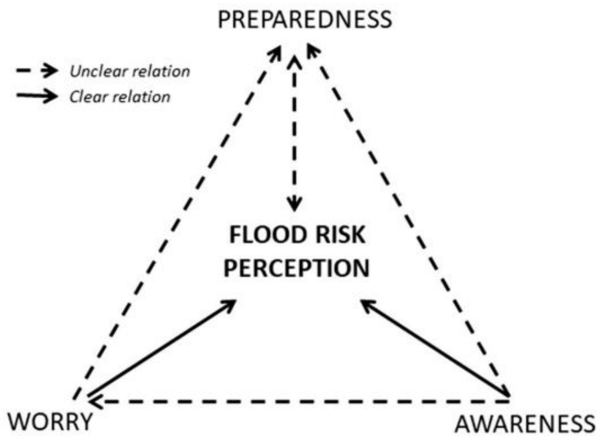
Although the model of Van der Linden (2015) is highly suitable for measuring the climate risk perception of an individual and will be applied in the first part of the survey used in this study, it does not focus on flood risks specifically. Several other studies present evidence on how to best measure flood risk perception. Raaijmakers et al. (2008) develop a survey to measure flood risk perception and the trade-off between risks and benefits. The authors measure flood risk perception in terms of awareness, worry, and preparedness. Staying within to context of survey design, Iqbal & Nazir (2023) apply the same three elements to investigate community perceptions of flood risks in Pakistan. Rufat & Botzen (2022) use a more extensive set of predictors and include past flood experience and risk communication in their model. Furthermore, Mondino et al. (2020) delve deeper into the role of risk awareness and find that knowledge and past experiences play an important role in defining flood risk awareness and perception. In contrast, Zabini et al. (2021) apply a different approach, analysing the perceived flood risk of a certain area, the likelihood of occurrence, the perceived impact of such event, and the perceived personal vulnerability. Using a similar design, Harlan et al. (2019) measured perceived likelihood and perceived severity to investigate flood risk perception in the United

States. In general, all the above-mentioned studies argue that socio-demographics are important factors in the measurement of flood risk perception.

To summarize the findings of academic literature on flood risk perception, Lechowska (2018) provides an extensive overview of the different factors that could be considered when measuring flood risk perception according to a set of fifty empirical studies. In general, these factors are divided into the three factors of risk perception (awareness, worry, and preparedness). Based on a systematic literature review, Lechowska (2018) concludes that the relationships between flood risk perception and these three basic elements are often unclear, and complex and that academic research provides mixed conclusions. Some academics find that the level of awareness could influence the level of worry, while others do not find such a relationship. The same holds for the interaction between awareness, worry and preparedness. Some academics suggest that higher levels of awareness and worry could lead to higher levels of preparedness, while others do not find such a relationship. On the other hand, the level of preparedness could in turn influence the level of worry. Despite this inconsistency in results, Lechowska (2018) concludes that awareness and worry are clearly direct indicators for measuring flood risk perception.

For preparedness, the story is a bit different. According to Lechowska (2018), higher levels of preparedness can lead to higher levels of flood risk perception. However, flood risk perception could also be a (weak) independent variable to flood risk preparedness (e.g., higher levels of flood risk perception could lead to higher levels of flood risk preparedness). Though, there seems no clear consensus among academics on whether preparedness influences risk perception and/or vice-versa. Therefore, Lechowska (2018) argues that preparedness is often analysed as a separate issue and is rather a secondary factor in measuring flood risk perception. The relationship between the three factors and flood risk perception is presented in Figure 1, indicating both clear and unclear interactions.

FIGURE 1: Triangle of flood risk perception



From: Lechowska, E. (2018). What determines flood risk perception? A review of factors of flood risk perception and relations between its basic elements. Natural Hazards, 94(3), 1341–1366.

3. Survey design

After investigating what is already known about the intersection of physical climate risk, social housing in the Netherlands and flood risk perception, this section will present the research design and discuss the survey developed for this study. First, this section will discuss the survey questions as presented to the respondents. Second, this section will elaborate on the data and sample selection. Finally, this section will test the survey's validity and reliability.

3.1. Survey questions

Before testing the flood risk perception of the housing association as an institution, I first want to assess the differences in climate risk perception of the individual respondents. As explained by Van der Linden (2015), cognitive factors, experiential processing, socio-cultural influences, and socio-demographics affect the climate risk perception of an individual. These factors explain why some people perceive climate-related hazards as extremely risky while others do not. The differences in risk perception are important to control for when measuring the flood risk perception of the institution, on whose behalf the respondent is answering the questions in the survey. By controlling for the variance in individual risk perception levels, I can elicit the personal response biases of the respondents and measure the flood risk perception of the housing association as an institution.

To test this individual risk perception, the first part of the survey will apply some of the questions used in the CCRPM of Van der Linden (2015). For the purpose of my study, I will only make use of the first eight questions developed by Van der Linden (2015). These questions measure the climate risk perception of the individual, four of which are about personal risk, while the other four are about societal risk. For example, respondents are asked to indicate, on a scale from 1-7, how concerned they are about climate change, how likely they and society, in general, are to experience threats from climate change, and how frequently they worry about negative effects of climate change. An overview of the questions adopted from Van der Linden (2015) can be found in Appendix H.

Next, two multiple-choice questions are presented to test the respondent's cause-knowledge of flooding. The first question asks the respondent what human-related factor is most directly linked to the increased risk of urban flooding. The correct answer, "urban development and impervious surfaces" is constructed based on the findings of the literature review. The second question asks which of the four presented factors primarily contributes to heightened flood risk and the correct answer, again based on the literature review, is "rising global temperatures". The answers to both questions are recoded into 0 (respondent cannot correctly state the causes of flooding) and 1 (respondent can correctly state the causes of flooding). Third, respondents are asked to indicate how often they personally have experienced flooding in their local area in the past five years and whether they experienced damage to their homes and personal belongings because of flooding. Responses are coded in 0= no experience and 1= has experience, where answers indicating "can't remember" are treated as no experience (0). The final set of questions from part one of the survey includes homeownership (yes/no), age, and gender.

The second part of the survey consists of questions about the risk perception of the housing association as an institution. First, respondents are asked about their role within the organisation and need to indicate whether they are a: Director/Board Member, Business Manager, Real Estate Manager, Asset Manager, Portfolio Manager, or "Other". Next, several questions related to the characteristics of the housing associations are presented. These questions include the region in which the housing association is most active based on the number of rentable units (Housing Market Region, municipality, and hometown), the size in terms of weighted rfentable units[8], the proportion of single-family homes in the portfolio, the average property age, and the internal Loan-To-Value ratio.

After answering these questions, respondents are asked to indicate the general level of flood risk awareness, worry, and preparedness of the housing association on a scale from 1-7. These three questions serve as the input for creating the overall flood risk perception index. Higher scores indicate a higher level of flood risk perception. Next, five statements specifically related to the level of awareness are presented, the first statements relate to how aware the organisation in general is, how often flood risks are discussed in business meetings, and how important flood risks are on the policy agenda of the organisation. The last two statements are related to how much attention is given to flood risks, indicating whether attention on flood risks is (1) increased after the occurrence of flood events in the Netherlands and (2) increased when more attention to flood risks is given in the (local) news. Answers to the statements are measured on a scale from 1 (strongly disagree) to 7 (strongly agree). Thereafter, a set of four questions related to the level of worry is presented. Respondents have to indicate how concerned they are that (1) floods can cause significant damages to the properties owned by the housing association, (2) flood risk can have a negative impact on the value of the properties owned by the housing associations, (3) flood risk can have a negative impact on the financial performance of the organisation, and (4) floods can cause significant threats to tenants. Again, questions are scaled from 1-7, where 1 reflects "Not concerned at all" and 7 "Very concerned". Following the questions related to the level of worry, five statements about the level of preparedness are presented. These statements try to identify how prepared the housing is to deal with flood risks. The first two statements reflect the general preparedness and level of mitigation and adaptation measures. The other three statements relate to investments in new construction and renovation projects and whether flood risks are taken into account in planning and decision-making. Again, answers to the statements are measured on a scale from 1 (strongly disagree) to 7 (strongly agree).

Then, two questions about the past flood experience of the housing association are asked. These questions ask respondents how often (in the past five years) the organisation had to deal with flooding in the local area and damages to properties because of flooding. Respondents could choose between the following answers: 1= "Never", 2= "Once", 3= "Twice", 4= "More than

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[8] See Appendix G for the size classes

twice", 5= "Can't remember". Responses are coded in 0= no experience and 1= has experience, where answers indicating "can't remember" are treated as no experience (0). Finally, two yes-or-no questions are asked to find out whether the housing association makes use of the Climate Impact Atlas maps to analyse flood risks and whether physical climate risks are included in the housing association's portfolio strategy. Answers are recoded into 0= no and 1= yes. The full set of questions as presented to the respondents can be found in Appendix H.

3.2. Data and sample selection

Data on the level of flood risk perception is collected via the online survey, as described in Section 3.1. Before distributing the survey, several tests among colleagues from Finance Ideas were conducted to measure the suitability, readability, and accessibility of the survey. The online survey was developed in Qualtrics and is available in both English and Dutch. To select the right sample, I first analysed the total population of housing associations in the Netherlands, which consists of 276 active associations at the beginning of 2024, 261 of which are a member of Aedes (based on their 2023 Benchmark) (Aedes, 2023; CBS, 2024; ILT, 2024c). A graphical presentation of the distribution of the total population of housing associations[9] per Housing Market Region is presented in Appendix F.

I was granted access to the extensive contact database of Finance Ideas, consisting of +3000 individual contacts, distributed across 283 organisations, and filtered by job title and function. After consulting my colleagues from Finance Ideas, I identified five different job functions in the contact database that would suit the sample for the survey based on whether these people would have to deal with, and are responsible for, managing climate risks within the housing association. These job functions include Director/Board Member, Business Manager, Real Estate Manager, Asset Manager, and Portfolio Manager. By filtering the database based on these functions, a list of in total 909 contacts, distributed over 274 unique housing associations, was constructed. Next, an email was sent to these people on April 29th, 2024, inviting them to participate in the study. Because in total 909 people were contacted, it is possible that several employees with different job functions but from the same housing association received an email.

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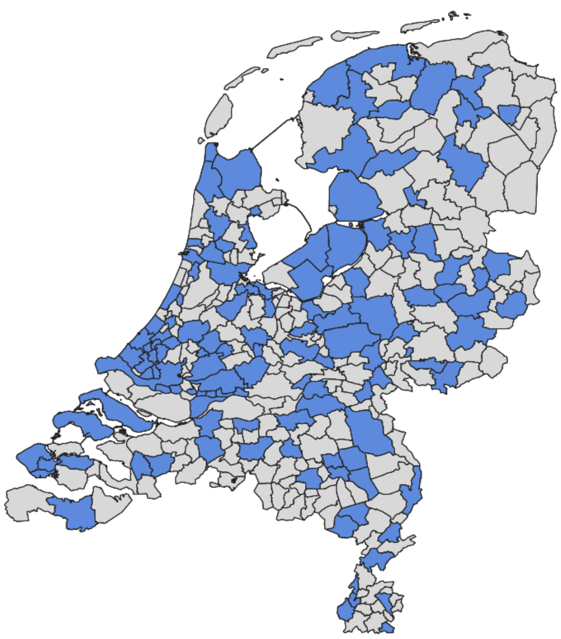
[9] Only members of Aedes due to data availability, plotted by visiting address

Data was collected over the period of 4 weeks, and a reminder was sent two weeks after the initial email. To increase the response rate of the survey, I offered an incentive: one randomly chosen housing association from the respondents would receive a free "flood risk QuickScan" for their real estate portfolio. Answers were collected anonymously and cannot be traced back to the individual respondent. In total 354 people responded to the survey. After cleaning the data from incomplete responses, the final sample consists of 252 respondents, distributed across 19 Housing Market Regions and 123 different municipalities. Finally, I identified 139 unique housing associations in the data by filtering on unique size. Although this number may differ slightly from the real amount of unique housing associations in the sample, due to the anonymity of the survey this is the only feasible estimation. A visual representation of the geographical distribution of the sample is provided in Figure 2.

FIGURE 2: Geographical sample coverage by municipality[10]



3.3. Survey reliability and validity

To construct the variables related to flood risk perception constructed from questions in the survey, I first conducted several analyses to test the survey's reliability and validity. Testing survey reliability and validity is important for obtaining reliable and valid information and ensuring accurate, consistent, and interpretable results (Hamed Taherdoost & Lumpur, 2016).

[10] Areas marked in blue represent the municipalities where housing associations in the sample are active.

First, to test the reliability of the questions in the survey, I calculate Cronbach's α as described in Cronbach (1951), which measures the correlation between a set of questions and provides a measure of internal consistency and reliability. Higher α scores reflect higher internal consistency, where acceptable levels are $\alpha > 0.70$ (Tavakol & Dennick, 2011). As shown in Table 1, Panel A-C, all variables exhibit α levels of > 0.70, indicating acceptable to excellent internal consistency levels.

Next, validity refers to how accurately the survey measures what it is intended to measure and consists of face validity, content validity, construct validity, and criterion validity. First, to establish face and content validity of the survey, questions in the survey were initially constructed based on the extensive literature review and subsequently tested among my colleagues at Finance Ideas, who served as experts in the Dutch social housing market. Second, to establish construct validity, I performed a Factor Analysis that investigates whether the variables in the model are measuring similar concepts or factors and can thus be put into a single (index) variable (Hamed Taherdoost & Lumpur, 2016). As shown in Appendix E, results show factor loadings of at least 0.40 for all flood risk perception variables, indicating that the questions indeed measure similar concepts and thus validating the use of an index variable (Hamed Taherdoost & Lumpur, 2016). Based on the conclusion of these tests, I constructed an index variable for each of the three concepts (awareness, worry, preparedness) by calculating the average score of the underlying questions.

TABLE 1: Cronbach's alpha for flood risk perception variables

Variable	**N**	**Cronbach's α**	**SD**
Panel A			
Awareness_1	252	0.86	1.5
Awareness_2	252	0.74	1.4
Awareness_3	252	0.76	1.4
Awareness_4	252	0.76	1.5
Awareness_5	252	0.81	1.5
Panel B			
Worry_1	252	0.93	1.5
Worry_2	252	0.92	1.5
Worry_3	252	0.92	1.4
Worry_4	252	0.93	1.5
Panel C			
Preparedness_1	252	0.83	1.4
Preparedness_2	252	0.82	1.5
Preparedness_3	252	0.81	1.6
Preparedness_4	252	0.81	1.6
Preparedness_5	252	0.81	1.4
Note: α > 0.70 Acceptable, α > 0.80 Good, α > 0.90 Excellent			

4. Survey results

Before performing the empirical analysis as described in Section 5, this section will first analyse the initial results from the survey. First, this section will discuss the general descriptive statistics of the data, presenting information about the characteristics of the respondents and the unique housing associations in the data. The results from the descriptive analysis are shown in Table 2 and supported by Figures 3-5. Finally, this section will elaborate on some specific results coming from the survey, identifying potential relationships in the data, and providing a direction for further analysis.

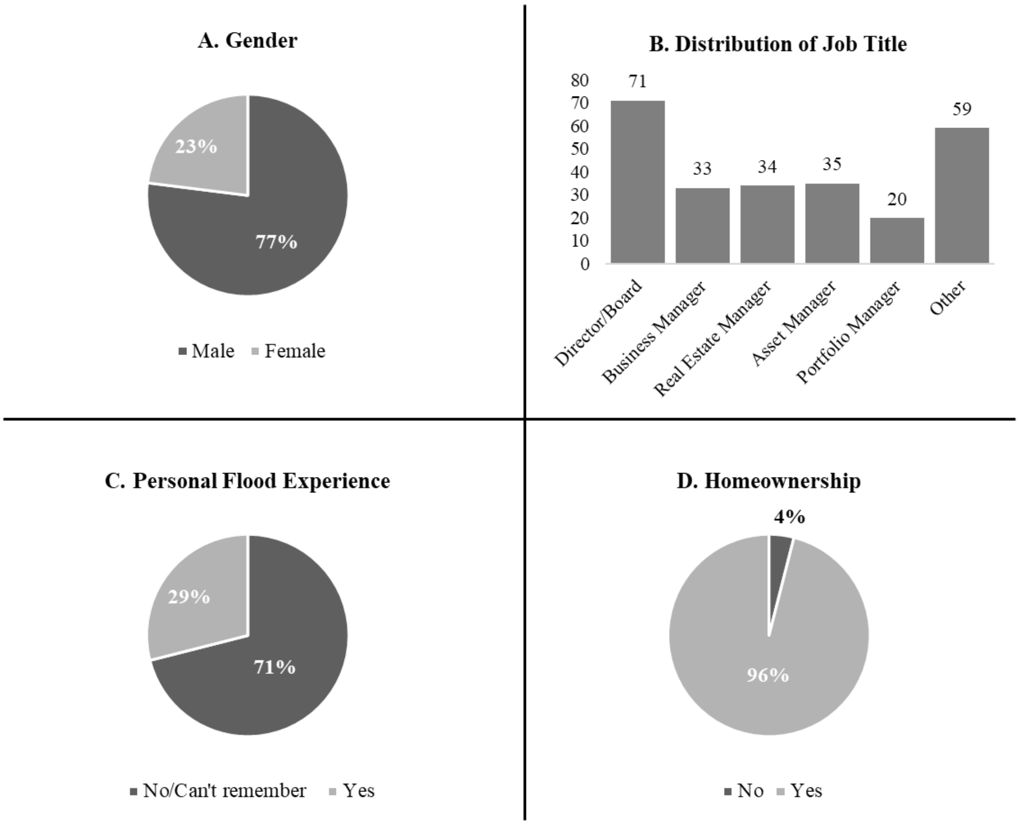
TABLE 2: Descriptive statistics

Variable	N	# Missings	Mean	SD
Respondent's Climate Risk Perception	252	0	5.29	0.86
Respondent's age	252	0	50.10	9.36
Flood hazard score (municipality)	252	0	0.0083	0.0171
Size (weighted rentable units)	252	0	13266	13235
Proportion of single-family homes (%)	252	0	0.47	0.24
Loan-To-Value ratio (LTV, %)	161	91	0.49	0.15
Overall FRP	252	0	3.86	1.13
Awareness Index	252	0	3.14	1.11
Worry Index	252	0	3.66	1.37
Preparedness Index	252	0	3.48	1.17

4.1. Characteristics of the respondents

As previously mentioned, after excluding incomplete responses, the total sample consists of 252 respondents. Based on the results from Table 2, the average age of the respondents is 50 years. Next, as shown in panel A of Figure 3, 77% of the respondents are males, whereas 23% are females. Furthermore, panel B shows the distribution of job titles, indicating that the majority of the respondents were directors or board members. The category "other" includes job titles such as sustainability manager/employee, project manager, and manager finance. Third, panel C shows the percentage of respondents that personally experienced flooding in their local area in the past five years. The results reveal that 29% of the respondents have recently experienced a flood, whereas 71% did not. Fourth, panel D illustrates the percentage of homeownership among the respondents, showing that almost all respondents are homeowners (94%). Next, as shown in Table 2, the mean climate risk perception of the individual respondent is 5.29 out of 7. Finally, due to numerous respondents expressing confusion regarding the two cause-knowledge questions and their possible answers, the responses to these questions will be excluded from the analysis. This decision aims to maintain the reliability of the analysis, as including potentially unreliable data could introduce inaccuracies and bias into the findings.

FIGURE 3: Respondent characteristics

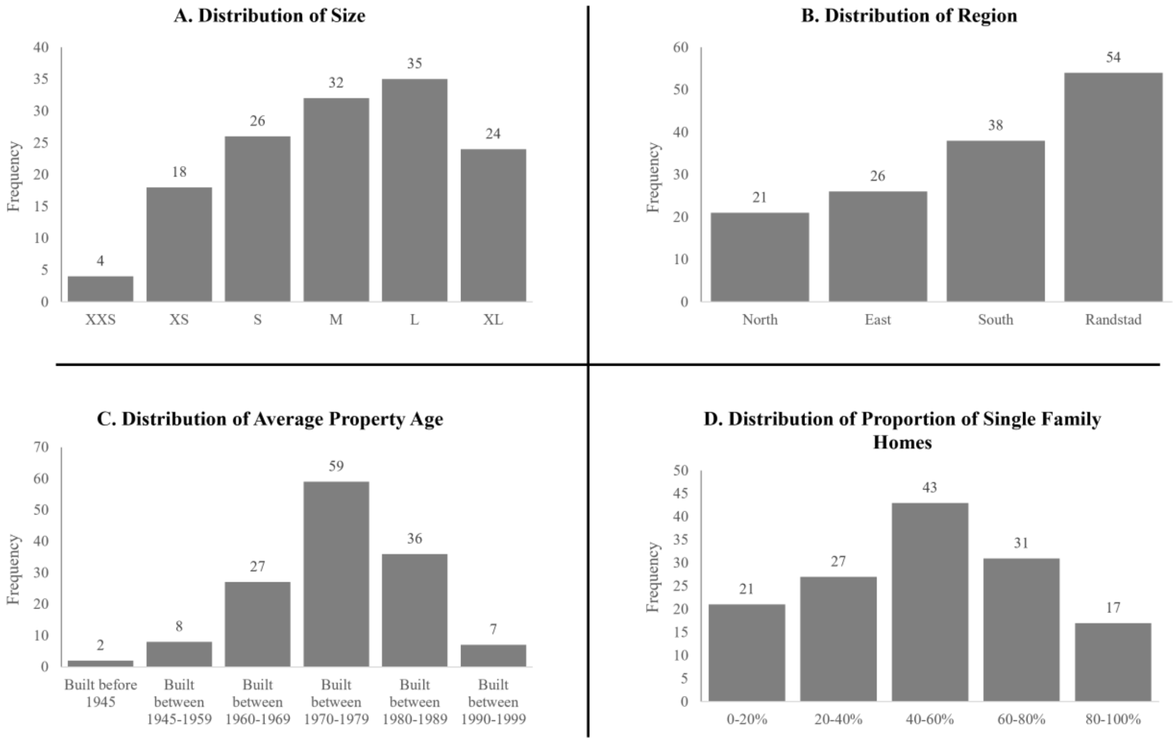


4.2. Characteristics of the housing association

As shown in Table 2, the average size of the housing association is roughly 13.000 weighted rentable units, which corresponds to size category L. Furthermore, the average proportion of single-family homes lies around 47 percent. The average internal LTV ratio is 49 percent; however, due to the significant number of missing values for this variable, the actual average ratio in the population may differ. Note that these average values are based on the full sample (N=252). When considering only unique housing associations in the data (N=139), both the average proportion of single-family homes and the average internal LTV ratio is 50%. The average size of the housing association remains roughly 13.000 weighted rentable units. Since this section will discuss the characteristics of the housing associations in the sample, I only consider unique housing associations (N=139) rather than all respondents (N=252) in the description of Figure 4 below. This figure shows the distribution of several characteristics of the housing association, with frequency on the Y-axis and different categories on the X-axis.

First, Figure 4 panel A shows the distribution of the size of the housing associations, split into six categories ranging from XXS to XL. These categories are created based on the same intervals as used by Aedes in their 2023 Benchmark[11]. As shown in the figure, size L represents the category with the highest frequency in the sample (35), followed by M (32). This means that most housing associations in the sample own between 5.000-10.000 (M) and 10.000-25.000 (L) weighted rentable units[12]. Second, panel B of the figure shows the distribution of the four regions, consisting of North, East, South, and Randstad. Here, Randstad represents the highest frequency of unique housing associations in the sample (54). Third, panel C presents the distribution of the average property age categories in the sample. Most housing associations in the sample (59) own dwellings built between 1970-1979. The average age categories indicating properties built after 2000 (2000-2010 and > 2010) are not represented in the sample. Panel D illustrates the distribution of single-family homes within the portfolios of housing associations. The majority of these housing associations (43) have a portfolio where 40% to 60% of their properties are single-family homes.

FIGURE 4: Distribution of housing association characteristics



[11] Size categories shown in Appendix G for reference
[12] Gewogen VHE's

4.3. Flood risk perception, experience, and climate adaptation

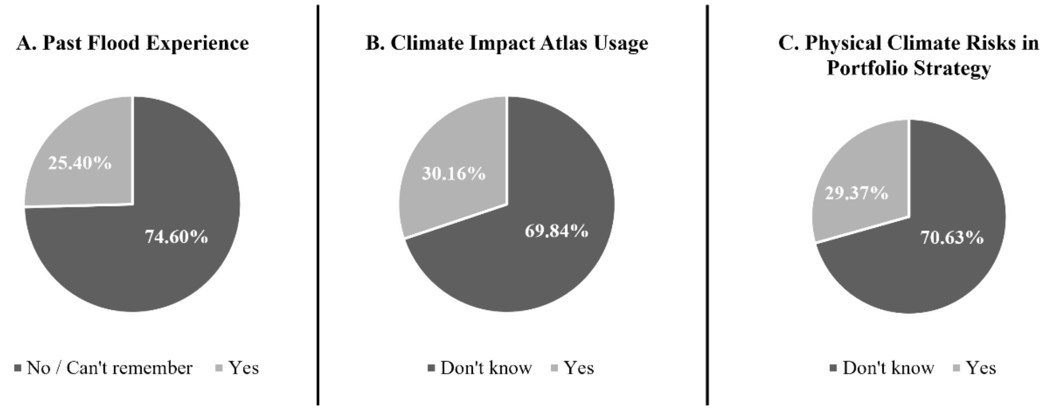
After analysing the characteristics of the respondents and the unique housing associations identified in the data, this section will provide a preliminary analysis of the characteristics of the flood risk perception variables and the remaining variables that describe the current climate change adaptation practices of the housing associations. This section will again focus on the full sample (N=252), meaning that it is possible that multiple individuals working for the same organisation are included in the total sample.

As described in Section 3.1, flood risk perception variables are assessed on a scale from 1 to 7, with 4 indicating a neutral stance towards the statement/question (e.g., neither agree nor disagree). Table 2 presents an average flood risk perception level in the complete sample of 3.86 out of 7, indicating a tendency towards low rather than high levels of flood risk perception. When examining flood risk perception in terms of awareness, worry, and preparedness separately, the results reveal slightly lower averages. For the level of awareness, the mean score in the sample is 3.14, indicating moderately low awareness among respondents. Somewhat surprisingly, for the level of worry, I observe a mean score of 3.66, suggesting rather low levels of worry as well. Conversely, the 3.46 mean score of preparedness also indicates moderately low levels of average preparedness.

Furthermore, I examined the proportion of past flood experiences within housing associations, the use of the Climate Impact Atlas, and the inclusion of physical climate risks in the organisations' portfolio strategy. As shown in Figure 5 panel A, 25.4% of respondents indicated that their housing association had experienced flooding in the past five years. Next, Panel B presents data on the usage of the Climate Impact Atlas. Approximately 30% of respondents were aware of its use within their organization. Notably, none of the respondents answered "no" to this question; nearly 70% responded with "don't know”. When analysing this ignorance by job title, business managers showed the highest percentage of unawareness at 78.98%, followed by directors/board members (77.46%), asset managers (74.29%), and real estate managers (70.59%). Portfolio managers and those with "other" job titles exhibited the lowest levels of unawareness at 50% and 59.32%, respectively. This may suggest that portfolio managers and those in other roles are either better informed due to their exposure to flood risk in their daily tasks or are working for housing associations with higher levels of flood risk perception. A visual representation of these findings can be found in Appendix C.

Lastly, panel C reports the proportion of respondents who indicated that physical climate risks are included in the portfolio strategy. Similar to the findings on Climate Impact Atlas usage, only 29.37% of respondents confirmed that physical climate risks are included in their portfolio strategy. Again, no respondent answered "no”, with about 70% responding "don't know”. When disaggregated by job title, similar levels of ignorance (70%-75%) were observed across all roles except for "other" (61%). This may suggest that individuals in “other” roles, such as sustainability managers, are more likely to be aware of physical climate risk inclusion in the portfolio strategy because of their daily tasks, or that these respondents work for housing associations with a stronger perception of flood risk. A visual representation of this analysis is included in Appendix D.

FIGURE 5: Experience, Climate Impact Atlas, and Portfolio Strategy



Although these observations already present interesting results, they do not provide any empirical evidence on the differences in flood risk perception levels among housing associations in the Netherlands or identify the key factors contributing to higher flood risk perception. To address these gaps, the next section will outline the empirical research design and discuss the hypotheses formulated based on the literature review and the preliminary analysis of the survey results.

5. Empirical research design

As mentioned before, this section will present the empirical research design. First, the variable construction and hypothesis development will be discussed. Second, this section will present the methods for empirical analysis and test the underlying assumptions.

5.1. Variable construction and hypotheses development

As outlined in the literature review, section 2.4.2., flood risk perception is generally measured through levels of awareness, worry and preparedness. To test whether these three concepts indeed correlate with the overall level of flood risk perception, I construct the first hypothesis indicating that there is a positive correlation between the level of awareness, worry, and preparedness, and the flood risk perception of the housing association.

***H*1:** There is a positive correlation between the level of awareness, worry, and preparedness, and the flood risk perception of the housing association.

After analysing the correlation of the three factors of flood risk perception, the main goal of this study is to investigate what key factors contribute to a higher level of flood risk perception. First of all, academic literature suggests that there is a positive relationship between the actual flood risk (objective risk) and the risk perception of an individual (subjective risk) (Ge et al., 2021; Horney et al., 2010; Iqbal & Nazir, 2023; Kellens et al., 2011; Rufat & Botzen, 2022; Zabini et al., 2021). For the Dutch context, Botzen et al. (2009) find a significant positive relationship as well, indicating that individuals who live in areas with higher levels of flood risk exhibit higher levels of flood risk perception. While these findings relate to how individuals perceive flood risks and no evidence is present whether this also holds for institutions like housing associations, I expect a similar relationship to hold for housing associations in the Netherlands. Based on these findings and my expectations, I construct the second hypothesis indicating that housing associations which operate in areas with higher estimated flood risk (hazard score) exhibit higher levels of flood risk perception:

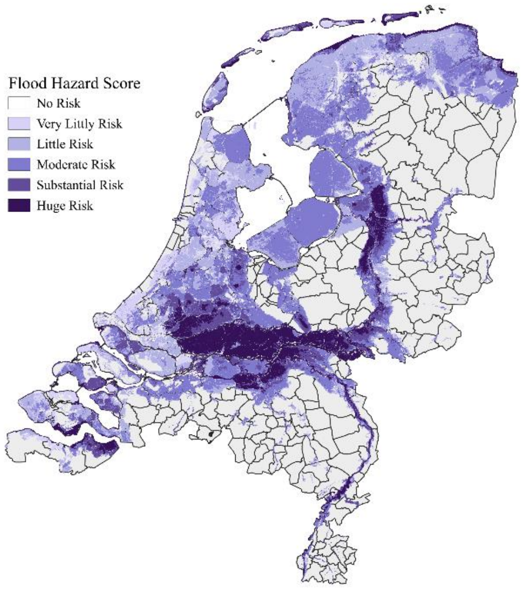
***H*2**: There is a positive relationship between the level of actual flood risk (flood hazard score) and the flood risk perception of the housing association.

To calculate the locational flood hazard scores for specific areas in the Netherlands, I make use of the flood fatality and damage hazard maps developed by De Bruijn et al. (2015). The underlying data of these comprehensive maps were made available to me by Deltares, one of the leading knowledge institutes in the field of water management in the Netherlands. What makes these maps unique and highly relevant for this study, is that De Bruijn et al. (2015) combine all the different types of flooding (pluvial, fluvial, dyke breach, etc.) and their underlying characteristics (probabilities, maximum water depth, flow velocity, duration, etc.). The hazard scores on the map do not take into account actual land use, the number and characteristics of objects, or the population of the area. Instead, they make use of hypothetical land use (standard single-family homes) and hypothetical population. The scores on the map represent the anticipated yearly proportion of the maximum potential damage to homes if they were situated in that specific location. Thus, hazard scores indicate the level of flood hazard tight to the specific location, not to the characteristics of what is built on the location (vulnerability). Since no property-specific data is used in this study due to the limited availability of information, the maps of De Bruijn et al. (2015) are suitable to measure the locational flood hazard score of a certain geographical area. To calculate the average (mean) flood hazard score of a municipality, I make use of Geographic Information System (GIS) techniques and combine the flood hazard zone map with geospatial data that outlines the different municipalities of the Netherlands.

An important point to make here is that these maps are constructed using data from the climate situation as of 2022 and the existing (current state of) flood protection infrastructure. The authors do provide an estimate of the 2050 situation; however, these estimates are only based on improvements in protection measures (as part of the Delta Programme) and do not take changes in the current climate into account. Therefore, in some areas, the level of flood hazard may be lower in the year 2050 compared to 2022. Since this study analyses the current actual flood risk versus the risk perception of the housing association, I will not make use of the 2050 flood hazard maps. A graphical presentation of the flood hazard map used in this study is given in Figure 6.

Next, I expect that several characteristics of the housing association would have an impact on the flood risk perception of the organisation. First, the size of the housing association, measured by the number of weighted rentable units (VHE), may have an impact on the flood risk perception of the housing association. Although no evidence in academic literature is present with regard to this relationship, I expect that larger housing associations exhibit higher levels of flood risk perception.

FIGURE 6: Flood hazard zones



Adopted from: De Bruijn, K. M., Klijn, F., Van De Pas, B., & Slager, C. T. J. (2015). Flood fatality hazard and flood damage hazard: Combining multiple hazard characteristics into meaningful maps for spatial planning. Natural Hazards and Earth System Sciences, 15(6), 1297–1309.

Larger housing associations manage a greater number of properties spread across diverse locations. With a larger portfolio, there may be a higher chance that some properties are situated in flood-prone areas. This broader exposure increases the likelihood of encountering flood-related issues, thereby raising their perception of flood risk. Furthermore, with more properties under their management, larger housing associations have a greater financial stake in protecting their assets from flood damage. The potential financial losses associated with flooding incidents can be significant for large organisations, leading to a heightened perception of flood risk. Additionally, larger organisations usually have better access to resources, including financial capital and expertise. This enables them to invest more in assessing and managing flood risks through measures such as flood risk assessments and infrastructure improvements, contributing to a higher level of flood risk perception. In the current academic literature, better access to information is found to be a positive indicator of increased flood risk perception (Lindell & Hwang, 2008; Miceli et al., 2008). Based on these findings and expectations, I construct *H*3, indicating a positive relationship between the size of the housing association and flood risk perception:

***H*3**: There is a positive relationship between the size of the housing association and the flood risk perception of the housing association.

Staying in the context of rentable units, the proportion of single-family homes (SFH) in the portfolio of the housing association may have an impact on the flood risk perception of the housing association. In the academic literature, Zabini et al. (2021) include house typology in their model to estimate the flood risk perception of individuals. However, the authors do not find any significant relationship between house typology and flood risk perception. Though, for housing associations, the story may be a bit different. On the one hand, single-family homes may exhibit a higher vulnerability to flood risks. This is because single-family homes typically occupy ground-level positions, lacking the buffer of additional units above or below, as seen in multi-family homes. Thus, a higher proportion of single-family homes may result in a higher overall exposure to flood risk for the housing association, thereby increasing the level of flood risk perception. Rufat & Botzen (2022) find a similar relationship for individual flood risk perception, indicating that respondents who live on lower floors have higher flood risk perceptions. On the other hand, multiple-family homes often have basements or underground parking facilities housing critical technical infrastructure like elevators and heating systems. These underground areas are especially vulnerable to flooding, resulting in higher overall exposure to flood risks. Thus, one could argue that a higher proportion of multiple-family homes may, as well, lead to higher levels of flood risk perception. Although there is no evidence on the direction of this relationship, I expect that the effect is stronger for single-family homes and therefore construct *H*4, indicating that housing associations which have a higher proportion of single-family homes in their portfolio exhibit higher levels of flood risk perception.

***H*4**: There is a positive relationship between the proportion of single-family homes in the portfolio of the housing association and the level of flood risk perception of the housing association.

Another characteristic that could influence the level of flood risk perception is the average property age. Since older properties often have inferior construction quality compared to newer ones, older properties may be more vulnerable to flood risks. Furthermore, newer buildings tend to already exhibit flood mitigation and adaptation in place due to building codes or regulations. On the one hand, this could mean that housing associations which have, on average, older properties in their portfolio exhibit higher levels of awareness and worry, while showing lower levels of preparedness. On the other hand, housing associations with a newer portfolio could exhibit lower levels of worry, while showing higher levels of awareness and preparedness. These complex interrelations and the lack of academic evidence regarding the relationship between property age and flood risk perception make it difficult to form expectations regarding the direction of the relationship. Therefore, I construct *H*5 as a non-directional hypothesis indicating that there is a relationship between the average property age and the flood risk perception of the housing association.

***H*5**: There is a relationship between the average property age and the level of flood risk perception of the housing association.

Next, the following hypotheses will test whether past flood experience has an effect on the flood risk perception of the housing association. The relationship between past flood experience is extensively tested in current academic literature, where findings suggest that past flood experience contributes to a higher level of flood risk perception (Bubeck et al., 2012; Harlan et al., 2019; Rufat & Botzen, 2022; Zabini et al., 2021). Based on these findings, I construct *H*6, indicating that there is a positive relationship between past flood experience and the flood risk perception of the housing association.

***H*6**: There is a positive relationship between past flood experience and the flood risk perception of the housing association.

Furthermore, the findings from the preliminary analysis in Section 4 already revealed interesting results concerning the usage of the Climate Impact Atlas. To test whether using the Climate Impact Atlas significantly affects the level of flood risk perception of housing associations, I construct hypothesis 7 indicating a positive relationship between the usage of the Climate Impact Atlas and the level of flood risk perception.

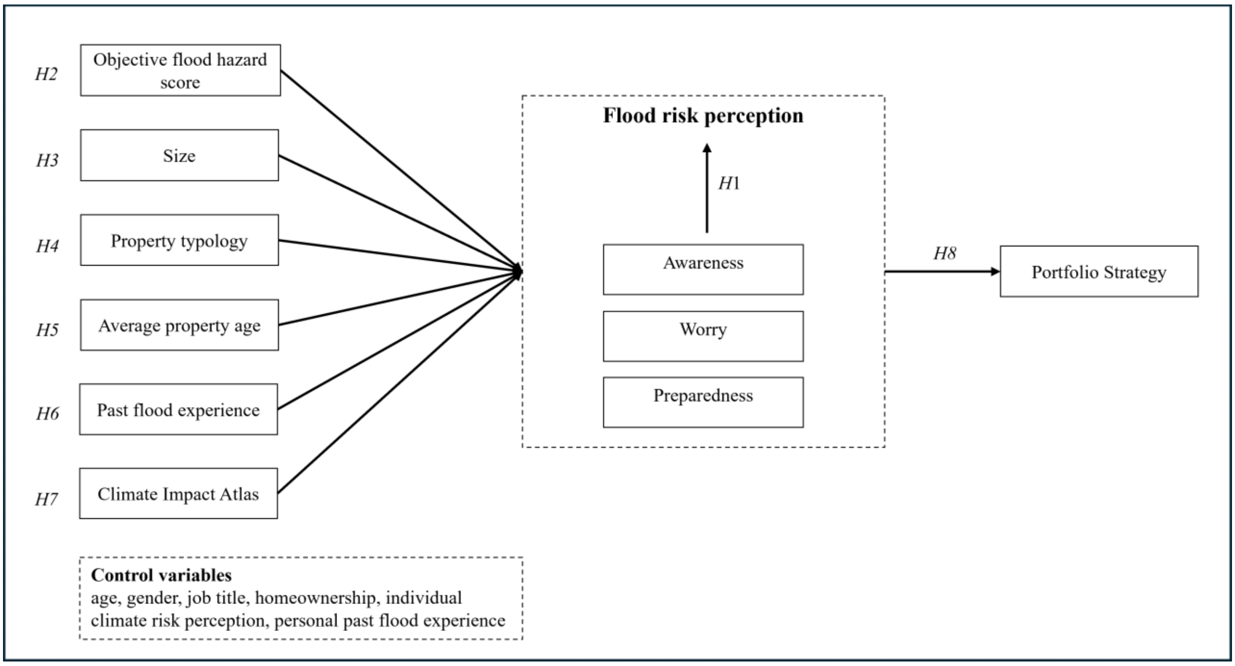
***H*7**: Housing associations that make use of the Climate Impact Atlas exhibit higher levels of flood risk perception.

Finally, to evaluate whether housing associations act on increased levels of awareness, worry, preparedness, and overall flood risk perception, I will investigate the relationship between these flood risk perception variables and the incorporation of physical climate risks into the housing association's portfolio strategy. I hypothesise that housing associations with higher levels of flood risk perception are more likely to integrate physical climate risks into their portfolio strategies. This yields the final hypothesis:

***H*8**: Housing associations with higher levels of flood risk perception are more likely to include physical climate risks in their portfolio strategy.

Besides testing the relationships between these variables and the level of flood risk perception, I include the respondent's age, gender, job title, homeownership, individual climate risk perception, and past personal flood experience as control variables in the model. This now yields the full conceptual framework as presented in Figure 7. Note that no hypothesis is formulated regarding the relationship between the internal LTV ratio and the flood risk perception of housing associations. This decision is primarily driven by the substantial amount of missing data, which significantly reduces the sample size and consequently undermines the reliability of any potential findings.

FIGURE 7: Conceptual framework



5.2. Statistical tests

This section will discuss the application and assumptions of the statistical models applied in this study. First, to test whether the level of awareness, worry, and preparedness indeed correlate with the general level of flood risk perception as indicated by *H*1, I perform a Pearson correlation analysis. Next, to test *H*2-*H*7 *as* described earlier, I will perform a multiple linear regression analysis consisting of 4 models, measuring the relationship between the predictor variables and the level of (1) Awareness, (2) Worry, (3) Preparedness, and (4) overall flood risk perception. Finally, to test the relationship between the level of flood risk perception and the likelihood of incorporating physical climate risks into the portfolio strategy of the housing association (*H*8), I perform a binary logistic regression analysis.

5.2.1. Multiple Linear Regression

The multiple linear regression model is a powerful statistical tool for examining the relationship between a single dependent variable and multiple independent variables (Uyanık & Güler, 2013). One critical assumption underlying this analysis is the treatment of the index variables derived from Likert scale questions as continuous rather than ordinal variables. While this assumption is the subject of ongoing debate, it finds support in academic literature, particularly in studies with more than five Likert scales and larger sample sizes (Norman, 2010). Moreover, in Section 3.3, I demonstrated that the Likert-scale questions concerning awareness, worry, and preparedness exhibit high internal consistency, reliability, and validity. This justifies the use of average index variables, thus effectively treating them as continuous variables.

Next, as input for the multiple regression models I constructed four regression equations based on the expected relationships from the conceptual framework. An important note to make here is that all continuous variables in the model are scaled to enhance the interpretability of the results. The regression equations for the four models are:

(1) $$Awareness = \beta 0 + \beta 1 Hazard\ score + \beta 2 Size + \beta 3 SFH\ proportion + \beta 4 Avg.\ property\ age + \beta 5 Past\ flood\ experience + \beta 6 Climate\ Impact\ Atlas + Controls + \epsilon$$

(2) $$Worry = \beta 0 + \beta 1 Hazard\ score + \beta 2 Size + \beta 3 SFH\ proportion + \beta 4 Avg.\ property\ age + \beta 5 Past\ flood\ experience + \beta 6 Climate\ Impact\ Atlas + Controls + \epsilon$$

(3) $Preparedness = \beta 0 + \beta 1 Hazard\ score + \beta 2 Size + \beta 3 SFH\ proportion + \beta 4 Avg.\ property\ age + \beta 5 Past\ flood\ experience + \beta 6 Climate\ Impact\ Atlas + Controls + \epsilon$

(4) $Overall\ FRP = \beta 0 + \beta 1 Hazard\ score + \beta 2 Size + \beta 3 SFH\ proportion + \beta 4 Avg.\ property\ age + \beta 5 Past\ flood\ experience + \beta 6 Climate\ Impact\ Atlas + Controls + \epsilon$

Where:

- *Awareness* is the dependent variable in model 1 representing the level of flood risk awareness of the housing association.
- *Worry* is the dependent variable in model 2 representing the level of flood risk worry of the housing association.
- *Preparedness* is the dependent variable in model 3 representing the level of flood risk preparedness of the housing association.
- *Overall FRP* is the dependent variable in model 4 representing the overall level of flood risk perception of the housing association.
- $\beta 0$ is the intercept of the regression equation.
- *Hazard score* represents the actual estimated flood risk (objective risk) in the municipality where the housing association is most active.
- *Size* represents the size of the housing association, measured by the number of weighted rentable units.
- *SFH proportion* represents the proportion of single-family homes in the portfolio of the housing association.
- *Avg. property age* represents the average age of properties in the portfolio of the housing association.
- *Past flood experience* represents the past flood experience of the housing association.
- *Climate Impact Atlas* represents whether the housing association uses the Climate Impact Atlas.
- *Controls* represents the collective set of control variables, including the respondent's age, gender, job title, home ownership, individual climate risk perception, and past personal flood experience.
- ϵ is the error term capturing the unexplained variability in flood risk perception.

To further support the robustness of the linear model, several assumptions must be met when performing a regression analysis (Uyanık & Güler, 2013) These include linearity, normality, linear independence, and homoscedasticity. To test these assumptions, I applied the Global Validation of Linear Model Assumptions (GVLMA) plugin in R that simultaneously examines these assumptions. By setting a significance level of 0.05, the plugin provides decision outputs indicating whether each assumption holds or should be rejected. The plugin conducts five distinct tests, including the overall validity of the model (Global Stat), assessing normality through Skewness and Kurtosis analysis, verifying model fit (Link Function), and heteroscedasticity.

After testing these assumptions for the four regression models, the following can be concluded: First of all, the output for models 1 (awareness) and 3 (preparedness) shows all assumptions are met, validating the use of the multiple linear model. Next, for model 2 (worry) only the kurtosis assumption is not satisfied. This suggests that while the other assumptions hold, there may be some deviation from normality in the distribution of residuals. Finally, for the overall flood risk perception level (model 4), the GVLMA output indicates satisfactory results for all tests except for Skewness. This implies a potential skewness in the distribution, which is likely influenced by the inherent nature of the underlying variables. For instance, factors such as individual climate risk perception and flood hazard scores might naturally exhibit skewness, thus affecting the overall skewness of the model.

In addition to assessing linearity, normality, model fit, and homoscedasticity, I evaluated the potential presence of multicollinearity in the four models. Utilising the Variance Inflation Factor (VIF), I concluded that there are no significant multicollinearity issues impacting the four models (all VIF values were below 5). This analysis provides further support for the robustness of the regression models and the reliability of their estimates.

Overall, the regression assumption tests suggest a reasonable level of robustness in the models examined. However, the identification of certain violations, particularly in some of the models, underscores the importance of interpreting the results cautiously. While most assumptions hold, these deviations signal areas where the reliability of the findings may be compromised to some extent. Hence, while the models provide valuable insights, careful consideration of the identified limitations is needed to ensure accurate interpretation and meaningful application of the results described in the next section.

5.2.2. Binary logistic regression

Finally, to investigate whether housing associations with higher levels of flood risk perception are more likely to include physical climate risks in their portfolio strategy, I perform a binary logistic regression analysis that measures the relationship between a binary outcome (dependent) variable and at least one predictor (independent) variable (Harris, 2021). In this analysis, the binary variable indicates whether the housing association incorporates physical climate risks into their portfolio strategy (yes/no). To perform the analysis, I constructed the following logistic regression equations:

(5) $logit(P) = \beta 0 + \beta 1 Awareness + \beta 2 Hazard\ score + \beta 3 Size + \beta 4 SFH\ proportion + \beta 5 Past\ flood\ experience$

(6) $logit(P) = \beta 0 + \beta 1 Awareness + \beta 2 Worry + \beta 3 Hazard\ score + \beta 4 Size + \beta 5 SFH\ proportion + \beta 6 Past\ flood\ experience$

(7) $logit(P) = \beta 0 + \beta 1 Awareness + \beta 2 Worry + \beta 3 Perparedness + \beta 4 Hazard\ score + \beta 5 Size + \beta 6 SFH\ proportion + \beta 7 Past\ flood\ experience$

(8) $logit(P) = \beta 0 + \beta 1 Overall\ FRP + \beta 2 Hazard\ score + \beta 3 Size + \beta 4 SFH\ proportion + \beta 5 Past\ flood\ experience$

In these equations:

- logit(P) represents the log odds of incorporating physical climate risks in the portfolio strategy.
- P represents the probability of incorporating physical climate risks in the portfolio strategy.
- $B0$, $B1$, …, $B7$ are the coefficients estimated by the model. They represent the effect of each predictor variable on the log odds of the event occurring.

Certainly, several assumptions must be met when performing a binary logistic regression analysis. These include independence of observations, linearity, and no multicollinearity (Harris, 2021). To satisfy the assumption of independent observations, I include only unique housing associations (N=139). This ensures that all observations in the sample are independent of each other. Next, the linearity assumption in logistic regression states that the relationship between the predictor variables and the log odds of the predicted probabilities for the outcome should be linear (Harris, 2021). To verify whether this assumption holds, I plotted the relationships for each predictor variable and carefully assessed their linearity. Based on this visual examination, it seems that the linearity assumption is adequately satisfied for all predictors. Finally, I again performed a Variance Inflation Factor (VIF) analysis to ensure no perfect multicollinearity in the model. The results show values around 1, indicating no multicollinearity issues. With all assumptions for the binary logistic regression satisfied, I validate the use of this model and ensure the robustness of the results.

6. Empirical results

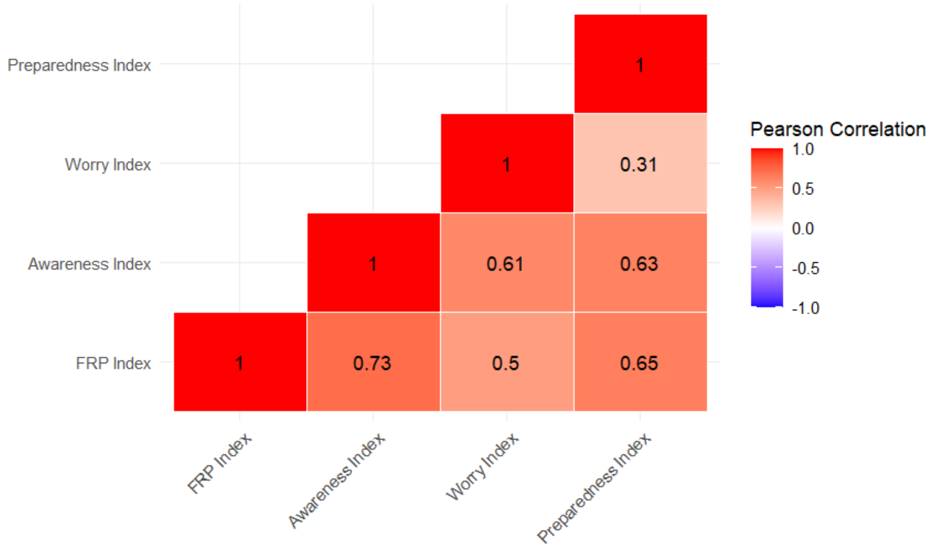
After discussing and validating the empirical design of this study, this section elaborates on the specific results coming from the Pearson correlation analysis, the general linear model, and the binary logistic regression. First, this section will discuss the analysis of the relationship between flood risk perception and its underlying factors (awareness, worry, preparedness), testing the first hypothesis. Secondly, this section will discuss the results coming from the multiple regression analysis, covering hypotheses 2-7. Finally, this section discusses the outcomes of the binary logistic regression analysis covering hypothesis 8.

6.1. Flood risk perception and its underlying factors

To analyse the relationship between awareness, worry, preparedness, and the general level of flood risk perception, I performed a Pearson correlation analysis. Figure 8 presents the correlation heatmap of the flood risk perception variables. The analysis reveals significant positive correlations between the three factors of flood risk perception and the general level of flood risk perception (FRP Index). Specifically, awareness exhibits a strong positive correlation with the FRP Index, with a correlation coefficient of 0.73. This indicates that higher levels of awareness are associated with a higher perception of flood risk. Worry also shows a positive correlation with the FRP Index, though to a lesser extent, with a correlation coefficient of 0.50, suggesting that increased worry corresponds to an increased perception of flood risk. Similarly, preparedness demonstrates a strong positive correlation with the FRP Index, with a coefficient of 0.65, indicating that increased preparedness is linked to a higher perception of flood risk. Based on these results, I find support for Hypothesis 1, indicating a positive correlation between the three flood risk perception factors and the overall level of flood risk perception.

Furthermore, the heatmap also presents the correlations among the three factors themselves. Awareness and worry are positively correlated, with a correlation coefficient of 0.61. Similarly, awareness and preparedness exhibit a positive correlation, with a coefficient of 0.63. However, the correlation between worry and preparedness is lower, with a coefficient of 0.31. These results highlight that while all three factors (awareness, worry, and preparedness) are positively associated with the general level of flood risk perception, their interrelationships vary in strength. Awareness tends to be more strongly associated with both worry and preparedness, suggesting that increased awareness might concurrently elevate levels of worry and preparedness. Conversely, the lower correlation between worry and preparedness indicates that these two factors might influence flood risk perception more independently from each other.

FIGURE 8: Correlation heatmap of flood risk perception variables



6.2. Key determinants of flood risk perception in Dutch social housing institutions

After investigating flood risk perception and its underlying factors, this section elaborates on the key determinants of flood risk perception in Dutch social housing institutions. The most important results from the multiple linear regression analysis are presented in Table 3, with the complete regression output available in Appendix A.

Firstly, I examine the relationship between the average flood hazard score of the municipality where the housing association is most active and the level of flood risk perception of the housing association. Hypothesis 2 describes a positive relationship between these variables. However, as shown in Table 3, the analysis does not reveal any statistically significant relationship between the flood hazard score and levels of awareness, worry, preparedness, or overall flood risk perception. Consequently, the findings do not support Hypothesis 2.

Next, I examine whether the size of the housing association affects the level of flood risk perception. As shown in Table 3, the size of the housing association is statistically significant only for the level of preparedness ($p < 0.1$), indicating that larger housing associations, as measured by the number of weighted rentable units, exhibit higher levels of preparedness (holding all other variables constant). However, for the levels of awareness, worry, and overall flood risk perception, there is no statistically significant relationship. Therefore, these findings provide only partial support for Hypothesis 3.

Third, I investigate the relationship between the proportion of single-family homes in the housing association's portfolio and the level of flood risk perception. As reported in Table 3, the proportion of single-family homes is statistically significant only for the level of preparedness ($p < 0.05$), holding all other variables constant. The positive and significant coefficient indicates that housing associations with a higher proportion of single-family homes report higher levels of preparedness. However, for the other flood risk perception variables—awareness, worry, and overall flood risk perception—the results do not show significant coefficients. Therefore, these findings provide only partial support for Hypothesis 4, specifically related to the level of preparedness.

Fourth, I analyse whether there is a relationship between the average property age of the housing association and the level of flood risk perception. After creating dummy variables for each of the six age categories, one can measure the difference between the categories compared to a reference category. In this case, properties built after 1990-1999 are used as the reference category. Note that the age categories 2000-2010 and > 2010 are not shown in the analysis since they were not present in the data. As shown in Table 3, no average age category is significant in one of the four models. While Hypothesis 5 expected a non-directional relationship between the average property age and the level of flood risk perception, the results thus do not provide significant coefficients to support the hypothesis.

Next, I examine the effect of past flood experience of the housing association on the level of flood risk perception. Based on the regression output in Table 3, I find significant positive relationships for past flood experience in all four models. These results imply that housing associations that experienced flooding in the past five years exhibit significantly higher levels of awareness, worry, preparedness, and overall flood risk perception. Not surprisingly, this effect is strongest for the level of worry, followed by the level of awareness, preparedness, and overall flood risk perception, respectively. Therefore, based on these results, I find support for Hypothesis 6.

Finally, I investigate whether the usage of the Climate Impact Atlas to analyse flood risks has a significant effect on the level of flood risk perception of the housing association. The regression results shown in Table 3 provide statistically significant and positive coefficients in all four models, indicating that housing associations which make use of the Climate Impact Atlas to analyse flood risks exhibit higher levels of awareness, worry, preparedness and overall flood risk perception. Therefore, I find support for Hypothesis 7. More specifically, this effect is strongest for the level of awareness, suggesting that the Climate Impact Atlas primarily enhances flood risk perception by creating more awareness within the housing association.

Altogether, the findings from Table 3 show support for *H*6, and *H*7, partial support for *H*3 and *H*4, and no support for *H*2 and *H*5. Therefore, I can conclude that the past flood experience of the housing association and the usage of the Climate Impact Atlas significantly contribute to higher levels of flood risk perception among Dutch social housing institutions, measured by awareness, worry, preparedness and an overall measure of flood risk perception. Furthermore, larger housing associations and housing associations with a higher proportion of single-family homes in their portfolio show significantly higher levels of self-reported flood risk preparedness. These results are robust when controlling for the respondent's individual climate risk perception, personal past flood experience, age, gender, property ownership, and job title.

TABLE 3: Multiple linear regression results

	Dependent variable:			
	Awareness	Worry	Preparedness	Overall FRP
	(1)	(2)	(3)	(4)
Individual climate risk perception	0.012	0.139^{**}	-0.144^{**}	-0.081
	(0.062)	(0.063)	(0.063)	(0.063)
Personal flood experience	0.232^{*}	-0.040	0.298^{**}	0.125
	(0.141)	(0.142)	(0.143)	(0.143)
"Other" job title	-0.160	-0.003	-0.093	-0.344^{*}
	(0.180)	(0.182)	(0.183)	(0.183)
Flood hazard score (municipality)	0.003	0.030	0.012	0.008
	(0.062)	(0.063)	(0.063)	(0.063)
Size (weighted rentable units)	0.003	0.032	0.155^{**}	0.097
	(0.073)	(0.073)	(0.074)	(0.074)
Proportion of SFH	-0.002	-0.036	0.174^{**}	0.084
	(0.071)	(0.072)	(0.072)	(0.072)
Built before 1945	0.626	-0.076	0.850	0.638
	(0.594)	(0.601)	(0.603)	(0.603)
Built 1945 to 1959	0.246	0.226	-0.361	0.113
	(0.361)	(0.366)	(0.367)	(0.367)
Built 1960 to 1969	0.324	0.364	-0.248	0.395
	(0.275)	(0.278)	(0.279)	(0.279)
Built 1970 to 1979	0.167	0.213	-0.275	0.233
	(0.258)	(0.261)	(0.262)	(0.262)
Built 1980 to 1989	0.197	0.438	-0.428	0.234
	(0.265)	(0.269)	(0.270)	(0.270)
Past flood experience	0.374^{**}	0.664^{***}	0.372^{**}	0.338^{**}
	(0.147)	(0.149)	(0.149)	(0.149)
Climate Impact Atlas	0.736^{***}	0.341^{**}	0.407^{***}	0.629^{***}
	(0.137)	(0.139)	(0.140)	(0.140)
Constant	-0.516	-0.823^{*}	0.220	-0.457
	(0.415)	(0.420)	(0.421)	(0.421)
Observations	252	252	252	252
R^2	0.206	0.186	0.180	0.180
Adjusted R^2	0.138	0.116	0.109	0.109
Residual Std. Error (df = 231)	0.929	0.940	0.944	0.944
F Statistic (df = 20; 231)	3.001^{***}	2.642^{***}	2.538^{***}	2.538^{***}
Note:				$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

6.3. Flood risk perception and portfolio strategy

To investigate whether housing associations act on increased levels of awareness, worry, preparedness, and overall flood risk perception, I investigate the relationship between these flood risk perception variables and the likelihood of integrating physical climate risks into the housing association's portfolio strategy. The binary logistic regression results are reported in Table 4, along with the Odds Ratio's (OR) in Table 5.

Starting with model 5, which includes only awareness as the flood risk perception variable, the results show that the level of awareness alone is a significant predictor for estimating the likelihood of including physical climate risks in the portfolio strategy of the housing association. Next, model 6 includes worry as an additional predictor. While awareness loses its statistical significance in this model, the level of flood risk worry is positively and significantly associated with the log-likelihood of portfolio strategy. Thirdly, when including the level of preparedness in Model 7, both worry and preparedness are positive and significant predictors. Awareness turned negative and remains non-significant in this model. Lastly, model 8 shifts the focus to the overall flood risk perception (FRP), which is positively and significantly related to the log-likelihood of the portfolio strategy variable. This model does not include awareness, worry, or preparedness as individual predictors.

These results show that increased levels of flood risk perception significantly affect the probability of including physical climate risks in the portfolio strategy of the housing association, controlling for objective flood risk (flood hazard score), size, the proportion of single-family homes and past flood experience. Based on these results, I thus find support for Hypothesis 8, implying that housing associations which exhibit higher levels of flood risk perception are more likely to include physical climate risks in their portfolio strategy. Furthermore, the negative and significant constant term in all four models implies a baseline tendency against including physical climate risks in the portfolio strategy when all predictors are at their reference levels.

To estimate the increased likelihood of a housing association incorporating physical climate risks in the portfolio strategy for a one-unit change in the predictor variables, I calculate the Odd Ratio (OR) for each predictor variable. Again, the continuous variables in the models are normalised with a mean of zero and a standard deviation of one to enhance interpretability.

While the output tables for all four models are reported in Appendix B, I only report on the Odd Ratio's for model 7 as it shows the strongest fit among the four models and includes awareness, worry, and preparedness. The ORs for model 7 are shown in Table 5 below. The results reveal that with each one standard deviation increase in the level of worry, housing associations are 2.37 times more likely to incorporate physical climate risks into their portfolio strategy, holding all other variables constant. For the level of preparedness, this increase would result in a 2.46-fold increase in the likelihood of the housing association incorporating physical climate risks into its portfolio strategy.

TABLE 4: Binary logistic regression results

	Dependent variable:			
	Portfolio Strategy			
	(5)	(6)	(7)	(8)
Awareness	0.753***	0.409	-0.144	
	(0.226)	(0.265)	(0.339)	
Worry		0.719**	0.863***	
		(0.288)	(0.307)	
Preparedness			0.902***	
			(0.322)	
Overall FRP				0.751***
				(0.249)
Flood hazard score (municipality)	-0.371	-0.394	-0.324	-0.413
	(0.288)	(0.306)	(0.293)	(0.297)
Size (weighted rentable units)	0.182	0.116	0.028	0.150
	(0.224)	(0.229)	(0.238)	(0.223)
Proportion of SFH	0.105	0.098	0.052	0.036
	(0.233)	(0.240)	(0.252)	(0.236)
Past flood experience	0.589	0.361	0.137	0.597
	(0.477)	(0.485)	(0.506)	(0.477)
Constant	-1.244***	-1.288***	-1.340***	-1.256***
	(0.248)	(0.263)	(0.276)	(0.250)
Observations	139	139	139	139
Log Likelihood	-72.129	-68.787	-64.367	-72.938
Akaike Inf. Crit.	156.259	151.575	144.734	157.876
Note:				*p<0.1; **p<0.05; ***p<0.01

TABLE 5: Odds Ratio table model 7

Model 7	Odds Ratio	95% CI	p-value
Constant	0.26^{***}	0.15 - 0.44	0.00
Awareness	0.87	0.44 - 1.67	0.67
Worry	2.37^{***}	1.33 - 4.47	0.00
Preparedness	2.46^{***}	1.35 - 4.81	0.01
Flood hazard score (municipality)	0.72	0.36 - 1.2	0.27
Size (weighted rentable units)	1.03	0.63 - 1.64	0.90
Proportion of SFH	1.05	0.64 - 1.74	0.84
Past flood experience	1.15	0.42 - 3.06	0.79
Note:		$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.1$	

7. Discussion

The previous section presented the results from the three statistical analyses. This section will now explore the implications of these findings from both academic and practical perspectives. Additionally, it will address the limitations inherent to this study and suggest directions for future research. This section will follow the same structure as previous sections, covering *H*1 to *H*8.

7.1. Academic and practical implications

Academically, this research contributes to the existing body of knowledge on flood risk perception, particularly within the context of housing associations in the Netherlands. It builds further on the flood risk perception studies by Iqbal & Nazir (2023), Raaijmakers et al. (2008), and Rufat & Botzen (2022), measuring flood risk perception in terms of awareness, worry, and preparedness. By combining survey responses with geospatial flood maps, this study measured both objective flood risk and subjective flood risk perception, following a similar approach as Mol et al. (2020) and Rufat & Botzen (2022).

First, Hypothesis 1 tested the relationship between the three flood risk perception variables and the overall level of flood risk perception of housing associations in the Netherlands. Based on the results from the Pearson correlation analysis, I find that the three factors significantly correlate with the level of flood risk perception. These findings build further on the research of Lechowska (2018), who described the factors of flood risk perception and their underlying relationships. From a practical perspective, the three factors of flood risk perception disaggregate the process of how individuals perceive flood risks: First, individuals must become aware of the risk by understanding the type of hazard, their vulnerability, and their level of exposure. Once individuals are aware of the flood risk, they may begin to worry about the potential negative consequences. This concern acts as a motivator, pushing individuals to take action to mitigate the risk and become more prepared. By addressing and understanding these factors of flood risk perception, policymakers and practitioners can more effectively support individuals as well as institutions in understanding and managing flood risks.

To investigate what these findings mean for the Dutch social housing sector, the next analysis focused on the key determinants for increased flood risk perception in Dutch housing associations. By regressing an extensive set of characteristics of the housing association against the level of awareness, worry, preparedness, and an overall measure of flood risk perception, I identified some significant contributors to an increased level of flood risk perception. First, while previous academic literature finds a significant relationship between the objective flood risk (flood hazard score) and the subjective flood risk perception of individuals, no such significance was found for housing associations in this study. On the one hand, this may suggest that housing associations which operate in areas with higher flood risk do not significantly have higher perceptions of flood risk compared to housing associations that operate in areas with lower objective flood risk. On the other hand, this lack of significant results may be due to the characteristics of the flood hazard variable used in this study. By relying on an average hazard score for the municipality where the housing association primarily operates, rather than property-specific data, the actual hazard score for the housing association could differ and potentially impact the results.

Next, I examined whether the characteristics of the housing association significantly affect its flood risk perception. For size and the proportion of single-family homes, the results were significant and positive when it came to the level of preparedness in model 3. For the average property age, no significant results were found in any model. Most importantly, past flood experience and the usage of the Climate Impact Atlas were significant predictors in all four models.

Starting with the size of the housing association, the results indicate that larger housing associations exhibit higher levels of flood risk preparedness. Larger housing associations can perhaps allocate more resources, implement better mitigation strategies, or have more robust emergency response plans, all of which contribute to higher levels of preparedness. The size advantage likely enables these larger organisations to take proactive measures to address (potential) flood risks, resulting in increased levels of preparedness compared to smaller housing associations.

Moreover, the findings show that housing associations with a larger proportion of single-family homes in their portfolio exhibit higher levels of preparedness. This may be attributed to several factors. On the one hand, single-family homes might be inherently easier to flood-proof compared to multiple-family homes. For example, multi-family homes often have more complex structural features such as elevators or underground parking garages, which can complicate flood-proofing efforts and increase vulnerability. On the other hand, housing associations with a higher proportion of single-family homes in their portfolio may face increased flood risk exposure due to the specific characteristics of their holdings. This may motivate them to place greater emphasis on mitigating and adapting to flood risks, ultimately resulting in higher levels of preparedness.

When it comes to past flood experience, the survey results revealed that roughly 25% of the housing associations in the sample experienced flooding in the past five years. Looking at the empirical evidence on the relationship between past flood experience and flood risk perception, this study finds similar results as previous academic literature. Specifically, past flood experience is significantly and positively related to the levels of awareness, worry, preparedness, and overall flood risk perception. This relationship has been emphasised in earlier studies by Bubeck et al. (2012), Harlan et al. (2019), Rufat & Botzen (2022), and Zabini et al. (2021), all of which highlight the importance of past flood experiences in shaping an individual's flood risk perception. This study extends these findings to demonstrate that the relationship also holds for housing associations as institutions. In practice, these findings imply that housing associations which previously experienced flooding are not only more worried about flood risk but also demonstrate greater awareness and preparedness in addressing them.

Another interesting finding from this study comes from the usage of the Climate Impact Atlas. The survey results showed that only 30% of respondents indicated that their housing association uses the Climate Impact Atlas to analyse flood risks. This relatively low percentage is rather surprising, given the significant impact that using the Climate Impact Atlas has on flood risk perception. Based on the empirical findings, housing associations which use the Climate Impact Atlas demonstrate significantly higher levels of awareness, worry, preparedness, and overall flood risk perception. From a practical perspective, these findings indicate a missed opportunity for many housing associations to enhance their flood risk management strategies. By not using the Climate Impact Atlas, the majority of housing associations may be less equipped to anticipate and respond to flood risks. This gap underscores the need for greater awareness and promotion of the benefits of using comprehensive tools like the Climate Impact Atlas in flood risk analysis. Given that the Climate Impact Atlas is publicly available and rather easy to use, encouraging more widespread adoption could lead to improved resilience for housing associations operating in flood-prone areas. By following a similar approach as Attoh et al. (2022) and using the Framework For Climate Adaptive Buildings developed by the Dutch Green Building Council (2022), Dutch housing associations can increase their awareness of flood risks and start climate-proofing their housing stock.

Finally, the findings on whether housing associations in the Netherlands incorporate physical climate risks into their portfolio strategy show somewhat surprising results. The survey revealed that less than 30% of the respondents indicated that physical climate risks are included in the portfolio strategy of the housing association. To understand what drives these actions, this study empirically investigated the relationship between flood risk perception and the likelihood of incorporating physical climate risks into the portfolio strategy. The results showed that the level of awareness, worry, preparedness, and overall flood risk perception are all significant predictors, depending on the model. This suggests that housing associations which exhibit higher levels of flood risk perception are more likely to incorporate physical climate risks into their portfolio strategy. In practice, such proactive measures can empower housing associations in the Netherlands to effectively mitigate and adapt to flood risks, safeguarding their dwellings and improving resilience in the face of climate-related challenges.

7.2. Limitations and suggestions for future research

Certainly, the findings of this study are subject to some limitations. First, this study relied on a self-developed survey. Although the survey was based on existing techniques and was initially tested by experts in the social housing sector, due to time constraints an extensive testing period was not possible. During the process of gathering responses, some participants informed me about their confusion regarding the terminology used in the survey. Although it was explicitly stated that the study focused on all types of flooding, some respondents were confused that flooding only includes riverine or coastal flooding and does not include nuisance flooding[13] resulting from extreme rainfall. This confusion stems largely from the difference in terminology used by the Dutch government and other institutions. Consequently, this may introduce some measurement errors, especially related to the measurement of the level of awareness, worry, and preparedness. Moreover, when it comes to the actual responses the survey introduces some potential response biases, such as social desirability bias. This may lead respondents to over-report positive behaviours or under-report negative behaviours related to flood risk perception and management.

Next, despite the sufficiently large and geographically diverse sample size across the Netherlands, this study could only identify 139 unique housing associations by filtering on unique size. Although this was the only feasible method due to the anonymity of responses, it may introduce some inaccuracies. For instance, it is possible that some housing associations were unintentionally included or excluded due to variations in the reporting of their size. Consequently, the sample of unique housing associations used in some of the analyses may not fully capture the diversity and nuances present in the actual population.

Looking at the specific variables used in this study, several limitations arise. First of all, the measurement of the flood hazard score is based on the average hazard score within a certain area, in this case, the municipality where the housing association is most active. This may result in either underestimating or overestimating the actual flood hazard score tight to the association's housing stock. This may also explain the lack of significant results on the relationship between objective flood risk and the flood risk perception of Dutch housing associations. Furthermore, the flood hazard score map developed by De Bruijn et al. (2015) has some inherent limitations. These include uncertainties regarding flood probability and severity, as well as challenges regarding its applicability on a local scale. Additionally, the map does not account for changes in climate over time, which could affect its accuracy and relevance.

[13] Wateroverlast als gevolg van extreme neerslag

Secondly, due to substantial missing values, this study fails to capture the internal LTV ratio for most housing associations in the sample, leading to its exclusion from the analysis. Although this is not problematic per se, including the LTV ratio could have provided more comprehensive results on the drivers of flood risk perception in Dutch housing associations.

Third, while the study includes key variables related to flood risk perception and the characteristics of housing associations, it may have omitted other potentially influential factors to avoid making the survey overly long. For instance, more sensitive factors, such as the political preferences of respondents, were not included in the survey. These factors, however, could be significant in shaping individuals' perceptions of climate risk and thus important to control for. Furthermore, this study does not make use of property-specific data when investigating flood risk perception. While the average property age and the proportion of single-family homes were included in the analysis, other property-specific characteristics might be significant factors in how housing associations perceive flood risks. These could include but are not limited to, the level of elevation, structural characteristics, existing flood protection measures, and tenant demographics. Including these variables could have provided more insightful results.

Based on these limitations, some suggestions for future research arise. First of all, future research could include a more extensive set of variables to measure the flood risk perception and characteristics of housing associations in the Netherlands. Second, including property-specific data could yield more comprehensive results, especially when measuring the actual (potential) flood risk tight to the real estate holdings of the housing association. Third, while this study already provides interesting findings on flood risk, it does not cover the other physical climate risks that social housing institutions in the Netherlands may encounter. Therefore, future research could explore a wider spectrum of physical climate risks, providing a more holistic overview of the risks that housing associations face due to climate change. Fourth, this study lacks elaboration on specific actions housing associations can undertake to mitigate and adapt to flood risks. Future research could offer valuable insights into how housing associations can analyse physical climate risks within their portfolios and identify effective measures to address these risks. Lastly, this study does not measure the change in flood risk perception over time. Using a longitudinal approach, future research could examine whether flood risk perception changes over time, providing a better understanding of the impact of climate change on risk perception.

8. Conclusion

Using a survey-based research approach, this study builds further on the current literature on flood risk perception. By focusing specifically on housing associations in the Netherlands, this study extends the understanding of how organisations within the real estate sector perceive and respond to flood risks. Previous research has largely concentrated on individual homeowners or broader economic implications, overlooking the unique challenges and considerations faced by housing associations. This study fills that gap by providing empirical evidence on the flood risk awareness, worry, and preparedness of Dutch housing associations and identifies what contributes to higher levels of flood risk perception.

The findings of this study show that past flood experiences and the usage of the Climate Impact Atlas significantly contribute to higher levels of awareness, worry, preparedness, and overall flood risk perception among housing associations. Moreover, larger housing associations and those with a greater proportion of single-family homes in their portfolio report significantly higher levels of flood risk preparedness. Despite the evident benefits of the Climate Impact Atlas in enhancing flood risk perception, the adoption rate among housing associations remains low, with only 30% utilising the tool. This gap underscores the need for increased promotion and integration of such resources to enhance flood risk awareness and preparedness across the sector.

Furthermore, the study demonstrates that heightened levels of worry and preparedness are associated with a greater likelihood of incorporating physical climate risks into the portfolio strategies of housing associations. Specifically, a one standard deviation increase in the level of worry or preparedness significantly increases the probability of including these risks by 2.37 and 2.46 times, respectively. However, the survey also reveals that less than 30% of the housing associations have currently integrated physical climate risks into their strategic planning.

After all, the question remains whether Dutch social housing institutions are prepared for the flood risk they face. Apparently, they are not well prepared yet. However, the findings of this study highlight the critical role of targeted tools and resources like the Climate Impact Atlas in enhancing flood risk perception. They also point to a significant opportunity for housing associations to further incorporate physical climate risks into their portfolio strategies.

Policymakers and stakeholders in the housing sector should focus on increasing the adoption of comprehensive risk assessment tools and encouraging proactive measures to mitigate and adapt to flood risks. By doing so, housing associations can enhance their resilience against flood risks and better protect their assets and residents in the face of climate change.

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10.Appendix

Appendix A: Complete multiple regression results

	Dependent variable:			
	Awareness	Worry	Preparedness	Overall FRP
	(1)	(2)	(3)	(4)
Individual climate risk perception	0.012	0.139**	-0.144**	-0.081
	(0.062)	(0.063)	(0.063)	(0.063)
Personal flood experience	0.232*	-0.040	0.298**	0.125
	(0.141)	(0.142)	(0.143)	(0.143)
Property ownership	0.086	0.271	-0.153	0.121
	(0.328)	(0.332)	(0.334)	(0.334)
Age	0.106	0.037	0.082	0.096
	(0.073)	(0.073)	(0.074)	(0.074)
Female	-0.197	0.207	-0.042	-0.230
	(0.150)	(0.152)	(0.153)	(0.153)
Business Manager	-0.226	-0.118	-0.136	-0.238
	(0.203)	(0.205)	(0.206)	(0.206)
Real Estate Manager	-0.142	-0.061	0.011	-0.210
	(0.205)	(0.208)	(0.209)	(0.209)
Asset Manager	-0.111	0.024	-0.239	-0.110
	(0.219)	(0.222)	(0.223)	(0.223)
Portfolio Manager	-0.104	-0.104	-0.139	-0.127
	(0.252)	(0.256)	(0.257)	(0.257)
“Other” job title	-0.160	-0.003	-0.093	-0.344*
	(0.180)	(0.182)	(0.183)	(0.183)
Flood hazard score (municipality)	0.003	0.030	0.012	0.008
	(0.062)	(0.063)	(0.063)	(0.063)
Size (weighted rentable units)	0.003	0.032	0.155**	0.097
	(0.073)	(0.073)	(0.074)	(0.074)
Proportion of SFH	-0.002	-0.036	0.174**	0.084
	(0.071)	(0.072)	(0.072)	(0.072)
Built before 1945	0.626	-0.076	0.850	0.638

	(0.594)	(0.601)	(0.603)	(0.603)
Built 1945 to 1959	0.246	0.226	-0.361	0.113
	(0.361)	(0.366)	(0.367)	(0.367)
Built_1960_to 1969	0.324	0.364	-0.248	0.395
	(0.275)	(0.278)	(0.279)	(0.279)
Built 1970 to 1979	0.167	0.213	-0.275	0.233
	(0.258)	(0.261)	(0.262)	(0.262)
Built 1980 to 1989	0.197	0.438	-0.428	0.234
	(0.265)	(0.269)	(0.270)	(0.270)
Past flood experience	0.374**	0.664***	0.372**	0.338**
	(0.147)	(0.149)	(0.149)	(0.149)
Climate Impact Atlas	0.736***	0.341**	0.407***	0.629***
	(0.137)	(0.139)	(0.140)	(0.140)
Constant	-0.516	-0.823*	0.220	-0.457
	(0.415)	(0.420)	(0.421)	(0.421)
Observations	252	252	252	252
R^2	0.206	0.186	0.180	0.180
Adjusted R^2	0.138	0.116	0.109	0.109
Residual Std. Error (df = 231)	0.929	0.940	0.944	0.944
F Statistic (df = 20; 231)	3.001***	2.642***	2.538***	2.538***
Note:				*p<0.1; **p<0.05; ***p<0.01

Appendix B: Odd Ratio tables for models 5-8

Panel A – Model 5	Odds Ratio	95% CI	p-value
Constant	0.29***	0.17 - 0.46	0.00
Awareness	2.12***	1.39 - 3.38	0.00
Flood hazard score (municipality)	0.69	0.35 - 1.12	0.20
Size (weighted rentable units)	1.20	0.77 - 1.87	0.42
Proportion of SFH	1.11	0.7 - 1.77	0.65
Past flood experience	1.80	0.7 - 4.58	0.22

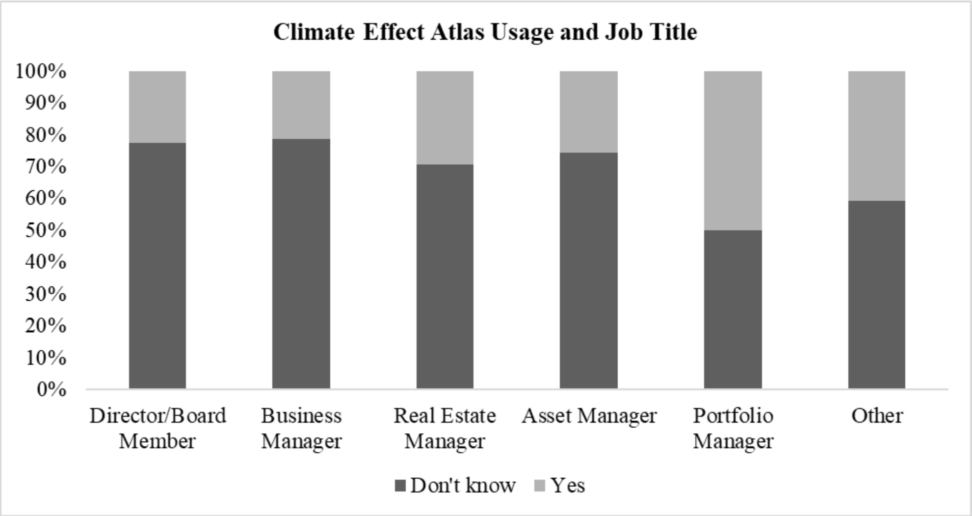
Panel B – Model 6	Odds Ratio	95% CI	p-value
Constant	0.28***	0.16 - 0.45	0.00
Awareness	1.50	0.9 - 2.56	0.12
Worry	2.05**	1.19 - 3.7	0.01
Flood hazard score (municipality)	0.67	0.33 - 1.13	0.20
Size (weighted rentable units)	1.12	0.71 - 1.77	0.61
Proportion of SFH	1.10	0.69 - 1.78	0.68
Past flood experience	1.43	0.55 - 3.7	0.46

Panel C – Model 7	Odds Ratio	95% CI	p-value
Constant	0.26***	0.15 - 0.44	0.00
Awareness	0.87	0.44 - 1.67	0.67
Worry	2.37***	1.33 - 4.47	0.00
Preparedness	2.46***	1.35 - 4.81	0.01
Flood hazard score (municipality)	0.72	0.36 - 1.2	0.27
Size (weighted rentable units)	1.03	0.63 - 1.64	0.90
Proportion of SFH	1.05	0.64 - 1.74	0.84
Past flood experience	1.15	0.42 - 3.06	0.79

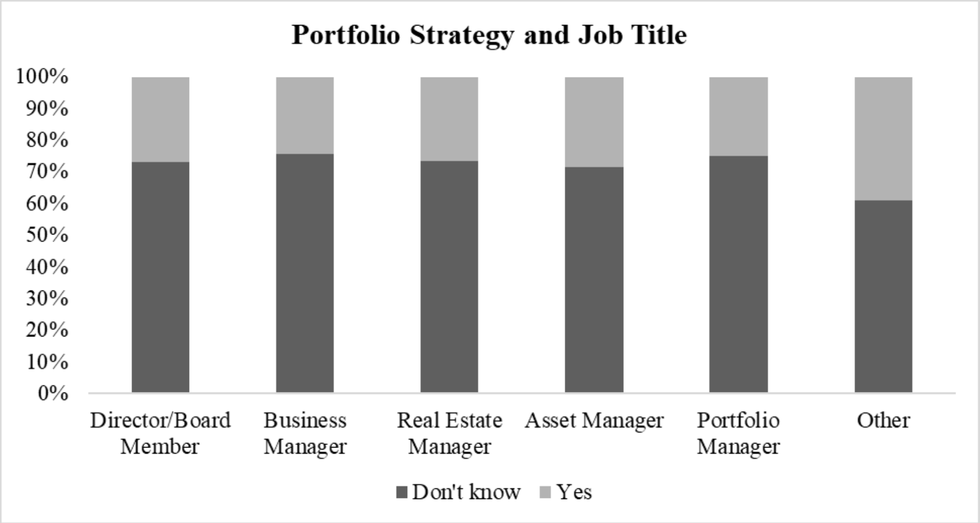
Panel D – Model 8	Odds Ratio	95% CI	p-value
Constant	0.28***	0.17 - 0.45	0.00
Overall FRP	2.12***	1.34 - 3.58	0.00
Flood hazard score (municipality)	0.66	0.33 - 1.09	0.16
Size (weighted rentable units)	1.16	0.75 - 1.81	0.50
Proportion of SFH	1.04	0.65 - 1.66	0.88
Past flood experience	1.82	0.7 - 4.62	0.21

Note: *p<0.1; **p<0.05; ***p<0.1

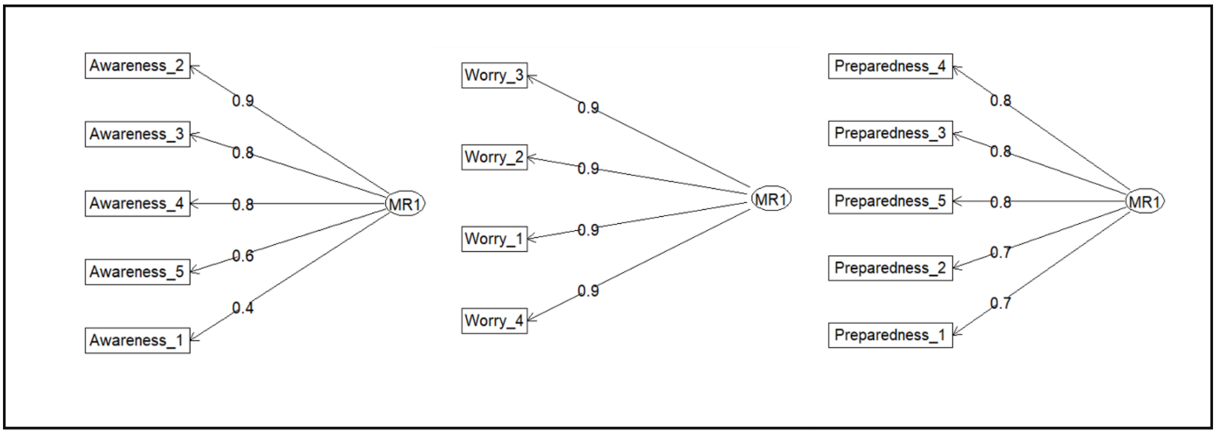
Appendix C: Climate Impact Atlas usage and job title



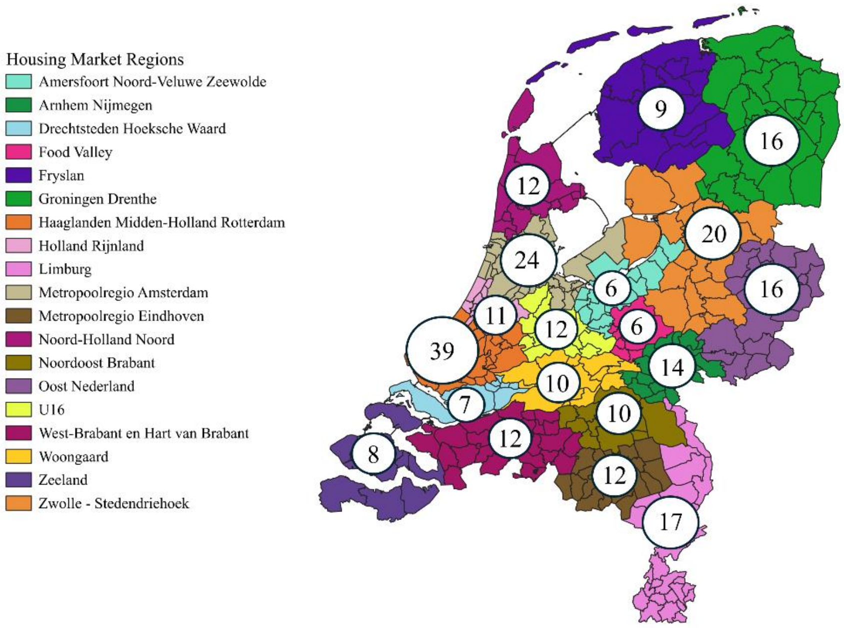
Appendix D: Portfolio strategy and job title



Appendix E: Factor loadings of flood risk perception variables



Appendix F: Total population of Aedes members per Housing Market Region (2024)



Appendix G: Size classification

Category	Rentable units
XXS	< 1.000
XS	1.001 – 2.500
S	2.501 – 5.000
M	5.001 - 10.000
L	10.001 - 25.000
XL	> 25.000

Appendix H: Survey

Maastricht University

Finance

Language

English

Dear participant,

Welcome to this study on the flood risk perception of Dutch housing associations. This research covers floods of all types and magnitudes: both shallow, frequent floods due to extreme rainfall and deep, rare floods following potential dike breaches.

This survey consists of 2 parts and takes only 5-10 minutes to complete. In the first part, I will ask you some questions about your own risk perception. The second part consists of questions about the housing association you work for. Your responses are saved in between, allowing you to complete the survey at any time.

Your answers will be collected anonymously and cannot be traced back to you as an individual. Data will be deleted after the completion of this research. If you have any additional questions or comments, please do not hesitate to contact me via yves.baljet@finance-ideas.nl.

* **By accepting your participation, you indicate to have read and understood all the information and you voluntarily choose to participate in this questionnaire.**

○ Accept

○ Refuse

Next page >

* **Please indicate how you feel about the following questions:**

	Not concerned at all	Not concerned	Somewhat not concerned	Neutral	Somewhat concerned	Concerned	Very concerned
How concerned are you about climate change?	○	○	○	○	○	○	○

	Very unlikely	Unlikely	Somewhat Unlikely	Neutral	Somewhat likely	Likely	Very likely
In your judgment, how likely are you, sometime during your life, to experience serious threats to your health or overall well-being, as a result of climate change?	○	○	○	○	○	○	○

	Very unlikely	Unlikely	Somewhat Unlikely	Neutral	Somewhat likely	Likely	Very likely
In your judgment, how likely do you think it is that climate change will have very harmful, long-term impacts on our society?	○	○	○	○	○	○	○

	Not serious at all	Not serious	Somewhat not serious	Neutral	Somewhat serious	Serious	Very serious
How serious of a threat do you think that climate change is to the natural environment?	○	○	○	○	○	○	○

	Not serious at all	Not serious	Somewhat not serious	Neutral	Somewhat serious	Serious	Very serious
How serious would you rate current impacts of climate change around the world?	○	○	○	○	○	○	○

How serious of a threat do you believe that climate change is, to you personally?	◯	◯	◯	◯	◯	◯	◯
	Not serious at all	Not serious	Somewhat not serious	Neutral	Somewhat serious	Serious	Very serious
How serious would you estimate the impacts of climate change for the Netherlands?	◯	◯	◯	◯	◯	◯	◯
	Very rarely	Rarely	Somewhat rarely	Neutral	Somewhat frequently	Frequently	Very frequently
How often do you worry about the potentially negative consequences of climate change?	◯	◯	◯	◯	◯	◯	◯

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*** What human-related factor is most directly linked to the increased risk of urban flooding?**

- ◯ Urban development and impervious surfaces
- ◯ Dam construction
- ◯ Excessive rainfall
- ◯ Deforestation

*** Which of the following factors primarily contributes to heightened flood risk?**

- ◯ Increased vegetation cover
- ◯ Enhanced floodplain management
- ◯ Expanded urban infrastructure
- ◯ Rising global temperatures

*** Considering roughly the last 5 years, how often have you personally experienced**

	Never	Once	Twice	More than twice	I can't remember
Flooding in your local area?	◯	◯	◯	◯	◯
Damage to your house or belongings as a result of flooding?	◯	◯	◯	◯	◯

*** Do you own a house?**

- ◯ Yes
- ◯ No

*** Please indicate your age**

[ ]

*** Please indicate your gender**

- ◯ Male
- ◯ Female
- ◯ I prefer not to answer

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*** Please indicate your role within the company:**

- ◯ Director/Board Member
- ◯ Business Manager
- ◯ Real Estate Manager
- ◯ Asset Manager
- ◯ Portefeuille Manager
- ◯ Other [ ]

*** Please select the housing market region of the housing association:**

Select one ⌄

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* In which municipality (gemeente) is the housing association most active?

Select one

* In which hometown is the housing associations most active?

* Roughly indicate the size of the housing associations in terms of total rentable units

* Roughly indicate the amount of Single Family Homes

* Roughly indicate the amount of Multiple Family Homes

* What is the average age of the dwellings owned by the housing association?

Select one

* What is the internal LTV (%) of the housing association?

%

LTV

☐ I do not know

0 100

* **Please answer the following questions based on your professional experience within your housing association:**

	Not aware at all	Not aware	Somewhat not aware	Neutral	Somewhat aware	Aware	Very aware
How aware is the housing association of (potential) flood risks?	◯	◯	◯	◯	◯	◯	◯
	Not concerned at all	Not concerned	Somewhat not concerned	Neutral	Somewhat concerned	Concerned	Very Concerned
How concerned is the housing association about (potential) flood risks?	◯	◯	◯	◯	◯	◯	◯
	Not prepared at all	Not prepared	Somewhat not prepared	Neutral	Somewhat prepared	Prepared	Very prepared
How prepared is the housing association to deal with (potential) flood risks?	◯	◯	◯	◯	◯	◯	◯

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* **Please indicate how you feel about the following statements based on your professional experience within your housing association:**

	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
Present day, our organisation is sufficiently aware of (possible) flood risks tight to the real estate holdings of the association.	◯	◯	◯	◯	◯	◯	◯
Flood risk is a regularly discussed topic in our business meetings.	◯	◯	◯	◯	◯	◯	◯
Flood risks are an important topic on the policy agenda of the housing association.	◯	◯	◯	◯	◯	◯	◯
After flood events in the Netherlands (e.g., flooding of Limburg in 2021) , more attention is given to flood risks within our association.	◯	◯	◯	◯	◯	◯	◯
When more attention to flood risks is given in the (local) news, our organization also increases its focus on flood risks.	◯	◯	◯	◯	◯	◯	◯

* **How concerned is your organization that floods**

	Not concerned at all	Not concerned	Somewhat not concerned	Neutral	Somewhat concerned	Concerned	Very concerned
Can cause significant damages to the properties owned by your organization?	◯	◯	◯	◯	◯	◯	◯
Can have a negative impact on the value of the properties owned by your organization?	◯	◯	◯	◯	◯	◯	◯
Can have a negative impact on the financial performance of your organisation?	◯	◯	◯	◯	◯	◯	◯
Can cause significant threats to tenants?	◯	◯	◯	◯	◯	◯	◯

*** Considering roughly the last 5 years, how often did your organization have to deal with:**

	Never	Once	Twice	More than twice	I can't remember
Flooding of the local area?	◯	◯	◯	◯	◯
Damages to properties as a result of flooding?	◯	◯	◯	◯	◯

*** Does the housing association make use of the Climate Effect Atlas to analyse flood risks?**

◯ Yes

◯ No

◯ I do not know

*** Are physical climate risks included in the association's portfolio strategy?**

◯ Yes

◯ No

◯ I do not know

Check this box if you want to apply for the free Flood Risk QuickScan raffle:

◯ I want to apply for the free Flood Risk QuickScan raffle

◯ I do not want to take part in the raffle

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