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Understanding Homeowners' Preferences and Motivations towards Public-Private Flood Protection

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By

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Preface

This thesis called “Understanding Homeowners’ Preferences and Motivations towards Public-Private Flood Protection” has been written to fulfil the graduation requirements of the Complex Systems Engineering and Management (CoSEM) program at the University of Delft. I was engaged in researching and writing this thesis from February 2023 to September 2023.

My choice of this thesis topic was driven by my passion for board games and fascination with their application in research. Throughout this journey, I noticed that organising the game sessions was a particular part the stepped me outside my comfort zone and required a lot of attention. How to organise these sessions, what process are involved and how to structure the thesis accordingly, were things I found to be difficult. These challenges, coupled with difficult personal family circumstances at the time, added a layer of stress. How to work through these struggles, cope with the stress and how to incorporate serious gaming into a research are the main things I learned from this project.

Therefore, I would like to thank my supervisors Dr.ir. Geke Bekebrede and Dr.ir. V. Juliette Cortes Arevalo, for their guidance and support during the process. Although the thesis had it rough patches and critical feedback, I thank you for maximizing the potential of this work. Additionally, I would like to thank the TU Delft Gamelab under the guidance of Doris Boschma for providing me with the serious game and Prof.dr. Tatiana Filatova and Asli Mutlu for helping me during this graduation project.

Finally, I want to thank my family and friends for being there for me. Especially during the difficult times concerning my personal family circumstances and organising the gaming sessions.

Jarno van Leiden

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Abstract

Due to climate change, the occurrence of increasingly severe weather and flood hazards is becoming more prominent. Residents residing alongside rivers face an increasing risk to flooding. While existing public flood defences, such as dikes and nature-based solutions (NbS), offer protection against floods, the events of 2021 in Limburg illustrate the need to address flood risk at a homeowner level. As there is a rising expectation that homeowners will need to accept a certain level of flood risk, and engaging homeowners is essential to address the growing challenges posed by the escalating impacts of climate change, it becomes imperative for homeowners to start implementing private flood measures. However, current homeowners do not recognise the urgency to implement such measures, leading to an inadequate uptake of private flood measures. With the Netherlands adopting a more shared responsibility approach to flood risk management, the provincial governments should better engage private actors such as homeowners to get their support in preparing for future increasing flood risk. In order to do that governments require insights into the preferences regarding public and private flooding measures and understand the key motivating factors that drive homeowners to take action. To address this the following main research question was formulated.

What are the profiles of homeowners regarding attitudes towards flooding and what are homeowners preferences and motivations towards public and private flood protection measures for floods?

In this thesis, a serious game has been conducted to this question. First, to select an appropriate serious game which encompasses all needed elements, a literature review was conducted highlighting the important theories such as the Tiebout model and the Protection Motivation Theory (PMT). Consequently, the serious game “Where We Move” was selected and techniques including the latent class analysis and ANOVA and T-tests were used to ascertain homeowner profiles and influences of perceived threat, coping abilities and ownership of the risk on the acquisition of private flood implementations.

Firstly, the research identified three distinct attitude profiles among homeowners: "Cautious Optimists," "Informed Preparers," and "Cautious Realists." These profiles reflected different levels of knowledge and expectations about future flooding. The findings show that individuals who have an optimistic perspective regarding future flood events are less likely to adopt private protective measures in contrast to those with a pessimistic outlook. A potential strategy for altering this perspective involves enhancing knowledge, particularly concerning the influence of climate change on flood probabilities, which suggests a heightened risk of more frequent and severe floods. Such knowledge might contribute to an increased perception of threat, thereby encouraging greater adoption of private flood measures. Secondly, the results indicate a general preference for private measures that offer environmental benefits, personal advantages such as aesthetics, and societal benefits. Individuals with higher financial means tend to invest in more expensive and effective measures. Conversely, those with limited financial resources choose less expensive but cost-effective measures. Additionally it was found that a higher income level does not lead to higher adoption of private implementation. This suggests that financial capabilities affect the type of measure purchased but not the inclination toward the protective response. Thirdly, the research highlighted that

the level of public flood protection influenced homeowners' choices of residency locations. In general, “grey” solutions like dikes are preferred among all homeowners. However, low welfare homeowners tended to prioritize living in well-protected areas (Nature-based Solutions), even at a higher cost. High welfare homeowners, on the other hand, often chose houses in the dike area, which were less expensive and offered less pluvial flood protection compared to Nature-based Solutions. These high welfare homeowners allocated their saved funds on housing mainly to saving money rather than implementing private measures. Fourthly, the results indicated that information regarding the risk reduction effect of measures played a crucial role in the adoption of private measures. Homeowners were more likely to invest in private protection when provided with information about the effectiveness of these measures due to having a higher coping ability. This finding aligned with previous research suggesting that informed decision-making (or familiarity) leads to increased adoption of private flood protection measures. In general, homeowners were motivated to implement private measures when they simultaneously perceived high levels of threat, possessed coping abilities, and took ownership of the risk. Fifthly, it was found that flood experience had limited influence on the amount of private measure adoption, except did influence the type of measure being bought. Individuals with flood experiences often opted for more familiar and cost-effective solutions.

To address the lack of urgency among homeowners regarding the adoption of private measures, this study puts forth a range of practical recommendations. Firstly, it advocates for the improvement of communication strategies by integrating information on how private measures can effectively reduce risks, thereby enhancing homeowners' ability to cope with potential threats. Additionally, it emphasizes the need to rectify disparities between high and low income homeowners by introducing subsidies or collaborative initiatives aimed at making highly efficient flood protection measures more financially attainable for those with limited financial resources. Lastly, it suggests broadening the scope of future scientific investigations to encompass factors beyond the confines of the used framework. This includes considering aspects such as cost-effectiveness, familiarity, knowledge levels, perspectives on future flooding events, and both personal and societal benefits. By doing so, researchers can develop a more holistic comprehension of human behaviour concerning both public and private flood protection measures. While this research has provided valuable insights, it is essential to acknowledge its limitations. These limitations encompass the inherent variations within the sample and concerns pertaining to sample size adequacy. Furthermore, the study did not delve into intangible factors, such as psychological stress, wishful thinking, denial, and fatalism, when interpreting the findings. To gain a more profound understanding of the motivations driving homeowners, future research should incorporate these nuanced factors and leverage analytical techniques like Structural Equation Modelling. This approach would offer a more comprehensive and interconnected perspective on the PMT. Additionally, forthcoming studies could build upon the insights derived from our research by enhancing the serious game, exploring digital formats, and directly engaging with homeowners residing in flood-prone regions.

In summary, while this research has shed light on critical aspects of homeowner behaviour in flood risk management, there are opportunities to further refine our understanding and improve flood risk mitigation strategies. By addressing the limitations and building on the insights gained, we can work towards safer and more resilient communities in the face of flooding.

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1. Introduction

1.1 Research Problem

In July 2021, extreme and exceptional flooding and precipitation occurred in the Netherlands and surrounding countries. In the Netherlands, the province of Limburg faced the most severe consequences due to its geographical position as the entry point for rivers flowing in from neighbouring countries. In Limburg, 2500 homes and 600 businesses were flooded due to the extreme flooding and precipitation and the total damage amount is estimated to be around 350 to 600 million (Task Force Fact-Finding Hoogwater 2021, 2021). The largest damages and losses occurred along the Meuse (Maas) regional rivers, mainly in the Geul floodplain. About 50.000 people along these flooded rivers needed to be evacuated. The flood risk protection conditions of the Dutch affected area is the reference point of this study and is illustrated in Figure 1, along with its primary river, the Maas (Meuse). The Meuse originates from Pouilly-en-Bassigny, located in France, and flows through Belgium and the Netherlands. The Limburg province is geographically positioned lower than Belgium and France but remains above the sea level. Consequently, water from these countries flows through Limburg and then through the province of North-Brabant before ultimately discharging into the North Sea via the Dutch river delta. Cities located on the waterfront of primary and tributary rivers in the Limburg province, such as Roermond, Valkenburg and Maasbracht, are therefore at a greater risk of flooding compared to most other cities.

Figure 1: Limburg, based on (Reeze et al., 2020)

The 2021 flood has resulted in significant emotional and physical destruction. This destruction has prompted the Dutch government to take decisive actions to prevent the recurrence of such events in the future. There's a projected increase in the intensity of flood events ranging from 0.8% to 6%, coupled with a higher probability of occurrence by a factor of 1.2 to 1.4 (WWA, 2021). Given these predictions, it becomes imperative for the government not only to learn from the destructive flooding event that occurred in Limburg in 2021 but also to urgently enhance and adjust existing systems designed to protect individuals from potential future flooding and heavy rainfall occurrences.

Currently, within the Netherlands, the provincial governments have implemented a variety of public flood defence measures to ensure the safety of the population. Particularly in the province of Limburg, two distinct protective strategies are in place. These include the civil engineered "Grey" solution, as well as the Nature-based Solution (NbS). The "grey" solution involves traditional engineering methods, such as constructing dikes along riverbanks. In Limburg, this approach is adopted for the Zandmaas area (*see* Figure 1). On the other hand, the NbS approach goes beyond mere protection, aiming to provide not only safety but also benefits for human well-being and biodiversity. In Limburg, this approach is employed for the Grensmaas area (*see* Figure 1). Here, a nature-focused strategy is implemented along the river, creating a designated natural area that is designed to allocate additional space for the river when facing high water levels and simultaneously enhances the overall natural environment.

While public measures, continue to be important, it is now recognized that managing the risk of floods cannot rely solely on holding back water through a narrow focus on big civil and natural engineering schemes (White, 2010; Zevenbergen et al., 2010). The 2021 floods in the Netherlands illustrate this point, as the areas along the tributaries were the most severely affected due to the difficulty in implementing civil engineering schemes in those regions (Task Force Fact-Finding Hoogwater 2021, 2021). Furthermore, due to the substantial costs associated with implementing and maintaining public flood protection measures, governments face limitations in providing such protection to every individual (Rauter et al., 2020). While local public authorities play a central role and carry significant responsibilities for climate adaptation, engaging private actors like homeowners becomes essential to address the growing challenges posed by the escalating impacts of climate change. The homeowners' involvement is particularly vital since adaptation efforts are inherently linked to properties owned by private individuals (Mees, 2017). Moreover, the present approach to flood risk management operates on a risk-based foundation, acknowledging the expectation that homeowners must acknowledge a certain level of flood risk (Bubeck et al., 2012, 2013; Scott et al., 2013). Recognizing that even with existing public flood defences, there will persistently remain a residual risk of flooding, and recognizing conventional strategies that have been effective in the past are now inadequate to manage the current and forthcoming flood risks, underscores the fact that flooding is a collective societal challenge. Consequently, it becomes imperative to integrate private flooding measures for homeowners in a more comprehensive manner. This collective responsibility entails the advocacy and integration of private flooding measures by both governments and citizens.

However, although homeowners may be willing to take private behavioural actions (Botzen et al., 2013), these actions first need to align with their preferences to get them to support and invest in these solutions. Furthermore, many homeowners fail to recognise the urgency of undertaking measures to mitigate the risk of flooding. This lack of urgency can be attributed to their limited awareness of the connection between flood risk and climate change, and their own responsibility to minimize potential flood damage on their properties. (Snel et al., 2020). In addition, despite the expectation of a positive link between an individual's flood risk perceptions and their willingness to take mitigation measures, empirical studies suggest that risk communication alone is insufficient to motivate private homeowners to act (Bubeck et al., 2012; Suijkens, 2022). This deficiency arises primarily from the prevalent emphasis on the nature of measures and associated expenses, rather than on the actual impact and practical implementation. In order to encourage homeowners to adopt private flooding measures, it is crucial to identify the key motivating factors that drive private actors, including homeowners, to take action. This identification is essential not only for improving risk communication but also for enhancing flood risk management overall. Given the substantial reliance on public measures, regions once deemed secure are increasingly susceptible to flooding. Implementing protection at the property level in these areas necessitates considerable investments that are not financially feasible for everyone. While relocating to safer locales might remain a possibility, the availability of existing buildings in flood-prone regions means that staying in these areas remains viable. Furthermore, the benefits of residing in flood-prone areas might outweigh the rising damages or other associated costs (Kreibich et al., 2015). Additionally, persistent flood risk and living near a river also results in discounted house prices (Mutlu et al., 2023). This indicates that homeowners' preferences and motivations on where to live align with their preferences for public flood protection.

In summary, achieving effective collaboration between public and private actors, including homeowners, requires an improved approach to flood risk communication. This improved communication involves taking into account individual perceptions of risk, actively involving vulnerable communities, and leveraging existing social networks to develop community-oriented strategies (MacIntyre et al., 2019). However, relying solely on risk communication is insufficient to motivate private homeowners to take action. A comprehensive strategy necessary to encompass various aspects, including addressing risks and associated responsibilities, providing incentives, and offering tangible support, especially for economically disadvantaged groups. By adopting such a comprehensive and multifaceted approach, it becomes possible for the government to overcome the prevailing reluctance among homeowners to invest in flood protection measures (Bichard & Kazmierczak, 2012).

1.2 Research Gap

Although extensive efforts were made in the Netherlands to mitigate flood risk, the 2021 floods proved to be highly destructive, especially in areas that couldn't benefit from large-scale engineered defences and NbS. With the Netherlands adopting a more shared responsibility approach to flood risk management, the provincial governments should better engage private actors such as homeowners to get their support in preparing for future increasing flood risk. To support communication and collaboration strategies, governments require insights into the preferences regarding public and private flooding measures and understanding the key motivating factors that drive homeowners to take action. Venkataramanan et al. (2020) suggest that homeowners may exhibit diverse motivations when it comes to implementing private flooding measures or choosing their living location, including factors like personal preference, attitude, knowledge, past, current and future experiences. Moreover, homeowners abilities to take action vary in terms of their income, expenditures, living situation, knowledge, flood risk perception, attitudes towards flood risk and preferences for public and private flooding measures. These factors will therefore significantly influence the actions homeowners take, or choose not to take, to safeguard themselves against floods.

The dynamic understanding of homeowners' preferences and motivating factors to take action in relation to flood protection measures is limited. Furthermore, existing approaches and communication strategies aimed at motivating homeowners to take action do not sufficiently consider the changing motivations. Rather than a one-size-fits-all approach, communication efforts can be enhanced by taking into account the distinct profiles of homeowners, each of whom holds unique viewpoints on flood risk management. By categorizing homeowners into specific classes, which acknowledge the diversity in their perceptions of flood risk or other homeowner attributes like income, effective communication becomes more streamlined. The homeowners categories helps to address their needs through more targeted and efficient flood risk management strategies, including, but not limited to communication.

1.3 Research Objective and Research Questions

The primary objective of this research is to gain a comprehensive understanding of the preferences of homeowners concerning public and private flooding measures taking into account there limitations regarding resources and knowledge in order to design communication strategies that are precisely tailored and more efficient in addressing the specific needs and attitudes of each homeowner group. By segmenting homeowners based on their income levels and categorizing them into different profiles, each reflecting a unique attitude on flood-related topics, it becomes possible to identify where communication strategies can improve, specifically for each group, addressing the specific needs and attitudes of each group. Additionally, the research seeks to uncover the motivations behind homeowners' decisions to undertake specific protective actions or refrain from taking action. These protective actions include the adoption of private flood protection measures as well as the residency location in relation to the existing public flood protection measures implemented.

Main research question:

What are the profiles of homeowners regarding attitudes towards flooding and what are homeowners preferences and motivations towards public and private flood protection measures for floods?

Sub-questions:

1. *What are the key concepts that drive the behaviour of homeowners in relation to their residency location, flood risk and the adoption of private flood protection measures?*
2. *Which profiles can be identified with regard to attitudes towards flooding and what differences can be identified between profiles regarding private implementation?*
3. *How do in-game choices for public and private flood protection vary among homeowner types, evolve in response to in-game flood experience, and relate to players' preferences?*
4. *What in-game strategies motivated the homeowner types to take protective measures and relocate?*

1.4 Research Relevance

1.4.1 Scientific Relevance

This thesis provides the following insights:

- Investigating the impact of varying perceived risk perception, coping abilities, and ownerships of the risk on homeowners' decision making.
- Inquire which attitude profiles people have toward flooding and how these profiles are related to the preferences and motivations regarding public and private flood measures.
- Exploration of which private and public measures are preferred among different profiles and homeowner types.
- Evaluate the influence of information presented in multiple scenarios on decision-making.

1.4.2 Societal Relevance

This thesis can contribute to the societal benefits, considering the widespread danger that floods pose to society. Accordingly, municipalities that incorporate the obtained insights into their flood risk management and communication strategies may incur reduced losses of both human life and property. This is due to the fact that the acquired information may guide decision-makers to identify and prioritize the crucial factors necessary for the successful implementation of public and private flood protection measures.

These insights will centre around the preferred types of public and private flood protection measures based on homeowner categories such as income or attitudes toward flooding (profiles). Additionally, the study will illuminate the underlying reasons guiding the decision to implement or abstain from such measures, and it will also investigate how information regarding the risk reduction potential of private measures impacts the adoption rates.

1.5 Methodology of the Thesis

Given that homeowners' preferences, motivations and risk perceptions may change over time under different flood experiences and consequences are not easily foreseen in a real-life setting, a serious game modelling approach is chosen for the research. This approach involves designing and implementing a game that simulates real-life scenarios and challenges, allowing participants to engage and make decisions within the game environment. This thesis will use and adapt an existing selected serious game that fits this research in order to investigate the preferences and motivations of homeowners.

According to Duke & Geurts (2004, pp. 35-37) a serious game or, alternately, a simulation game, "is a model of the real world where human actors partially recreate behaviour through specified roles". This allows for learning, designing, exploring and taking actions by players who base their role-play behaviour on interpretation, experience and intuition as well as formal simulation-based logic, rules and natural laws (Grogan & Meijer, 2017). To optimize the design of a simulation game a balance must be found between three conflicting dimensions: play, meaning and reality (Harteveld et al., 2010). To illustrate the uses of gaming methods four canonical applications are identified by Grogan & Meijer (2017). These are policy, teaching, design and research. According to Grogan & Meijer (2017, p4) a research game "acts as a model of the real world to support observation, hypothesis generation, and hypothesis testing or, alternately, a platform on which to evaluate the efficacy of other artifacts". Since this research aims to simulate the real world in order to gain insights into preferences and motivations in private and public measures in different circumstances, it can be said that this research follows the research application type identified by Grogan & Meijer (2017). The research and game design will take inspiration from Limburg's flood risk protection conditions. Therefore, the research excludes the consideration of coastal flooding resulting from storm surges, as Limburg is not situated along the coast.

This approach is preferred compared to interviews, surveys and choice experiments, as serious gaming has the potential to improve the quality of data collected. Concerning this research, real-life conditions that have not yet happened can be simulated, allowing players to take a given role to make choices, to improve the engagement of players with future scenarios and to compare data collected per role played. This quality of data improvement is illustrated by the research of Gordon and Yiannakoulias (2020), who conducted a serious game to understand the factors that influence flood risk mitigation decisions. In the game, players made decisions regarding their place of residence and income allocation based on information provided on flood risks. The results suggested that the serious game offered more enriching and engaging experience for participants than surveys and laboratory-based choice experiments. The serious game provided some feeling of realism that allowed players to analyse scenarios from a perspective they may not have encountered in real life. As the game offered a more immersive environment than surveys, it can serve as a platform for revealing preferences like a revealed preference data collection tool. Thus, it could be concluded that serious games have the potential to improve the quality of data collected in research experiments.

However, designing and applying a simulation game involves many difficult processes that need to be done properly. These include modelling, abstraction, experimental or study design, group facilitation, data collection, and analysis. Games are often simplifications of reality and require significant resources to design, test and refine. Therefore, the extent to which the outcomes of the game can narrow the knowledge gap is often limited (Grogan & Meijer, 2017). Nevertheless, this approach is favoured over alternative methods that could be utilized. As behaviour theories will be used in this study, which are more commonly paired with surveys and interviews, it adds an intriguing dimension to the research, as the integration of serious gaming offers a novel perspective on investigating behaviour theories.

In order to address the research questions, the study will first conduct a mapping of the key concepts regarding flood risk and protection and key theories explaining homeowners' decision-making to establish delineations. Through a literature review of relevant theories, the factors influencing homeowner behaviour will be identified, enabling the selection of an appropriate serious game.

1.6 Structure

To prepare for the upcoming chapters, the research design will be used as a framework for exploring what lies ahead in this study. In Figure 2, the research design is depicted. As previously mentioned, the approach to addressing the research questions involves using a serious game to gather data. The selection of the appropriate serious game began by considering the motivation, problem statement, and research objectives outlined in the study. These elements then informed the formulation of the research questions (*see* Chapter 1). Drawing from both the theoretical framework and the conceptual framework, which will be developed through a thorough literature review, the essential components of the research will be identified to guide the upcoming choice of a suitable serious game (*see* Chapter 2). Consequently, in Chapter 3, the employed research methodology is outlined, detailing game selection, data collection and analysis approaches. The heart of data exploration lies in Chapter 4**Error! Reference source not found.**, where profiling, scenarios, and implementation analyses are dissected. Ultimately, Chapter 5 and chapter 6 wraps up the research with the discussion of the data and made conclusions which address the overarching aim of this thesis to unveil the multifaceted dynamics underlying homeowners' choices in flood risk protection.

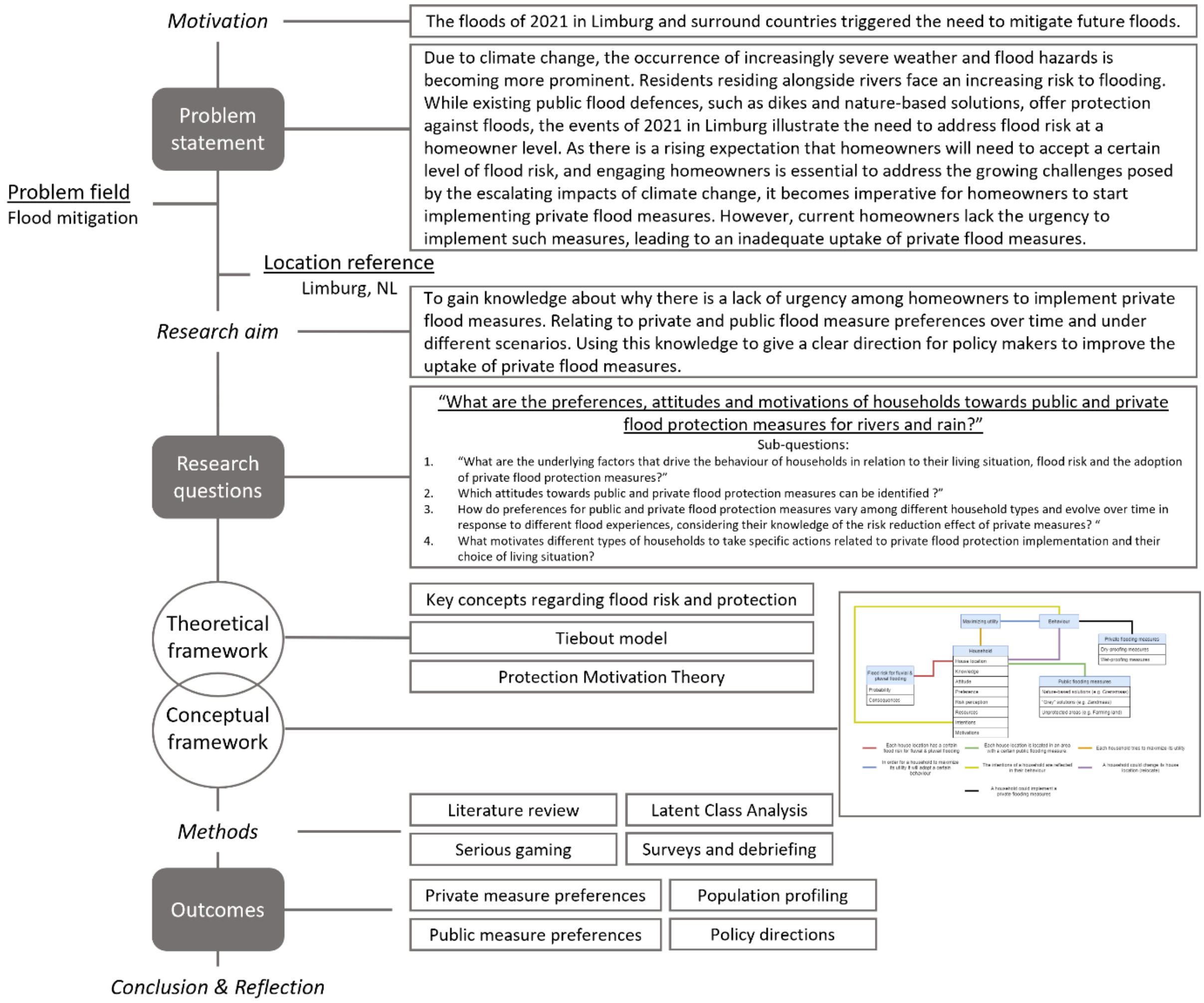

Figure 2: Research design

2. Theoretical Framework

This chapter will present the key concepts regarding flood risk and protection under consideration in this research. Relevant theories will be discussed to explain homeowners decision-making regarding flood protection, which will help identify key variables that are critical for determining the appropriate serious game to gather the preferences towards private and public flood measures.

2.1 Key Concepts regarding Flood Risk and Protection

2.1.1 Flood Risk Probabilities and Flood Types

In order to gain a clear understanding of the concept of flood risk, this research will adopt the definition provided by FLOODsite (2009) in this report. According to this definition, flood risk is the combination of the likelihood of a specific event occurring and the resulting impact it would have if it were to happen. Risk, therefore, consists of two essential elements: the probability of an event taking place and the consequences associated with that event. These consequences can be either positive or negative. Consequences can be understood as comprising both exposure and vulnerability. Where exposure relates to the people, assets and activities threatened or potentially threatened by a hazard and the vulnerability relates to the characteristics of a system that describes its potential to be harmed. The following can thus be stated about risk:

$Risk = Probability \times Consequence.$

Within this report, flood risk pertains to two distinct types of flooding: fluvial and pluvial flooding.

Fluvial Flooding

Fluvial flooding (*see* Figure 3) is a type of flooding that occurs when there is persistent heavy rain in a basin or a lot of excess melt water. This causes significant floods in river channels and localized flooding in urban areas, like cities. Due to the flow of torrential rainwater or meltwater into the rivers, the water level rises beyond the river banks, making the river overflow its banks. The excess water spills out of the channels and floods surrounding floodplains. In addition, the huge amount of torrential rain flowing into the river can also cause a dike to break, causing major damage to the surrounding floodplains. This type of flood usually lasts several days, or even weeks, and can have a significant impact on floodplains along the river (Chen et al., 2010).

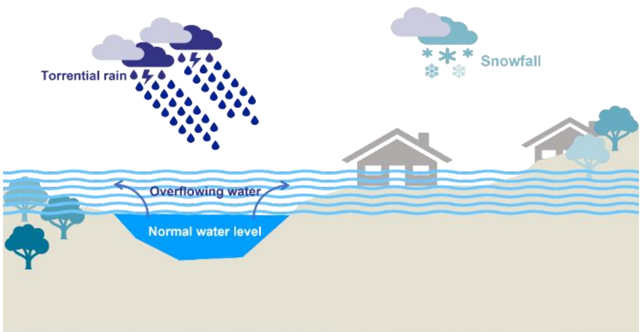

Figure 3: Visual representation of fluvial flooding (based on (Gong, 2020))

Pluvial Flooding

Pluvial flooding (*see* Figure 4) is a type of flooding that is independent of an overflowing water basin. This type of flood can occur in various locations, including urban or rural areas, and even in places without any nearby bodies of water. Pluvial floods can be caused in two ways. First, the drainage systems of modern cities can be saturated due to heavy rainfall, causing the drain system to be unable to cope with the surface runoff produced by rainfall. This is dependent on the design capacity of the drainage system which restricts the maximum discharge capabilities of the system. When this capacity is exceeded, water will flow into the streets, basements and other structures causing damage. Second, run-off or flowing water from rain falling on elevated terrain, which is unable to absorb the water, can cause damage. This flood can be very dangerous and destructive, because, in addition to the force of the water, hurtling debris is also often swept up in the flow downstream. Pluvial flooding is a type of flooding that usually lasts for less than a day and is limited to specific local areas. Unlike the other type of flooding, pluvial flooding is most of the times a gradual process that does not pose an immediate danger, allowing people to evacuate the area in time (Chen et al., 2010).

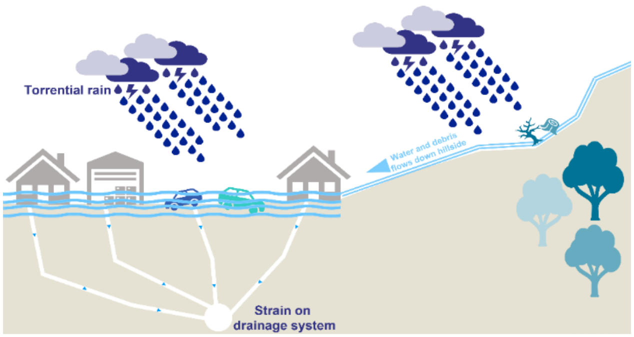

Figure 4: Visual representation of pluvial flooding (based on (Gong, 2020))

2.1.2 Private Flood Protection

Private flood protection measures at property scale can be categorized into two types, flood resistance measures (dry-proofing) and flood resilience measures (wet-proofing) (White et al., 2018), these will be explained below.

Flood Resistance Measures (Dry-proofing)

Dry-proofing measures are a set of measures that aim to prevent or reduce the ingress of water into a building or property. Dry-proofing measures include the use of waterproof membranes, sealants, (mobile, automatic) barriers, and coatings, as well as the elevation of the building or its contents above the potential flood level. These measures are intended to keep buildings and their contents dry, even in the event of a flood or water intrusion (White et al., 2018). According to the ICPR (2002) dry-proofing can decrease the damage by between 60% and 100%, if a flood occurs. Research indicates, however, that dry-proofing loses its effectiveness significantly when the water height exceeds 1 meter. This limitation is attributed to the potential risks of overtopping an structural failure caused by variations in water pressure (EA, 2003).

Flood Resilience Measures (Wet-proofing)

Wet-proofing measures are techniques employed to mitigate the damage caused by water that has infiltrated a building or property. These measures encompass the use of materials and finishes that can withstand water exposure, such as water-resistant plaster or paint. Additionally, wet-proofing measures involve the implementation of drainage systems and sump pumps to extract water that has entered the building. The primary objective of wet-proofing measures is to minimize water damage, reducing the time and resources required for clean-up and recovery (White et al., 2018). According to Kreibich et al. (2005) wet-proofing can decrease the damage by a maximum of 53% up to an inundation depth of 2 meter. The wet-proofing measures can reduce damage to buildings by between 36% and 53% and can reduce damage to homeowner contents by between 48% and 53% (Kreibich et al., 2005). The ICPR (2002) showed, however, that above 2 meters of water, the damage-reducing capacity of wet-proofing measures significantly decreases and can therefore be considered negligible.

While resistance measures are effective at preventing floodwater from entering a building or property up to a certain depth, they can also impede the rate at which water infiltrates, resulting in additional time to evacuate in life-threatening situations. Hence, resistance measures can enhance flood resilience by affording more time to implement evacuation plans. Both types of measures can be implemented in existing buildings and to be developed buildings, but wet-proofing measures are generally less expensive and therefore highly interesting for future development (White et al., 2018).

Effectiveness of Dry- and Wet-proofing in the Geul Catchment

Suijkens' (2022) research indicates that the implementation of private measures by homeowners in the Geul catchment can significantly reduce flood risk. Since other cities and areas in Limburg around the Meuse share many geographical characteristics, it can be assumed that dry-proofing and wet-proofing measures can also be effectively applied in these areas. In addition, the research highlighted that the decision to implement flood measures is not solely based on the benefits and costs of such measures, but rather on the prevention of experiencing another stressful event or disruption. Bubeck et al. (2020) emphasized the significance of intangible flood impacts such as psychological stress. The study found that while many respondents fully recovered from the flooding, a significant proportion of them continued to be affected chronically by the flood event. This addresses the importance of identifying other factors that can influence homeowners' motivation to implement flood measures or not.

2.1.3 Public Flood Protection

Currently, the Netherlands has implemented several public flood defences to safeguard citizens. These flood defences can be classified into two distinct approaches for flood management.

First, a traditional “grey” approach. This method falls into the realm of standard urban civil engineering practices designed to counter both pluvial and fluvial flooding. This approach involves the construction of embanked high-water channels and dikes along a river. This approach was taken for the Zandmaas project to reduce flood risk along the Meuse River in North Limburg (Rijkswaterstaat, 2018).

The occurrence of two significant river floods in Limburg during the 1990s brought about a transformative change in the flood management policy of the Netherlands. Since that time, a more sustainable and environmentally-friendly approach to flood management was advocated (Klijn et al., 2018). This led to the second approach, the nature-based solutions (NbS) approach. In addition to tackling flood risk, the NbS approach also takes into account local environmental quality issues and offers supplementary advantages for well-being, such as opportunities for recreation. The International Union for Conservation of Nature (IUCN) defines NbS as: “Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.” (Cohen-Shacham et al., 2016). Furthermore, NbS can provide substantial economic benefits, such as boosting tourism and creating job opportunities (Kok et al., 2021). NbS can also positively impact the property market (Bockarjova et al., 2020), support biodiversity conservation and restoration (Kabisch et al., 2016), and provide recreational areas for communities (Vermaat et al., 2016). In Limburg, this approach was used for the Grensmaas project, which is part of the “Room for the River” program in the Netherlands. The “Room for the River” program creates more space for the river in order to safely discharge the water flowing through it. This extra room allowed for the creation of approximately 1500 ha of nature development (Rijkswaterstaat, 2018). The Grensmaas project is widely regarded as a highly effective NbS that simultaneously tackles flood events and local environmental issues. As a result, the NbS approach has become a crucial strategy in the Netherlands to safeguard water safety by incorporating natural processes into hydraulic engineering and considering natural, social and economic systems.

Lastly, there are regions in the Netherlands that lack protection from human-engineered solutions. These are primarily areas adjacent to rivers, encompassing agricultural and cultivated land, henceforth being referred to as “farmland” within this report.

Effectiveness Public Flood Protection

To ensure that current and future public flood defences are capable of protecting the quality of life in the Netherlands, the Water Act has established standards for public flood defences. These standards must be ensured by the water boards and Rijkswaterstaat, who manage these primary flood defences (ENW, 2017). To determine if the flood defences in one of the areas with a protective measure meets the required standards, practically applicable, uniform calculation methods, with which an assessment can be made of the safety of an existing or newly designed flood defence, are defined.

In Limburg, the Grensmaas and Zandmaas projects stand out as notable instances of recently constructed public flood defences. While both projects resulted in comparable enhancements in fluvial flood safety, it's worth noting that pluvial protection proves more efficacious in Nature-based Solutions (NbS) areas. This effectiveness discrepancy can be attributed to the impediments faced by grey urban solutions areas in absorbing water, primarily due to their tendency for extensive paving. Another difference between the two approaches used in Limburg lie in the fact that Grenmaas (NbS) provides additional nature amenities, while Zandmaas (“grey” solutions) does not.

In relation to the flood probabilities linked with the types of public flood protection, this report will employ the flood probabilities derived from the executed Zandmaas and Grensmaas projects to establish the flood probability for each respective type. Table 1 depicts the flood probability for each type in relation to fluvial and pluvial flooding. These probabilities were documented by Rijkswaterstaat (2018) in their conclusive evaluation report.

Table 1: Flood probabilities per public flood protection type

Area	Chance of fluvial flood	Chance of pluvial flood
NBS protected	1:250 year	1:10 year
Dike protected	1:250 year	1:5 year
Unprotected (Farmland)	1:50 year	1:10 year

2.1.4 Housing Market and Economic Relevance for Flooding Measures

Mutlu et al.'s (2023) research has shown that the housing market plays a significant role in determining homeowner preferences for flood management approaches. By analysing the property values and desired attributes of properties, it is possible to identify a direction towards a preferred public flood management strategy. It can be seen that a house has a higher house value in an area with an NbS than a "grey" solution (Mutlu et al., 2023). Since there is no difference in fluvial flood protection, only in nature amenities and pluvial protection, it can be said that houses in these areas are more desirable (Mutlu et al., 2023). The knowledge and awareness of potential buyers regarding flood risk and flooding measures are crucial factors that influence their perception of flood risk and potential loss, ultimately affecting property values. Furthermore, the financial stability of both the public and private sectors is closely linked to the strength of the housing market (Bishop et al., 2020), underscoring the importance of considering the housing market when determining the preferences and motivations of homeowners with regard to flood risk management. In the housing market, people often try to find a house that best suits their needs, leading towards a decision-making model that tries to maximize utility. Hence, this study approaches the matter through a utilitarian perspective by employing the Expected Utility theory (Machina, 1987). However, it is important to recognize that flood-prone markets often involve information asymmetry, meaning that residents do not have full knowledge on flood probabilities and the risk reduction effects of private measures, and therefore, other decision-making models beyond the Expected Utility theory (Machina, 1987) should be considered. The Prospect theory (Kahneman & Tversky, 1979) and Protection Motivation Theory (Rogers, 1975) are two models that could be useful in studying risk perceptions, risk communication, and individual adaptation behaviour in such markets (Babcicky & Seebauer, 2019; Bubeck et al., 2012; Noll et al., 2022). Therefore, it is necessary to consider, beside the Expected Utility theory, one of these theories when analysing flood-prone markets.

2.1.5 Key Factors for Decision-Making about Flood Risk Protection

In this report, insights into the preferences and motivations of homeowners with regard to public and private flood protection are being pursued. While the earlier sections have defined the meanings of private and public flood measures there remains an absence of distinct elucidation regarding the concepts of "preferences," "motivations," and "homeowners." Consequently, it becomes imperative to establish precise definitions for these elements, along with a comprehensive exploration of the factors that exert influence upon them. Therefore, the following key factors are identified and explained for the decision-making about flood risk protection:

Homeowners: A person that owns a house which is bought by his available resources.

Resources: Tangible and intangible assets available to actors that enable them to achieve their objectives. These resources are the elements that actors have control over and in which they hold a certain level of interest. By leveraging these resources, actors gain the ability to influence their surroundings, including other actors, relationships, and the established rules within a network (Enserink et al., 2022).

Preference: Preferences are the result of translating values into a specific ordering of preferences regarding particular solutions or policy outcomes. These preferences are closely connected to an individual's perceptions and attitudes (Enserink et al., 2022).

Risk perception: Intuitive judgements of an individual, involve the evaluation of potential impacts and consequences of a hazard, leading an individual to choose appropriate behavioural responses (Slovic, 1987). An individual’s judgements and decision-making processes are assumed to be influenced and limited by their social environment (Dake, 1992). These social environments can also shape behavioural choices due to power dynamics and disparities in access to resources and knowledge (Tierney, 1999).

Attitude: Attitudes represent the values that individuals associate with an object or outcome (Glanz et al., 2015).

Profiles: A collection of views or values under which an individual is associated.

Motivations: The reasons why an individual has chosen to adopt a certain behaviour.

Behaviour: The actual action the individual performs. This actual behaviour relates with the intentions of the individual.

Intentions: Intentions encompass an individual's willingness to contribute financially, implement, support, or volunteer for the construction, maintenance, or execution of specific actions within hypothetical situations (Venkataramanan et al., 2020).

Knowledge: "Knowledge" encompasses understanding the existence and scale of an issue, as well as knowledge about potential solutions. Such knowledge can shape an individual's attitudes, including their perceived benefits, perceived harms, perceived vulnerability to a problem, and their preference for particular solutions (Venkataramanan et al., 2020).

Utility: The total satisfaction or well-being that an individual experiences in relation to their living conditions.

2.2 Relationships between the Key Concepts

After presenting all contextual information in Chapter 2.1, the system is depicted in Figure 5, discussing all mentioned topics and linking them together.

A homeowner owns a house that he purchased using his resources. The house is situated in one of three areas, each of which employs a distinct approach to flood protection: Natural-based Solutions (NbS), Grey solutions, or no protective measures. The homeowner possesses a certain level of knowledge regarding flood-related subjects, which shapes his perception of flood risks, his attitude towards them, and his subsequent intentions. Consequently, the homeowner's intentions and attitude play a role in shaping his preferences and motivations. The homeowner can be classed into a profile that describes his views and values about flooding. Given that the home's location carries a specific flood risk associated with both fluvial and pluvial flooding, characterized by their probability and potential consequences, the homeowner might decide to mitigate this risk by adopting private flood protection measures. These measures can be categorized into two types: dry-proofing measures and wet-proofing measures. The behaviour the homeowner ultimately makes, whether to implement these private measures or not, hinges on his attempt to optimize his satisfaction (utility) while also considering his underlying intentions.

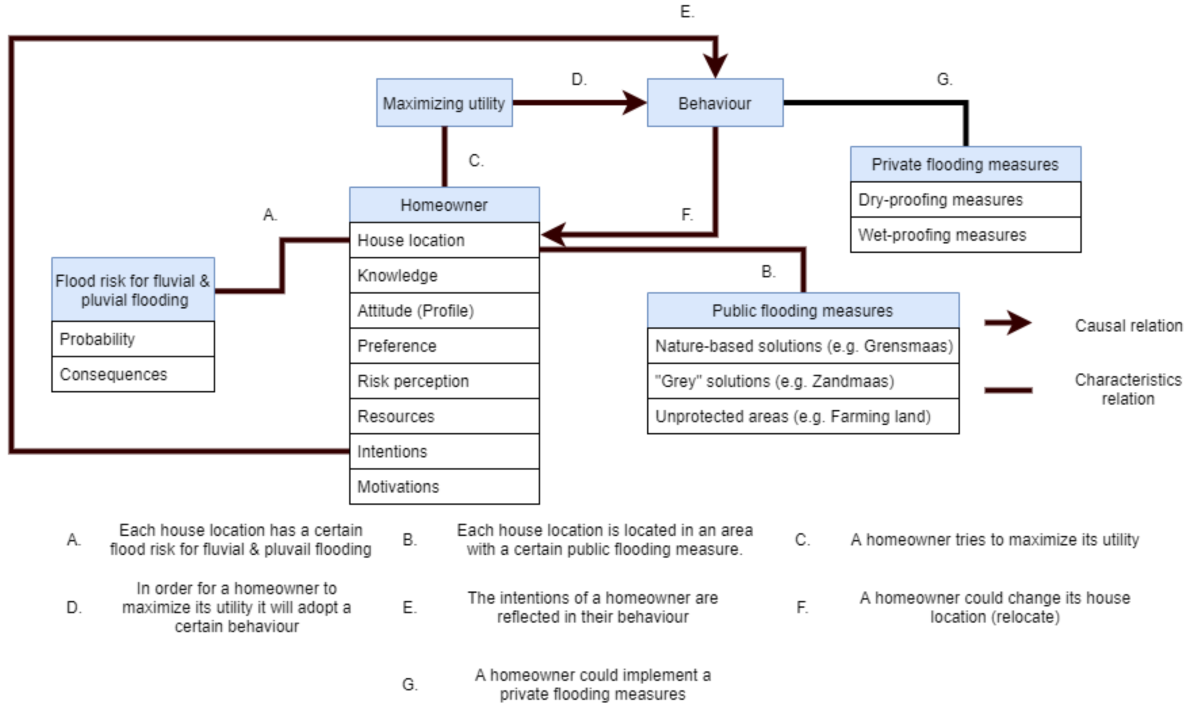

Figure 5: Relationships between key concepts

2.3 Key Theories explaining Homeowners Decision-Making

To get a clear insight into the choices of homeowners towards public flooding measures a utility-based model of the system will be used. By looking how homeowners maximize their utility, one can determine which public measures are preferred. This was illustrated in Chapter 2.1.4 and showed that the housing market can properly reflect preferences for public flooding approaches. A theory must be selected that highlights the importance of available services by a region and how it affects the utility of homeowners. The Tiebout model (Tiebout, 1956) and the Rosen-Roback model (Roback, 1982) are two models that can be used for this research to explain the observed behaviour. The Tiebout model is chosen, as this model can be used to explain how individuals sort themselves into communities based on their preferences for public goods and services, highlighting the importance of public flooding approaches. By contrast, with the Rosen-Roback model the trade-off between local public goods and private consumption is at its centre, meaning that less focus is applied to the preferences of individuals and public goods and services. As these aspects are of most importance for this topic and the Tiebout model is considered to be more influential, the Tiebout model is chosen over the Rosen-Roback model to explain this part of the system.

As mentioned in Chapter 1.1, regarding private flooding measures, only flood risk perceptions aren't sufficient to fully explain why homeowners do or do not take private mitigation measures. By using the Tiebout model, an already utility-based perspective is taken on the system, however as in reality flood-prone markets often involve information asymmetry, and to fully capture the motivations of homeowners and therefore understand why certain actions are taken by homeowners, an appropriate behavioural theory needs to be added. This theory needs to capture the intangible flood impacts on homeowners, as Bubeck et al. (2020) already stressed these impacts' significance. Both the Prospect Theory (PT) (Kahneman & Tversky, 1979) and Protection Motivation Theory (PMT) (Rogers, 1975) can be useful to capture an individual adaptation behaviour as mentioned by multiple studies (Babcicky & Seebauer, 2019; Bubeck et al., 2012; Noll et al., 2022). For this research, PMT is chosen, as this theory is closely related to the flooding topic and discusses adaptation of measures. The framework addresses the fact that in addition to an individuals' risk perceptions, it needs to be accompanied by coping appraisal to result in a protective response. The research of Suijkens (2022) showed that the theory was very useful to gain insights into what motivates residents to undertake private measures. Moreover, PT is only concerned with giving more weight to perceived gains versus perceived losses and therefore does not address issues such as coping, response efficacy and self-efficacy, which are more important in flood measures adoption since the opportunity for action lies with the government and homeowners.

2.3.1 Tiebout Model

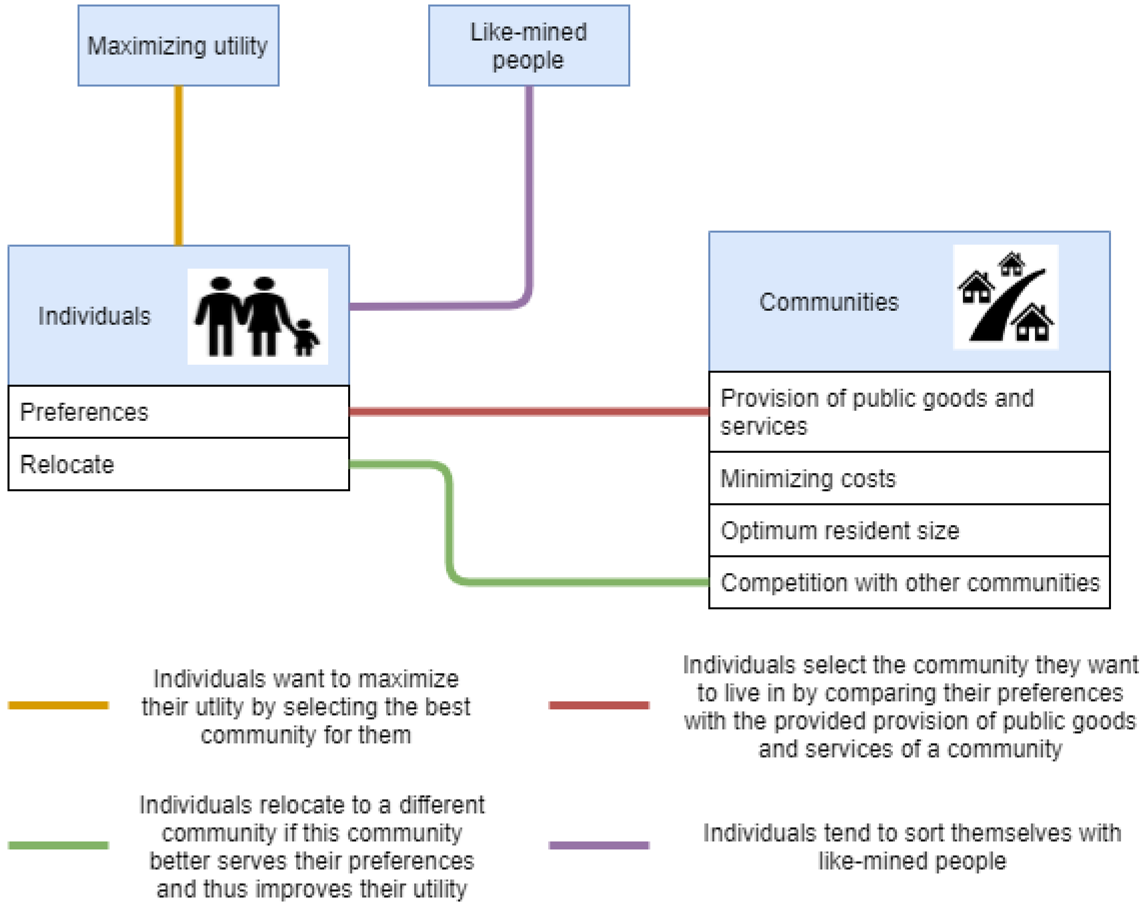

Figure 6: Visual representation of the Tiebout model

In Figure 6, the Tiebout model considered in this research is depicted. Charles M. Tiebout (1956) underlines the importance of individual preferences in shaping the provision of local public goods and services. It does this by presenting a theoretical framework. This framework explains that individuals choose to live in communities that provide the level of public goods and services they desire. Tiebout also highlights the fact that multiple local governments in a region can lead to competition among them to provide better public goods and services. This can then result in more efficient provision of public goods and services.

The model considers the following assumptions:

- The individuals have perfect mobility, meaning that they can easily move between communities to find the bundle of public goods that best matches their preferences.
- The individuals have complete information about the characteristics of different communities, including the quality of public goods and services provided.
- Some factor or resource is fixed, which results in a limited availability for residents in a community. An example could be that the total amount of land for housing in each community is fixed, resulting in the fact that the number of residents is limited. This means a community can have an optimum size which minimizes the average cost.
- It is assumed that the communities compete with each other for residents, and that this competition creates incentives for communities to efficiently provide public goods and services. Therefore, communities that are below their optimum size seek to attract new residents to lower average costs and those above the optimum size do the opposite. Communities therefore also operate under a balanced budget, meaning that it raises revenues from taxes and uses those revenues to provide public goods and services.
- It is assumed that the provision of public goods and services of a community does not exhibit external economies or diseconomies to other communities.
- Individuals seek to maximize their utility and have different preferences for local public goods and services. Restrictions due to employment opportunities are not considered.

Alonso (1964) observed that individuals tend to cluster together in certain areas based on their preferences for local public goods and services. This can result in residential areas becoming differentiated based on factors such as income, ethnicity, and other demographic characteristics. Alonso suggests that the reason for this spatial differentiation can be explained by individuals' demand for local public goods. They choose to reside in areas that offer the goods that provide them with the most utility, while considering the costs of acquiring land and commuting. Therefore, the pattern of residential differentiation is a result of individuals optimizing their preferences to maximize their utility.

To conclude, the Tiebout model can help determine which public flood measure has the preference among homeowners, by seeing the public flood measure as the public good and service a region provides and homeowners seeking to maximize their utility. This does need to consider the public cost (taxes and house prices) and availability for residents for each region.

2.3.2 Protection Motivation Theory

Rogers (1975) introduced the Protection Motivation Theory (PMT), a theoretical model that explains how fear appeals can lead to changes in attitudes and behaviour. This theory suggests that individuals' decision to adopt protective behaviour depends on their assessment of the severity of danger and their ability to cope with it. There are four key components of fear appeals according to PMT:

1. The perceived severity of a threat. This is the individual's perception of how severe the potential threat is.
2. The perceived vulnerability to a threat. This is the individual's belief that they are personally at risk of experiencing the threat.
3. The perceived efficacy of the recommended behaviour. This is the individual's belief that the recommended behaviour will be effective in reducing the threat.
4. The perceived self-efficacy in carrying out the recommended behaviour. This is the individual's belief in their ability to take action to protect themselves from the threat.

According to Rogers (1975), fear appeals are most effective when they achieve a balance between perceived severity and vulnerability of the threat and the perceived efficacy and self-efficacy of the recommended behaviour. If the threat is viewed as overly severe or the recommended behaviour is too challenging to execute, people may feel overwhelmed and powerless, resulting in defensive responses or avoidance. Conversely, if the threat is seen as too mild or the recommended behaviour as too effortless, people may lack the drive to take action.

Oakley et al. (2020) visualized the main elements of PMT and can be seen in Figure 7. It can be seen that PMT consists of two stages. The first, threat appraisal, relates to the perceived vulnerability and perceived severity of the consequences. The second stage, the coping appraisal can be triggered whenever this threat appraisal reaches a significant level. The coping appraisal is composed of three components, which are the perceived response efficacy (the effectiveness of the response), perceived self-efficacy (the individual's confidence in their ability to respond) and perceived response cost (the anticipated costs associated with the respond). An individual will take action when both the threat and coping appraisal are high. If only the threat appraisal is high, it does not generally result in action, but could lead to wishful thinking, denial and fatalism (Bubeck et al., 2018).

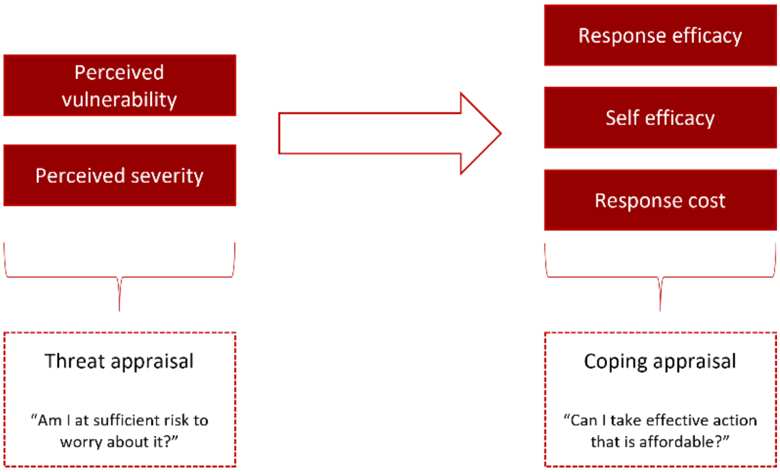

Figure 7: Visualization of the Protection Motivation Theory (Oakley et al., 2020)

Oakley et al. (2020) expanded PMT by stressing the importance of acceptance of ownership of the threat (*see* Figure 8). By adding the ownership appraisal an emphasis is placed on the communication of risk, costs, possible actions and the need for action. The authors suggest that "communication could have a strong role to play in supporting the take up for property flood resilience measures" (Oakley et al., 2020, p. 7). This could, for example assist homeowners in understanding that they bear some responsibility in protecting their homes.

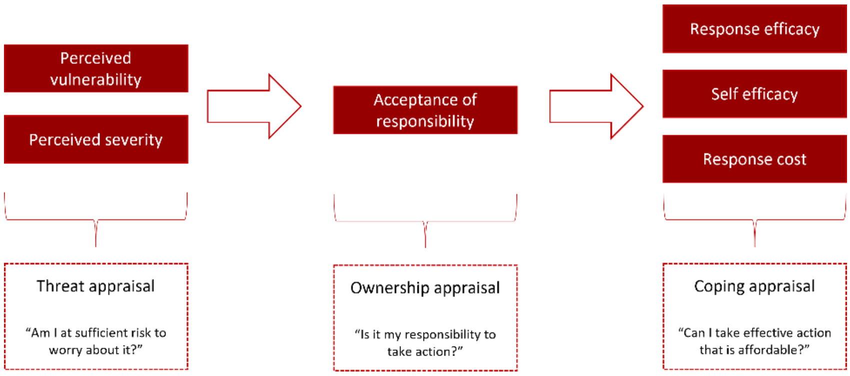

Figure 8: Augmented visualization of the Protection Motivation Theory (Oakley et al., 2020)

Noll et al. (2022) suggested that an individual’s motivation to protect themselves can be substantially impacted by emotional states such as fear, anxiety and panic. Moreover, social factors, including support, norms and trust can also be instrumental in shaping an individual's behaviour towards protection. The study of Noll et al. (2022) concluded that “social influence, worry, climate change beliefs, self-efficacy and perceived costs exhibit universal effects on household adaptations” (Noll et al., 2022, p. 1). Knowledge about whether and how intentions lead to actions however is still missing. PMT also doesn’t explicitly consider preferences for public measures. (Noll et al., 2022). Addressing the importance of including the Tiebout model for gaining knowledge about the preferences of homeowners for public flooding measures.

In the paper of Babcicky and Seebauer (2019), the model structure of PMT is revisited by means of structural equation modelling. It concluded that an individual has two possible routes of response. First, a protective route, where the individual undertakes protective behaviour resulting from a high level of the coping appraisal. The second is a non-protective route, where the individual exhibits non-protective behaviours resulting from a low level of the threat appraisal. It is said in the paper that private flood adaptation policy must target the protective route behaviour and avoid incentivising the non-protective route. However, how the two routes interrelate over time and which preferences there are for recommendations for public flood adaptation policy are still missing.

In Figure 9, a visual representation is given of the describe and expanded PMT that is considered for this research. The appraisals interact with each other while maintaining their distinct identities. Specifically, high levels of the threat, coping and ownership appraisals are more likely to lead to a protective response than low levels of the appraisals. Similarly to the findings of Babcicky and Seebauer (2019), the non-protective route will result from a low threat appraisal. However, this research expands on this by including the ownership appraisal. To elaborate, in the non-protective response route, the focus centres on relying on public protection measures, and it includes the involvement of the individual's consideration of assuming personal responsibility to mitigate any perceived residual risk. Concerning the protective route, a focused is placed on the coping appraisal and on the preventive measures and structural protection the individual can take as the protective response. Lastly, factors such as knowledge, external influences, climate-related beliefs, flood experience, uncertainty and demographics can influence the perceived threat, coping abilities and ownership of the risk. By including this framework in this research and analysing the data with the appraisals, the decision-making process of a household regarding the protective and non-protective can be elicited.

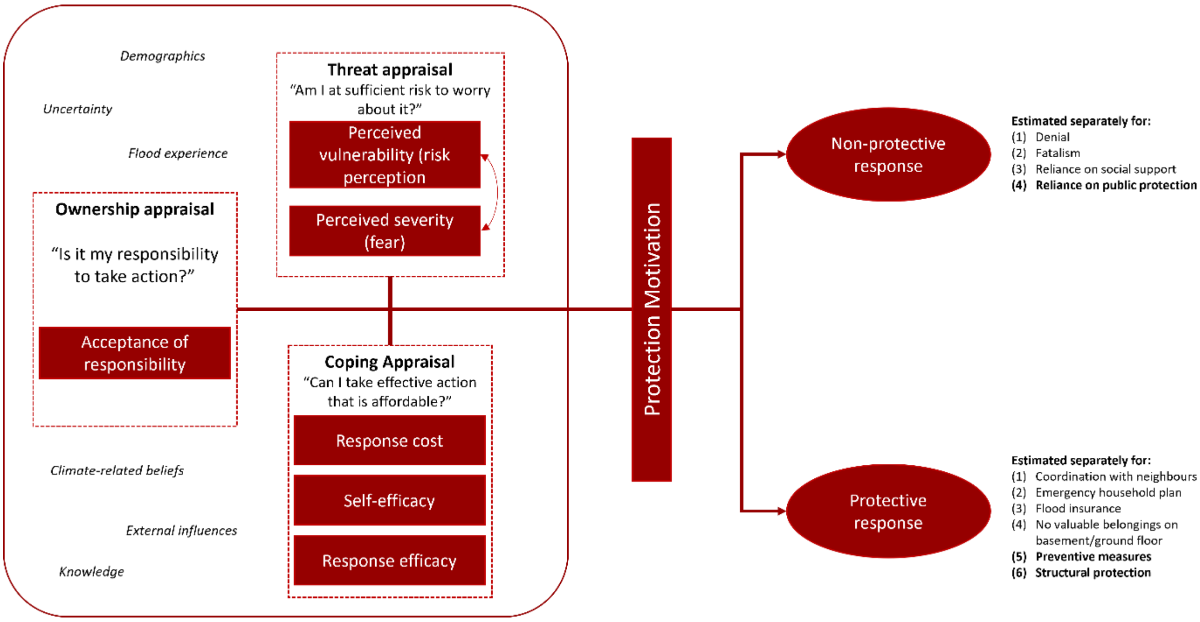

Figure 9: Visual representation of the describe and expanded PMT based on Babcicky and Seebauer (2019) and Oakley et al. (2020)

2.3.3 Applying Theoretical Framework to the Context of this Research

To answer the research questions, key concepts and relevant theories were formulated and explained. This framework includes the key concepts regarding flood risk and protection, Tiebout model and PMT and can be used for the selection of the serious game, which this research uses to gain insights into the preferences and motivations of homeowners regarding public and private flood measures. By selecting key variables related to the framework, an experiment simulating the environment (serious game) can be set up that closely resembles the real-world. Table 2 presents the comprehensive overview of the key variables that should be included in the serious game related to the framework. These encompass various aspects such as types of flooding and their associated risks, different forms of public and private flood protection measures, and attributes of homeowners. The attributes of homeowners encompass factors like the location of the house, the homeowner's level of knowledge, attitude, preferences, perception of risk, available resources, intentions, motivations, and behaviour.

To effectively model the decision-making process of homeowners within this system, two specific theories were chosen, the Tiebout model and the PMT. These theories provide insights into how homeowners make decisions regarding both the location of their houses and the implementation of private flood protection measures. Below, these theories are applied to the context of this research, allowing for a more comprehensive understanding of the decision-making dynamics at play.

The Tiebout model will be applied to reinforce the occurrences of homeowners relocating in reality. The Tiebout model describes individuals with different preferences looking at the availability and quality of public services in each community. Individuals then use this information in their decision-making process to determine which community corresponds best to their preferences and move there. To relate this to the study, the research will look at the public flood management approaches mentioned in Figure 5. Homeowners are able to choose to live in an area that has NbS, traditional "grey" solutions or an area that is unprotected. The areas have a certain amount of tax to be paid by homeowners that relates to the amount of residents living in the area. This enables cost minimalization for the areas themselves. Moreover, homeowners have the opportunity to relocate between the areas to find the place that maximizes their utility or in other words maximizes their satisfaction towards their living situation. By implementing the Tiebout model to the context, the research can determine in which public flood protection area homeowners prefer to living in (in relation to the costs).

The PMT will highlight the importance of behavioural motivations in the decision-making process. The theory describes that if a threat, in this case, a flood, is viewed as too alarming or the recommended behaviour for preventing it is too challenging to execute, people may feel overwhelmed and helpless, resulting in defensive responses or avoidance. Conversely, if the threat is seen as too mild or the recommended behaviour is too effortless, people may lack the drive to take action. To relate this to the study, flood probability is important as it signals to homeowners if there is a threat. Moreover, the amount of flood damage and the worry about the potential impact of a flood relates to the threat appraisal of the PMT. The income of a homeowner will relate to the coping appraisal and influence the response efficacy of a homeowner. The amount of available income of a homeowner will therefore also influence the response cost. Self-efficacy will relate to the confidence a homeowner has in the public and private flooding measures taken. Additionally, the sense of responsibility is also essential to determine whether a homeowner adopts a protective or non-protective response. Failing to acknowledge their responsibility for self-protection may result in a non-protective response, whereas a protective response is more likely when homeowners assume responsibility.

In Table 2 it is presented how the Tiebout model and PMT are covering the essential concepts in this research. It shows how the Tiebout model will supplement the research of homeowner preferences towards public flooding measures by looking were homeowner move to. Moreover, it shows how PMT will supplement the research of preferences, motivations and attitudes of homeowners towards (private) flooding measures by looking at the threat, coping and ownership appraisal.

Table 2:Key concepts related by the PMT and Tiebout model

Key variable	**Description related to theory**	**Related to this research**
	Tiebout model	
Communities & competition	There are multiple communities which each providing different provision of goods and services. They compete with each other for residency by individuals.	Areas with different public protections implemented (NbS, Grey solutions, unprotected)
Cost minimization & taxes	Each community strives for the optimal resident size and tries to achieve this by regulating taxes. In the optimal residency size taxes are at its lowest.	Areas each have a different maximum capacity, NbS has less space for residency due to needing it for its flood protection implementation. (House market)
Individuals	The Tiebout model is discussed in terms of individuals.	Homeowners
Unique preferences	Each individual has preferences towards the provision of goods and services	Each homeowner has preferences for public flood protection and private protection.

Utility maximization	Individuals will try to maximize their utility by seeking the community that best fits their preferences	A homeowner want to increase their well-being (satisfaction)
Housing market & relocating	Each house is located in one of the communities and provides a certain utility. An individual can choose to live in one of these houses.	Location of a house
Information provision	The Tiebout model considers that individuals have complete information about the characteristics of different communities, including the quality of public goods and services provided.	The amount of protection a public protection provides is available. This concerns a risk probability.
	Protection Motivation Theory	
Threat appraisal	Is an individual at sufficient risk to worry about it?	Perceived flood probability and perceived potential consequences (damage)
Response efficacy & Response cost (coping appraisal)	Can an individual take effective action that is affordable?	Resources (income)
Ownership appraisal	Does the individual find it his/her responsibility to take action?	Responsibility
Non-protective response	An individual chooses to not take action, because one of the appraisal is considered too low.	Reason to not implement a private measure
Protective response	An individual chooses to take action, because the appraisals are considered high enough.	Reason to implement a private measure
General key variables	**Description**	
Income, savings & living costs	To be able to buy a house, implement private measures and pay living costs, a homeowners pay with a currency.	
Flood probability	How often a flood occurs on the property on which an individual lives.	
Flood damage	In the event of a future flood, an individual will suffer physical damage to its property.	

3. Methodology & Game Selection

This chapter delves into which serious game is selected, how it relates to the formulated key variables and how the data is collected and analysed. Furthermore, the chapter outlines the player participation and presents the most important game elements.

3.1 Game Selection

The game should encompass the key variables related to the Tiebout and PMT theories, as detailed in Chapter 2.3.3 (Table 2). Considering a previous project's incorporation of these key variables, which involved the Tiebout model and the PMT and resulted in the creation of a game, the current research will adopt this existing game ensuring proper implementations of these theories. Developed by TU Delft Gamelab under the guidance of Doris Boschma, this game already encompasses the requisite elements for this study. The game is called “Where We Move” and in this game, participants assume the role of homeowners equipped with specific financial resources, which they can use to purchase properties within three available areas with each a different protection value against river (fluvial) and rain (pluvial) flooding. Each game round involves rolling dice to determine the occurrence of river or rain floods. Players have the option to acquire additional private measures during each round, supplementing the existing area protection or buy/save for satisfaction points, which determines the winner of the game (player with the most satisfaction points wins). A player sheet is used to keep track of their property and private measure acquisitions throughout the game. This sheet, consulted at the end of each round, provides a platform to inquire about the threat, ownership and coping appraisal. A more elaborate description of the game can be found in Appendix A: Game description.

In Figure 10 all interrelations between game elements are shown. “Protection level fluvial” and “protection level pluvial” are combined into “private protection level” to keep as much overview as possible in the figure. For the same reason, some elements can sometimes be seen multiple times in the figure. When comparing this illustration to the key variables described in Table 2, it becomes evident that all components are present within the game, validating that the game can help achieve the objective of this research. Additionally, the game is somewhat more comprehensive in nature, given the incorporation of additional elements like mortgages, living expenses, and debts. Furthermore, during the debriefing, participants had the chance to provide feedback and suggest any ways the game could be enhanced. From this discussion, it became clear that participants found the game to be realistic and fitting to the research. However, players noted that digitalization of the game could have significantly improve the understandability and playability of the game. Descriptions of the game elements and their dependencies are given in Appendix B: Game Elements.

Table 3 outlines the key variables that are integrated into the game, along with their respective operationalisation within the chosen game. The key variables are drawn from the Tiebout model (*see* Figure 6), the PMT (*see* Figure 9) and the key variables identified in Chapter 2.3.3 (*see* Table 2).

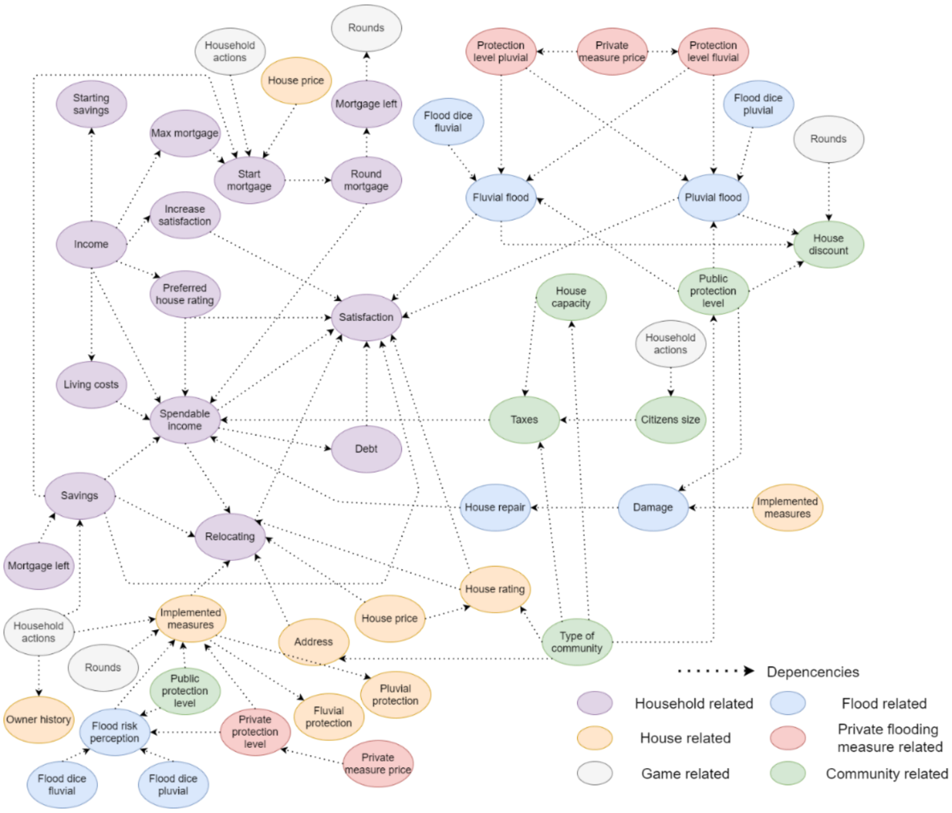

Figure 10: Visualisation of interrelations between game elements

Table 3: Key variables and how they are implemented into the game

Key variable	Operationalisation in the game
	Tiebout model
Communities & competition	There are three types of communities. Each community has a different amount of protection level and rating influence on houses.
Cost minimization & taxes	There is a limited amount of space for people to live in a certain area. Taxes will be regulated and only during the optimal size are taxes at its lowest. This means for each area they are differ tax values for different residency sizes.
Individuals	In the context it discusses this model in terms of homeowners. These homeowners will be represented by players of the game.
Unique preferences	Each homeowners can have a preference for either NbS, "Grey" solutions or unprotected areas. Additionally, they have a preference for a certain rating of house and private measure.
Utility maximization	Each homeowner tries to maximize their satisfaction towards their living situation and amount of money available (savings). The player with the highest satisfaction at the end of the game wins.
Housing market & relocating	Houses for homeowners are located in one of the three mentioned areas and have a certain rating that needs to align with the homeowners preferences to maximize satisfaction. A homeowner has multiple houses to choose from and range in price.
Information provision	In the context of this research, two scenarios can be thought of. One that provides all flooding information and another that has information symmetry and therefore has limited information.

Protection Motivation Theory	
Threat appraisal	In the game, each round, dices are thrown to decide whether a river or rain flooding occurs. The players are asked to fill in how much they consider to be at risk to worry about being flooded. This represents the threat appraisal level. With one of the following 5 statements players convey how they feel: 1. I won’t get flooded 2. I won't get damaged 3. I might suffer minor damage. 4. I will suffer minor damage 5. I will get seriously damaged
Coping appraisal	In the game, homeowners have a certain spendable income available to purchase additional components in the game. If this amount is capable to purchase all or even multiple private measures the coping appraisal is considered high and the homeowner can take effective flooding measures that are affordable.
Ownership appraisal	In the game, a homeowner is protected by the public flood measure of the region he is living in. The players are asked to fill in a question on whether they consider the public measure that protects them will be enough to protect them from flooding or not. This represents the ownership appraisal. With one of the following 5 statements players convey how they feel: 1. I fully trust the public measure in my area to protect me. 2. I trust the public measure in my area to protect me. 3. I’m inconclusive whether the public measure in my area will protect me. 4. I don’t trust the public measure in my area to protect me. 5. I absolutely don’t trust the public measure in my area to protect me.
Non-protective response	A homeowner is able to not implement any private flooding measures if he wants to. This is then because the player either considers to be at insufficient risk, cannot take effective affordable action or thinks it is the responsibility of the community (the public measure will protect them).
Protective response	A homeowner is able to implement any private flooding measures if he wants to. This is then because the player considers to be at sufficient risk, can take effective affordable action and think it is his/her responsibility (unsure whether the public measure will protect).
General key variables	
Income, savings & living costs	The amount of income, living costs and savings a homeowner has can influence, where they can live, what they can afford and how must satisfaction they can gain.
Flood probability	Two types of floods can happen (pluvial and fluvial) where probabilities of flooding dependent on the implemented public and private flooding measures.
Flood damage	This damage is dependent on how severe the flood was compared to the protection. Also price discounts are observed on houses that fade over time.

3.2 Important Game Elements

3.2.1 Homeowner types

To investigate the potential impact of different types of homeowners in relation to financial resources and housing needs on the selection of both public and private flood measures, participants will assume the roles of one of six distinct homeowners categories (as outlined in Table 4). This categorization provides insights into the participant's income and expenses per round, the upper limit for mortgage, initial savings, the cost of enhancing satisfaction by one point, and specific home requirements. This comprehensive description is referred to as "welfare." Notably, Table 4 includes two "average welfare" categories that mirror the average financial circumstances in the Netherlands. These categories are thus constructed using actual income and expenditure figures, representing an aggregate over a span of 3 to 5 years. It's important to note that these values have been recorded by Gamelab, enhancing the game's realism and practicality. To facilitate smoother gameplay and overall user experience, the maximum mortgage values have been intentionally slightly reduced from real-world figures. This calibrated approach optimizes the gameplay experience, while still maintaining a robust connection to real-world financial dynamics. In the context of house rating, a premise is established where a homeowner's financial resources directly influence the standards they hold for their residence. This implies that the sought-after degree of house rating aligns with the homeowner's earnings – a higher income corresponds to elevated preferences. Similarly, this principle extends to acquiring a single unit of satisfaction. As a homeowner's earnings increase, so does the monetary requirement to enhance their contentment, exemplified by endeavours like vacationing or acquiring gifts. Regarding starting savings, research indicates that higher income people save more than people with lower incomes (Dynan et al., 2000) and in general invest less than they save (Ezekiel, 1942).

Table 4: Homeowner types

Homeowner type	**Income**	**Living costs**	**Maximum mortgage**	**Starting savings**	**Increase satisfaction**	**Preferred house rating**
Very low welfare	50k	20k	80k	0k	4k	3
Low welfare	65k	30k	110k	5k	6k	4
Low average welfare	80k	40k	130k	15k	8k	5
High average welfare	100k	50k	170k	30k	10k	6
High welfare	120k	65k	200k	50k	13k	7
Very high welfare	180k	105k	300k	80k	21k	8

3.2.2 Private Flood Measures

In the game participants can choose between the following private flooding measures: Green garden, automatic steel walls, install a water pump, self-rising bulkhead, rise ground level, water resistant walls & floors, sandbags and underground rain barrel.

A description of what they are and do in the game can be found in Appendix C: Private Measures. Considering that these measures are typically the most frequently adopted and encompass the wide array of private measures available (acquired from the damage limitation guide of EA (2003), https://www.waterklaar.nl and FEMA documents (FEMA, n.d., 2014)), these specific private flooding measures are selected for integration into the game. The costs associated with these private measures are derived from real-world prices. By doing so, the alignment between the inclination to adopt a private measure and the perceived cost-effectiveness within the game closely mirrors reality as much as feasible. In In the game, the private measures protect against river (fluvial) or rain (pluvial) flooding. This enables a comparison between the two types of measures identified in Chapter 2.1.2: dry- and wet-proofing measures. To illustrate, measures primarily focused on water management or drainage, such as water pumps, underground rain barrels, green gardens and water-resistant walls & floors, fall under the jurisdiction of wet-proofing techniques and protect against rain flooding. Conversely, automated steel walls, self-raising bulkheads, sandbags, and elevating the ground level are more closely aligned with dry-proofing strategies and protect against river flooding. However, it's worth noting, as explained in Chapter 2.1.2, that dry-proofing just as wet-proofing measures, despite their differences, enhance flood resilience by mitigating the pace at which water infiltration occurs. This means some dry- and wet-proofing measures, which have both functionalities provide protection for both types floodings.

Table 5, the actual and in-game prices of each measure is depicted. Based on the data provided in In the game, the private measures protect against river (fluvial) or rain (pluvial) flooding. This enables a comparison between the two types of measures identified in Chapter 2.1.2: dry- and wet-proofing measures. To illustrate, measures primarily focused on water management or drainage, such as water pumps, underground rain barrels, green gardens and water-resistant walls & floors, fall under the jurisdiction of wet-proofing techniques and protect against rain flooding. Conversely, automated steel walls, self-raising bulkheads, sandbags, and elevating the ground level are more closely aligned with dry-proofing strategies and protect against river flooding. However, it's worth noting, as explained in Chapter 2.1.2, that dry-proofing just as wet-proofing measures, despite their differences, enhance flood resilience by mitigating the pace at which water infiltration occurs. This means some dry- and wet-proofing measures, which have both functionalities provide protection for both types floodings.

Table 5 and Appendix C: Private Measures, it can be concluded that sandbags are the cheapest one-time solution for safeguarding against river flooding. Conversely, the self-rising bulkhead appears to offer the most affordable long-term protection against river flooding. Furthermore, the installation of a water pump emerges as the most budget-friendly choice for mitigating the risk of rain flooding.

In the game, the private measures protect against river (fluvial) or rain (pluvial) flooding. This enables a comparison between the two types of measures identified in Chapter 2.1.2: dry- and wet-proofing measures. To illustrate, measures primarily focused on water management or drainage, such as water pumps, underground rain barrels, green gardens and water-resistant walls & floors, fall under the jurisdiction of wet-proofing techniques and protect against rain flooding. Conversely, automated steel walls, self-raising bulkheads, sandbags, and elevating the ground level are more closely aligned with dry-proofing strategies and protect against river flooding. However, it's worth noting, as explained in Chapter 2.1.2, that dry-proofing just as wet-proofing measures, despite their differences, enhance flood resilience by mitigating the pace at which water infiltration occurs. This means some dry- and wet-proofing measures, which have both functionalities provide protection for both types floodings.

Table 5: Real and in-game costs of private flood measures

Private measure	Price in-game	Actual price
Green Garden	20.000	The price is dependent on extensivity.
Automatic steel walls	12.000	The price is dependent on how long the wall is, how high the wall is, if it is automatic or not and with or without a foundation. The price without installation is starting from 2000. (Vlaamse milieumaatschappij, 2015b). With installation it will be a lot more.
Install a water pump	6.000	The price starts from 4000 euro for a buffer pump specifically and depends on how large the buffer reservoir is (Vlaamse milieumaatschappij, 2015a).
Self-rising bulkhead	8.000	The costs of this bulkhead is 6.000 per meter (Waterklaar.nl, n.d.)
Rise ground level	35.000	The prices found are those from America, meaning that in the Netherlands it would probably be a lot more. Average cost is about 28.000 and between 20.000 and 100.00 to raise the home specifically so that it is above the flood zone (Crail, 2023).
Water-resistant walls & floors	20.000	The price is dependent on what you want to build/replace. Can be very expensive.
Sandbags	3.000 (one-time use)	There are different types of sandbags, but generally for one 50 pound bag it costs between 20 and 50 dollar (howmuchisit.org, n.d.). Of course, one bag is not enough to protect your house. At most 150 bags can be bought with 3.000 dollar.
Underground rain barrel	11.000	The price is dependent on how large the reservoir is under the ground. It starts from around 7000 euro. The most expensive option is around 12.000 euro (wildkamp.nl, n.d.).

3.2.3 Public Flood Measures

As established, three distinct forms of public protection exist against pluvial and fluvial flooding. These comprise the unprotected area, designated as farmland, the urban area referred to as the dike area (“grey” solutions), and the sector employing a nature-based solution (NbS). These delineated regions are also components within the game. Notably, each of these zones in the game bear a protective value grounded in real-world parameters (protection values and explanation can be found in Appendix A: Game description Stage 4: Flooding Event).

3.2.4 Game Scenarios

According to Suijkens (2022), current approaches and communication to motivate private measures were found to be ineffective. This is because existing strategies primarily concentrate on increasing awareness of flood risk among the public. However, since only a weak relation between flood risk perceptions and the adoption of private flood mitigation measures is found in the literature (Bubeck et al., 2012), it ultimately results in a low uptake of private flooding measures. Kunreuther (1996) also stated that individuals living in areas prone to risks are not proactive in taking mitigation measures. In his paper, practical experiences indicate a reluctance among such individuals to voluntarily undertake mitigation measures. The paper of Suijkens (2022), addresses the lack of data available on the effect of private flooding measures in its literature review and suggests according to the PMT (coping appraisal), that a communication strategy that focuses on the relative risk reduction effect of private measures results in more adoption of private flooding measures by individuals. To test this statement two scenarios are considered in the game:

1. Participants are given both public and private flooding protection information.
2. Participants are only given public flooding protection information.

As current and future public flood defences must follow certain standards (ENW, 2017), flood risk probabilities for these public measures is widely available. Therefore, in both scenarios, flood protection information is provided for the public measures. To assess whether providing more information on the risk reduction effect of private measures will lead to more adoption, these scenarios can be tested. In addition to this, it can also be examined whether the scenarios have an effect on participants' preferences and motivations. Below a more in-depth description is shared about the scenarios.

Providing Limited Flooding Protection Information

Each private measure has a protection level against rain (pluvial) and river (fluvial) flooding. Additionally, it is possible that the measure can give some satisfaction points to the participant. In the limited information scenario river and rain protection of private measures will be given as a question mark. The participant will not know how much (additional) protection the measure will give. They do know, however, the protection level of the public flooding measures. Moreover, they know that a private measure can either protect or not protect against river floodings and that a private measure if protected against river flooding (which they do not know) adds to the cumulative protection level of river floods. However, participants can acquire knowledge regarding which type of protection the private measure gives. This can be acquired by reading the descriptions of the measure itself. Additionally the price can give away if it will offer high protection or not. During the first round, the news item will explain the private measures and this will be different from the other scenario to explain what they do and do not know.

Providing All Flooding Protection Information

Each private measure has a protection level against rain (pluvial) and river (fluvial) flooding. Additionally, it is possible that the measure can give some satisfaction points to the participant. In the all information scenario river and rain protection of private measures will be given. The participant will know how much (additional) protection the measure will give. They also know the protection level of the public flooding measures. Moreover, they know that a private measure can either protect or not protect against river floodings and that a private measure if protected against river flooding (which they do not know) adds to the cumulative protection level of river floods. During the first round, the news item will explain the private measures.

3.2.5 Game Rounds

In the game multiple events take place. These are organized per round:

- Round 1: Introduction: Here, only a short description is given of what is to come for players and what they can expect from the game.
- Round 2: Including house discounts: The rules of the house discount will be explained. This means if a flood has occurred in an area, house prices drop (potentially temporarily).

- Round 3: Increased river and rain flood probability: The players are told due to climate change the flood probabilities will increase. In-game this is done by decreasing the protection levels of the public measures.
- Round 4: Taxes increase for NbS area: The players are told due to an increase demand for NbS areas, taxes will increase. In-game this is done by increasing the taxes of the NbS area by 5.
- Round 5: Two satisfaction gain for people relocation or living in NbS area: The players are told due to the multiple beneficial aspects of the NbS area, people living there will gain two satisfaction. In-game this is done by giving players 2 satisfaction points.

3.3 Collecting the Data

The data for this research will be obtained in four ways. Namely:

1. With the pre-game survey
2. With the game data
3. With the post-game survey
4. With the debriefing

3.3.1 Pre-Game Survey

To sort participants into specific groups, personal information from each person is required. This information is gathered through the pre-game survey[1]. The survey asks questions about experiences with floods, how much participants acquire knowledge regarding flood topics, how they predict future floods, the influence of climate change on flood chances, expected harm from possible future floods, and who they consider responsible. Depending on the answers provided, each person will belong to a distinct profile. This profile is determined by using a process called Latent Class Analysis (LCA), which helps identify different groups of people based on their answers. LCA is a statistical procedure used to identify different groups of people within a larger group who seem similar on the outside. These smaller groups are called "latent groups" or "classes". To find these latent groups, LCA uses participants' responses to categorical indicator variables and looks at where groups of people answer in a similar way. It can also be said that LCA is used to detect latent heterogeneity in samples to divide participants into smaller groups based on how they answered the questions (Weller et al., 2020). The questions asked in the pre-game survey can be found in Appendix E: Pre-Game Survey.

3.3.2 Game Data

The primary data source is the individual player sheet provided to each participant during every round. This sheet comprises empty fields that participants must fill in (*see* Figure 11). These sections encompass their earnings, expenses, disposable income, address, player identification number, satisfaction level, and flood-related details. The player identification number serves the crucial purpose of connecting the in-game player with the data collected from both pre- and post-game surveys, thereby facilitating a comprehensive analysis. Furthermore, the player sheet contains two specific questions. These inquiries aim to measure

[1] This research was given permission from the ethical committee of TU Delft to gather personal information.

the extent of threat appraisal and ownership appraisal. To determine the level of threat appraisal (in-game question 1), the following methodology was employed:

1. I won’t get flooded
2. I won't get damaged
3. I might suffer minor damage.
4. I will suffer minor damage
5. I will get seriously damaged

The player now needs to choose one of these 5 statements to convey how he/she feels in that round. By asking this an insight is given on the amount of worry he or she has that she will get flooded in the next flooding event in the game. This therefore can then encompass the threat appraisal in a 5 level scale. To determine the level of ownership appraisal (in-game question 2), the following methodology was employed.

1. I fully trust the public measure in my area to protect me.
2. I trust the public measure in my area to protect me.
3. I’m inconclusive whether the public measure in my area will protect me.
4. I don’t trust the public measure in my area to protect me.
5. I absolutely don’t trust the public measure in my area to protect me.

This question evaluates the player's trust in the efficacy of the public measure they are encountering. This evaluation pertains to the ownership appraisal, as a player who lacks confidence in the public measure can only protect themselves within the game by undertaking actions for himself. Additionally, the protection power of the public measure remains unaffected by the player's influence. This implies that attributing a sense of "ownership" to the matter is achievable solely by either placing faith in the public measure or taking individual initiatives in the game.

The house sheet (*see* Figure 11) will serve to ascertain the houses that participants have acquired and any associated private flood measures they might have obtained. Finally, the homeowner type sheets are employed to categorize each participant according to their respective homeowner type within the game.

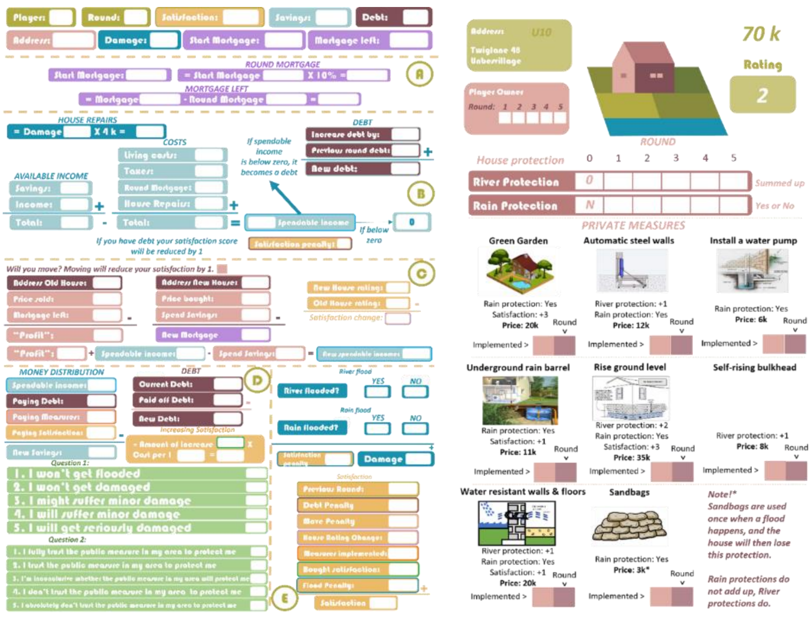

Figure 11: Player and house sheet

3.3.3 Post-Game Survey

The post-game survey will help determine if the preferences participants had in the game align with their real preferences regarding private and public measures. The survey will include questions about their choices in the game for both private and public flooding measures, as well as their overall strategy in the game. This can shed light on the reasons behind certain actions they took. Lastly, participants will be queried about their confidence in and the cost-effectiveness of private and public measures. Although the-se questions may not have a direct analysis purpose, they could provide valuable additional insights regarding the motivators of homeowners. The questions asked in the pre-game survey can be found in Appendix F: Post-Game Survey.

3.3.4 Debriefing

Once the game session concludes, there will be a debriefing to discuss the experience. This discussion will uncover their preferences and conversations related to private and public measures. The insights gained from this debriefing can guide any future iterations of the game and help clarify any observations made during the gameplay. In Appendix G: Debriefing, the list of prepared questions are given, which were already formulated by the Gamelab. While these questions give the debriefing some structure, they serve as a guideline and can be facilitated by asking unrelated or more in-depth questions after a response is given to the prepared questions. This approach aims to encourage more natural and conversational discussions, rather than a formal interview-style interaction.

3.4 Analysing the Data

Within the game, the preference towards private measures will be assessed by considering the count of individual implementations for each distinct private measure. The preference towards public measures will be deduced by examining a player's in-game residence and whether they relocate to a different area. Through this approach, the density of players residing in a particular zone will reflect preferences for specific public measures. This implies that distinct public measures have been adopted in different zones. Here, the assumption will also be made that a player will move to an area that meets its preferences regarding the provision of public goods (Tiebout model).

Additionally, by documenting the reasons behind a player's decisions to move and factoring in their levels of perceived threat, ownership appraisal and coping appraisal, it becomes possible to explain the rationale behind specific actions taken within the game (PMT). Anticipated findings suggest that players exhibiting high levels in all three appraisals are likely to implement a greater number of private measures, in contrast to players with lower values in these appraisals. Additionally, it is expected that factors such as flood experience, knowledge, anticipation of future floods and welfare (financial capabilities) affect the appraisals.

Concerning the profiling, because the indicators used for this research closely resemble those used in the research of Franceschinis et al. (2021), it's anticipated that comparable profiles will emerge from the LCA. In Franceschinis et al. (2021)'s study, the population was categorized into three classes: Risk monitoring, risk minimising, and risk downplaying. Individuals belonging to the “risk monitoring” group are those who experienced flood events in the past, think such events will happen again in the future and have low trust in structural flood protections. Individuals belonging to the "risk minimising" group are those without prior flood experience, who don't expect similar flood events to reoccur in the future, and who reside outside mountainous regions. The “risk downplaying” group includes everyone else. Franceschinis et al. (2021)' research revealed that the largest portion of the population fell into the Risk minimising group (46%). Consequently, a similar classification of groups with roughly the same population distribution is anticipated in this study.

In order to see if significant differences in the data are found between for example the profiles, scenarios, flood experience and relocation, ANOVA tests, T-tests and Paired T-tests are used. These are statistical tests to determine if there is a significant difference between the means of two groups (more than two for ANOVA tests) and how they are related. Concerning paired T-tests, these compare the means of two measurements taken from the same participant (used for relocation data).

3.5 Player Participation

After organizing serious gaming sessions in IHE-Delft and the municipality of Nissewaard (A detailed description of the organization process can be found in Appendix D: Organizing Game sessions and Inviting Participants), a total of 53 individuals eventually participated in the game. While a larger participant pool was initially desired, constraints on time prompted the decision to analyse the data from this group. In Table 6, the participation of players in the surveys and game rounds is detailed. A total of seven games were played, and each game or group of players is denoted by a letter. Notably, players 6F and 8F were not part of the sessions, and participants from group C discontinued playing after the second round, prior to making decisions about how to allocate their spendable income. Additionally, player 2E stands out as the only participant who completed the pre-survey but did not engage in the game. This decision was due to her limited proficiency in English. When comparing data between the game and the pre- or post-survey, only data points from players who participated in both are considered.

Table 6: Player participation in the game sessions

Player	Pre-survey	Post-survey	Round 1	Round 2	Round 3	Round 4	Round 5
1A							
Remainder of Group A members							
1B, 6B and 7B							
5B							
Remainder of Group B members							
Group C				*			
Group D							
2E							
Remainder of Group E members							
*Group F***							
Group G							

Green boxes indicating the player participated the specified event and the red boxes indicating the player did not
** The players stopped before they had decided what to do with their spendable income.*
*** Players 6F and 8F were not present for the surveys and the game.*

4. Results

This chapter provides the data needed for the research questions. Player profiles, derived from pre-game surveys (Latent Class Analysis), address sub-question 2 by revealing how different player attitudes impact in-game private implementation. Data on private and public flood measures, organized by homeowner types, scenarios, rounds, flood experience answers sub-question 3, while also connecting with Protection Motivation Theory resolves sub-question 4.

4.1 Profiles

In this subchapter, the profiles of the participants are developed by using the Latent Class Analysis (LCA). The questions (indicators) used to facilitate the subdivision in the LCA can be found in Table 7.

Table 7: Questions (indicators) used for LCA

Question number in the pre-survey	Question	Description
Question 4	Have you ever personally experienced any type of flood (e.g. coastal, river or rain flood)	Experience with floods.
Question 5-1	How often do you actively listen or read information about floods from the following sources? (Government, i.e. official letters, warnings, announcements etc.)	Knowledge obtained from the government about flood related subjects.
Question 5-2	How often do you actively listen or read information about floods from the following sources? (Scientific, i.e. academic reports or publications)	Knowledge obtained from scientific sources about flood related subjects.
Question 5-3	How often do you actively listen or read information about floods from the following sources? (General media, i.e. news, TV and radio)	Knowledge obtained from general media about flood related subjects.
Question 5-4	How often do you actively listen or read information about floods from the following sources? (Social network or media, i.e. friends, family and colleagues)	Knowledge obtained from social networks and media about flood related subjects.
Question 6	How likely do you consider a flood event to happen to you in the next 5 to 10 years?	The possibility of a flood happening in the future.
Question 7	To what extent do you believe climate change will increase your likelihood or chance of being flooded in the next 5 to 10 years?	The impact of climate change on the likelihood of flooding.
Question 8	To what extent do you believe you will get damaged in the event of a major flood in the next 5 to 10 years?	Expected damage from a potential flood in the future.
Question 9	Whom do you consider to be responsible for providing/having flood protection?	Whom is considered responsible for flood protection

Typically, the model with the lowest values of both the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) is considered the best fit for the data. Additionally, an entropy value approaching 1 is considered optimal (Weller et al., 2020).

Table 8 shows the different values of AIC, BIC and entropy for three different models (with 2,3,4 or 5 classes). When examining Table 8, the model choice remains unclear. The BIC value is lower for the model with 2 classes (1480), suggesting that according to the BIC test, it fits the data best. On the other hand, the AIC value is lowest for the model with 3 classes (1304), indicating that according to the AIC test, it's the best fit. However, looking at the entropy value, the model with 5 classes appears preferable due to its closeness to 1 (0,973). To determine the best fitting model, it's crucial to understand that the AIC test is more inclined to select a complex model for a given sample size, whereas BIC is less likely to choose an overly complex model when the sample size is adequate. However, BIC is more prone to selecting a model that's too simplistic when the dataset is small (Lin, 2021). Given the small sample size of 54 in this research, relying solely on the BIC value for model selection might lead to choosing a model that is both too simple and too small. Therefore, the model selection process will prioritize the AIC value as the most important factor. While the model featuring 5 classes presents the highest entropy value, it's worth noting that an entropy value nearing 1 is optimal, and a value exceeding 0.8 is still considered acceptable (Weller et al., 2020). Consequently, considering that the model comprising 3 classes exhibits superior AIC and BIC values and possesses an entropy value approaching 1, it can be concluded that this specific model is the most appropriate choice.

Table 8: AIC, BIC and entropy values of the models

	AIC	BIC	Entropy
Model with 2 classes	1343	1480	0,831
Model with 3 classes	1304	1510	0,949
Model with 4 classes	1339	1616	0,969
Model with 5 classes	1376	1722	0,973

4.1.1 Labelling of the Classes

In Figure 12, one can observe how the different classes have responded to the indicators (exact numbers can be found in Table 34 in Appendix H: ANOVA Test). The population size of each class is as followed: Class 1 is the most prevalent, constituting 46.8% of the dataset belonging to this group. Class 2 and Class 3 are represented in the dataset by 23.8% and 29.4% respectively. Referring to the visualization of these scores (*see* Figure 12), it is possible to assign labels to each class based on this information. The analysis of class mean differences of the indicators (highlighted in Table 7), along with the identification of significant distinctions, is detailed in Appendix H: ANOVA Test, relating to the One-way ANOVA examination of the dataset.

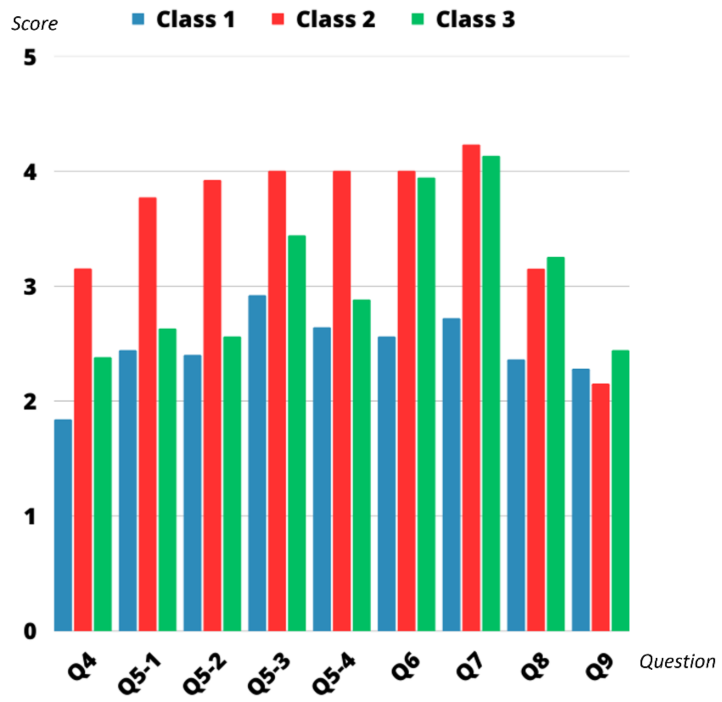

Figure 12: Visualisation of scoring of each class on the indicators

Considering the scores and ANOVA test, the following can be stated about the classes: When comparing the classes, Class 2 individuals possess the most experience with flooding, have significantly obtained more knowledge regarding flood-related topics from governmental, scientific and social network sources and consider the likelihood of flooding to be high. Additionally, they expect to incur damage if such a flooding event occurs. On the other hand, Class 1 is characterized by having the least experience with flooding and obtained less information about flood-related subjects compared to Class 2. These individuals also anticipate a lower probability of future floods, with minimal impact from climate change. Consequently, they expect minimal damage if such a flooding event takes place. Class 3 should be compared with Class 2 and Class 1. These individuals have the same flood experience as Class 1 and also obtained the same amount of information about flood-related subjects. However, Class 3 significantly differs in perceived probability of future floods, perceived influence of climate change and anticipated damage from future flooding compared to Class 1. Here, the class follows the same characteristics as Class 2, implying that this class perceives a higher probability of future floods, influenced by climate change. Similarly, the individuals in Class 3 anticipate incurring damage if a flooding event occurs in the future. Furthermore, each class almost scores the same when it comes to responsibility. The differences observed in this aspect are not significant. This indicates that each class predominantly believes that the government should assume the most responsibility for flood protection, with some responsibility placed on the residents themselves.

In Appendix H: Questions 10 and 11 of the Survey an overview of each class's evaluation of the effectiveness of both private and public flooding measures (question 10 and question 11 in the pre-game survey) is provided. From this overview, it can be concluded that there were no significant distinctions observed among the classes regarding their perceptions of the efficacy of private and public flooding measures. However, a significant difference emerged in the evaluation of water pump and waterproof walls & floors effectiveness. Specifically, the mean scores for Class 2 were significantly divergent from those of Class 1 in relation to the water pump (Class 2: mean=3,38, Std D=0,77 / Class 1: mean=2,56, Std D=1,16) and a significant distinction from Class 3 in terms of the effectiveness of waterproof walls & floors (Class 2: mean=3,67, Std D=1,07 / Class 3: mean=2,44, Std D=1,40). In both instances, the averages were higher for Class 2, with Class 3 having the lowest and Class 1 the in-between values.

Based on this data, the following labelling has been assigned to the classes:

- Class 1: Cautious optimists
- Class 2: Informed preparers
- Class 3: Cautious realists

The label of Class 1 reflects their cautious approach due to limited experience and information, but also their optimism about the likelihood of future floods and damage. The label of Class 2 reflects their informed stance with a focus on future preparedness, as they consider the likelihood of future floods and damage high. The label of Class 3 reflects their cautious mindset that leans towards realism due to the realisation of the upcoming threat of future floods. It should be mentioned that most players who belonged to the "informed preparers" were following a study at IHE-Delft (11 out of 13) and those who belonged to "Cautious realists" (20 out of 25) or "Cautious optimists" (12 out of 16) were mainly people from either the municipality or another study rather than a study at IHE-Delft.

4.1.2 Class related to Private Implementation In-Game

Before the amount of private implementations per class is analysed, it is important to clarify that the private implementations are correlated with the classes and only marginally influenced by the homeowner type they had in the game in order to make sound conclusions about the data. In Table 9, the actual and desired count of players per homeowner type ordered by class is provided. The desired count represents the correctly distributed amount of players per homeowner type in order to have no influence of the homeowner type. In Table 9, it can be observed that this distribution is largely in line with the actual distribution. The main difference is that Cautious optimist were slightly given more wealthier homeowner types and Informed preparers and Cautious realists slightly less wealthier homeowner types.

Table 9: Amount of observed and desired amount of players per homeowner type ordered by class

	Cautious optimists		**Informed preparers**		**Cautious realists**		**Total**
	Actual[a]	**Desired**[b]	**Actual**[a]	**Desired**[b]	**Actual**[a]	**Desired**[b]	
Very low welfare	2	3,17	2	1,72	3	2,11	7
Low welfare	2	3,17	3	1,72	2	2,11	7
Low average welfare	7	6,79	2	3,68	6	4,53	15
High average welfare	7	5,89	4	3,19	2	3,92	13
High welfare	2	2,26	1	1,22	2	1,51	5
Very high welfare	4	2,72	1	1,47	1	1,81	6
Total	24		13		16		53

[a] *Actual (observed) number of players per homeowner type for each class in-game.*
[b] *Desired number of players per homeowner type for each class in-game. Calculated by the percentage of the total players per class (Class 1=24/53, Class 2= 13/53 and Class 3= 16/53) times the total amount of players observed per homeowner type.*

Table 10 displays the count of private flood implementations per identified class within the game. It can be observed that primarily “cautious realists” make purchases of private measures. Additionally, it's noteworthy that when accounting for population variations within the game, “cautious optimists” implement the fewest private measures. Lastly, focusing on the "informed preparers," they implement less than “cautious realists” but more than “cautious optimists”.

Table 10: Number of private implementations ordered by class (all games)

	Cautious optimists (46,4%, N=24)*	Informed preparers (27,3%, N=13)*	Cautious realists (26,4%, N=16)*	Total
Green garden	7	7 (11,9)	9 (15,8)	23
Automatic steel walls	3	2 (3,4)	5 (8,8)	10
Water pump	5	2 (3,4)	5 (8,8)	12
Self-rising bulkhead	9	4 (6,8)	6 (10,5)	19
Rise ground level	7	4 (6,8)	7 (12,3)	18
Waterproof walls & floors	3	2 (3,4)	4 (7)	9
Sandbags	6	12 (20,4)	7 (12,3)	25
Rain barrel	4	8 (13,6)	5 (8,8)	17
Total	44	41 (69,7)	48 (84,4)	133

**How much percentage of the players played the game times how many rounds they played.*
()Values between the brackets represent the values when equal sample size of the amount of players is assumed.
The green boxes represent the class with the highest amount implementations of a specific private measure.

4.1.3 Effect of the Profiles on the Appraisals

We expect from the PMT (*see* Chapter 2.3.2) that different attitude profiles (classes) have different values for the treat and ownership appraisal. To determine if a statistically significant mean difference between the profiles is observed in terms of the threat and ownership appraisal in the game, an ANOVA test is performed on the acquired values regarding the appraisals during each game round. From this test a p-value of $< .001$ is observed for the in-game threat appraisal question and a p-value of 0.234 is observed for the in-game ownership appraisal question. This means that there is statistical significance in the differences between the means of the profiles for the perceived threat, but no statistical significance in the differences between the means of the profiles for ownership. To identify significant differences between the profiles for perceived threat, a post-hoc test for pairwise comparisons is conducted. Given the utilization of Welch's ANOVA, the Games-Howell multiple comparisons method is applied for this analysis. In Table 11, the results are shown. From these results it can be said that participants, classified as “Cautious optimists” perceive significantly less threat than “Informed preparers” and “Cautious realists” in the game and “Informed preparers” and “Cautious realists” do not significantly differ in their perceived threat. This is also in line with the answers on perceived future flood probability (pre-game survey Q7) and climate change impact on flooding (pre-game survey Q8), with Informed preparers and Cautious realists scoring higher on both questions than Cautious optimists.

Table 11: Games-Howell Post-Hoc Tests for the in-game threat appraisal question (Q1) concerning profiles

	Mean Q1	Cautious optimist	Informed preparers	Cautious realists
Cautious optimist	1.92	-	0.029	<. 001
Informed preparers	2.40		-	0.673
Cautious realists	2.58			-

4.1.4 Conclusion Profiles

In brief, to answer sub-research question 2, three profiles are identified, “Cautious optimists” (46,8%), “Informed preparers” (23,8%) and “Cautious realists” (29,4%). They differ in flood experiences, obtained knowledge, perceived likelihood of future flooding and perceived influence of climate change, but not in responsibility. The profiles do not significantly differ in the perceived effectiveness of private flood measures. In the game, players who were classified as “Cautious optimists” perceived significantly lower threat and bought the least amount of private measures compared to the other profiles. Players who were classified as “Cautious realists” bought the most amount of private measures and perceived together with the ”Informed preparers” the highest threat. The ownership appraisal was the same for all profiles. Cautious optimist were slightly given more wealthier homeowner types and Informed preparers and Cautious realists slightly less wealthier homeowner types.

4.2 Homeowner Types

In this section, the data on private and public flood measure implementation, organized by homeowner type, is presented. Participants in the game were assigned one of six homeowner types, each with specific income, expenses, savings, maximum mortgage limits, and preferred house ratings, as explained in Chapter 3.2.1 It's important to note that houses acquired by players with pre-existing private flood measures are categorized as "purchased" private measures. This is because players intentionally chose these houses, likely influenced by the presence of existing flood measures. This classification applies to all data related to private flood measure implementation.

4.2.1 Private Implementation of Flooding Measures

We expect from the PMT (*see* Chapter 2.3.2) that differences in welfare (homeowner types) influences taking private measures. To test this, we analyse which private measures are taken by different homeowner types. Table 12 shows the number of private flood measure implementations by homeowner type. Sandbags were the most popular choice, purchased 25 times, followed closely by green gardens, bought 23 times. Among the lowest and low average welfare homeowners, sandbags were most preferred (6 and 8 times). Participants with high and very high welfare tend to choose green gardens or raising the ground level (4 times each), both offering protection and satisfaction, with the latter providing more of both. Low and high average welfare homeowner types had the highest frequency of private flood measure purchases, with the low and high welfare types having similar numbers of implementations.

Table 12: Number of private implementations ordered by homeowner type (all games)

	Very low welfare (N=30)*	Low welfare (N=30)*	Low average welfare (N=65)*	High average welfare (N=53)*	High welfare (N=20)*	Very high welfare (N=22)*	Total (N= 220)*
Green garden	2	4	4	5	4	4	23
Automatic steel walls	1	2	4	3	0	0	10
Water pump	3	1	5	2	0	1	12
Self-rising bulkhead	1	3	6	6	1	2	19
Rise ground level	2	1	2	5	4	4	18
Waterproof walls & floors	0	2	2	2	0	3	9
Sandbags	6	1	8	5	3	2	25
Rain barrel	2	3	5	3	3	1	17
Total	17	17	36	31	15	17	133

**N^r is the sample size that considers the number of players times the amount of rounds each player played. Green boxes represent the most bought private measure for each homeowner type. In the totals, the green box represents either the most-bought private measure or the homeowner type with the most implementations.*

4.2.2 Chosen Public Flooding Measure

The theory (Tiebout model) shows that people move to the area that best fits their preferences. To research the preferences for public perception of the different homeowners, we look at the residential areas at the end of the game. Table 13 provides the geographical distribution of participants' residential areas at the end of the game. Participants display a clear preference for areas utilizing either dike (22 times) or nature-based solutions (19 times). Low welfare homeowners lean towards the nature-based solution area, even though it comes at a higher entry-level cost (70k in farmland, 80k in dike area, and 100k in NbS area). High welfare homeowners tend to favour the dike area.

Table 13: Geographical distribution of participants' residential areas in final round (all games)

	Dike	Nature-based Solution	Farmland
Very low welfare (N=7)	2	3	2
Low welfare (N=7)	2	4	1
Low average welfare (N=15)	5	6	4
High average welfare (N=13)	6	4	3
High welfare (N=5)	3	1	1
Very high welfare (N=6)	4	1	1
Total	22 (41,5%)	19 (35,9%)	12 (22,6%)

Green boxes represent for each homeowner type the area that they most resided in. In the totals, the green box represents the area that participants resided in the most.

4.2.3 Effect of the Homeowner Type on the Appraisals

We expect from the PMT (*see* Chapter 2.3.2) that differences in welfare (homeowner types) influences the treat, coping and ownership appraisal. To see whether this is the case, the research will look at the observed in-game appraisals per homeowner type. Table 14 displays the averages of the appraisals categorized by homeowner type and Table 15 displays the tactic, public preferences, average final savings, average spendings on private measures and average spendings on satisfaction. Threat and ownership are overall low, with the highest values referencing to minor damages or inconclusiveness about the protection of the public measure (referencing Chapter 3.3.2, for the treat and ownership statements). Therefore, these values will be compared among the homeowner types to find distinctions. The following can be stated per homeowner type:

- **Very low welfare:** The average observed threat and ownership values for this homeowner type are the highest among all the homeowner types (3,21 and 3,29 respectively), however the coping appraisal is the lowest among the homeowners (5.767). The average amount that is spend for private measures (7.180) is higher than the average spendable income (5,767), which means that these players had to save money in order to buy a private measure. The amount of implementations (17) is low compared to the other homeowner types.
- **Low welfare:** The average observed threat and ownership values for this homeowner type are one of the lowest among the homeowners (1,89 and 1,86 respectively). The spendable income of this group is higher than that of the very low welfare group (15.837). Although this group can buy 5 out of 8 private measures with this spendable income, they cannot buy multiple private measures, keeping their options limited.
- **Low average welfare:** With this type, the average threat and ownership values are of a medium level compared to the other homeowner types (2,11 and 2,37 respectively). This homeowner type has a fairly significant amount of money available per round on average (20.567) and can afford to purchase 7 out of the 8 available measures, albeit not multiple at once. This implies that the coping appraisal is quite high. Additionally, numerous measures were acquired (36), which are mainly the cheaper options among the private measures.
- **High average welfare:** Compared to the other homeowner types this type has medium values for the perceived threat and high values for the ownership appraisal (2,08 and 2,42 respectively). This type also made the second highest amount of private implementations (31). Since this type has the means to acquire all available measures, including multiple ones simultaneously, the coping appraisal is considered to be high. The average expenditure on private measures is higher than all previous mentioned homeowner types. This suggests a tendency among these individuals to opt for more costly measures, which often tend to be more effective. Additionally an elevated acquisition of direct satisfaction, a figure considerably higher than that of other types is observed for this type.
- **High welfare:** This particular type has all three appraisals being notably high in comparison to the other homeowner types (coping=53.790, threat=2,68 and ownership=2,39) . However, this type has the lowest amount of adoption of private measures (15). This is not in line with the general association that argues that higher values of the appraisals lead to more adoption of private measures. On the other hand, the average value of the bought private measures is very high compared to the other homeowner types (20.770). The players of this type did not allocate their spendable income toward the acquisition of direct satisfaction (5 times). Instead, they chose to save a substantial portion of this money, with the goal of accumulating additional

satisfaction at the conclusion of the game (67.333 of savings). While the very high welfare type inherently possess a substantial reserve of funds, the players of the high welfare type have managed to accumulate close to the same amount as the very high welfare type, facilitated by the strategic decision to save.

- **Very high welfare:** Compared to the other homeowner types this type observed the lowest perceived threat in the game (1,75). Moreover, the ownership appraisal values are considered to be of a medium level compared to the other homeowner types (2,39). The amount of implementations is low compared to the other homeowner types, but not the lowest (17). These players predominantly lived in the NbS area, the best protected area, and these players bought the most expensive and thus the most effective measures. Most of these players also decided to invest in directly buying satisfaction (26 times).

Table 14:Average of the appraisals categorized by homeowner type

Homeowner type	Number of private measures bought	Average Spendable income (coping appraisal)[a]	Average flood risk perception (threat appraisal)[b]	Average trust in public measure (ownership appraisal)[c]
Very low welfare (N=7)	17	5.767	3,21	3,29
Low welfare (N=7)	17	15.837	1,89	1,86
Low average welfare (N=15)	36	20.567	2,11	2,37
High average welfare (N=13)	31	41.284	2,08	2,42
High welfare (N=5)	15	53.790	2,68	2,50
Very high welfare (N=6)	17	93.439	1,75	2,39

[a] Unit used for average spendable income is the in-game currency, reflecting the euro.
[b,c] The unit (likert scale questions) used for the threat and ownership appraisals can be found in Chapter 3.3.2.

Table 15: Tactic, public preference, savings, spending and satisfaction ordered by homeowner type

Homeowner type	Reported Post-survey Tactic	Public preference	Average final savings score*	Average spending on private measure	Bought satisfaction
Very low welfare (N=7)	Saving or being safe	NbS	3.000 (N=5)	7.180	6
Low welfare (N=7)	Being safe or all	NbS	19.200 (N=5)	11.540	14
Low average welfare (N=15)	Saving, being safe or all	NbS	23.456 (N=11)	12.000	24
High average welfare (N=13)	Saving or being safe	Dike	36.833 (N=9)	15.790	33
High welfare (N=5)	Being safe or all	Dike	67.333 (N=3)	20.770	5
Very high welfare (N=6)	On all	Dike	87.377 (N=3)	24.540	26

**Only the values of players who have finished the game are included.*

4.2.4 Conclusion Homeowner types

In summary, to partially answer sub-research question 3 and 4, generally sandbags and green gardens are purchased the most. High and low welfare types bought about the same amount of private measures and the average welfare types purchased the most private measures. The high welfare homeowners bought the more expensive and effective measure, like rising the ground level and low welfare homeowners bought the least expensive measures (*see* Table 15) such as sandbags. Low welfare types mostly preferred the dike or NbS area and higher welfare types the dike area. Higher welfare types, as assigned, had a higher coping appraisal compared to the lower welfare types. The high welfare type did not conform to the pattern of the PMT, showing high appraisal levels but a low number of implementations.

4.3 Scenarios

In this subchapter, data on private measure and public measures by scenario is presented. The game was played in either the all information scenario or the limited information scenario, as explained in Chapter 3.2.4 . In short, the all information scenario included private measure effectiveness, while the limited information scenario did not. In Table 16, private flood measure implementation in the all information and limited information scenario games can be seen. A comparison between the limited and all information scenario reveals a significant decrease in the use of self-rising bulkhead (18 vs. 1), automatic steel walls (9 vs. 1), and waterproof walls & floors (6 vs. 3) in the limited information scenario. Furthermore, low average, high and very high welfare homeowners show fewer instances of private implementations in the limited information scenario compared to the all information scenario. Overall, this means that considerably fewer private flood measures were purchased in this scenario (all information=83 and limited information=50).

Table 16: Number of private implementations ordered by homeowner type and scenario

	Verly low welfare		**Low welfare**		**Low average welfare**		**High average welfare**		**High welfare**		**Very high welfare**		**Total**	
*Scenario**	A	L	A	L	A	L	A	L	A	L	A	L	A	L
Green garden	1	1	1	3	2	2	2	3	3	1	3	1	12	11
Automatic steel walls	0	1	2	0	4	0	3	0	0	0	0	0	9	1
Water pump	1	2	1	0	3	2	1	1	0	0	0	1	6	6
Self-rising bulkhead	1	0	3	0	6	0	5	1	1	0	2	0	18	1
Rise ground level	1	1	0	1	2	0	2	3	2	2	3	1	10	8
Waterproof walls & floors	0	0	2	0	1	1	1	1	0	0	2	1	6	3
Sandbags	2	4	1	0	6	2	1	4	2	1	1	1	13	12
Rain barrel	1	1	0	3	3	2	1	2	3	0	1	0	9	8
Total	7	10	10	7	27	9	16	15	11	4	12	5	83	50

**A represents the column of values for the all information scenario and the L represents the column of values for the limited information scenario*

The green boxes represents for each homeowner type the private measure that is implemented the most per scenario. For the totals the green box represents the private measure that is implemented the most or the homeowner type that implemented the most per scenario.

Table 17 shows the geographic distribution of participants' residences in the final round per scenario. In the all information scenario, the distribution closely resembles Table 13. However, in the limited information scenario, there were percentage-wise slightly more participants in the NbS area and fewer in the dike and farmland area compared to both the all information scenario and Table 13, although this difference is minimal.

Table 17: Geographical distribution of participants' residential areas in final round ordered by homeowner type and scenario

	Dike		**Nature-based Solution**		**Farmland**	
*Scenario**	A	L	A	L	A	L
Very low welfare (N=7)	1	1	2	1	1	1
Low welfare (N=7)	1	1	3	1	0	1
Low average welfare (N=15)	3	2	2	4	3	1
High average welfare (N=13)	3	3	2	2	2	1
High welfare (N=5)	2	1	0	1	1	0
Very high welfare (N=6)	3	1	1	0	0	1
Total	13 (43,33%)	9 (39,1%)	10 (33,33%)	9 (39,1%)	7 (23,33%)	5 (21,8%)

**A represents the column of values for the all information scenario and the L represents the column of values for the limited information scenario*
The green boxes represents for each homeowner type the area that they most resided in per scenario. For the total the green box represents the area that participants resided in the most per scenario.

Table 18 presents the average savings amount and the percentage of rounds in which satisfaction is directly purchased for each scenario. The data clearly illustrates that in the limited information scenario, players tend to allocate more funds toward the direct acquisition of satisfaction while also saving more within the game, as compared to players participating in the all information scenario.

Table 18: Average savings and percentage of rounds satisfaction being bought

	All information scenario	**Limited information scenario**
*Percentage of rounds were satisfaction is directly bought**	23,3%	31,3%
Average amount of savings (all rounds combined)	€15.674	€22.983

** Calculated by looking at how many rounds players did not buy satisfaction and how many rounds they did.*

4.3.1 Effect of the Scenarios on the Appraisals

Importantly for the interpretation of the differences between the scenarios, the appraisals will be looked at. Here, the dice numbers rolled for determining flooding and indicating the effectiveness of private measures are important to consider. This is because these influence the threat and coping appraisals, respectively. In Table 19, the data relevant for the appraisals are ordered by scenario. In addition to the difference in the provision of effectiveness information regarding private flood measures, Table 19 indicates that both the threat and ownership appraisals are higher when the limited scenario was played. Although the difference is statistically significant for the threat appraisal, this does not hold for the ownership appraisal. This means that only the perceived threat by players was significantly higher in games with the limited information scenario compared to the game with the all information scenario. Another disparity is the thrown flood probabilities. These were lower in the limited information scenario (9 floods occurred) compared to the all information scenario (34 floods occurred). Lastly, a lower number of private implementations is observed for the limited information scenario compared to the all information scenario.

Table 19: Appraisals related to the scenarios

	Limited information	**All information**
Threat appraisal		
Thrown flood probability	Lower (9 floods)[a]	Higher (34 floods)[b]
Perceived threat	2,41[c]	2,10
Coping appraisal		
Income	Equal[d]	Equal
Effectiveness of private measures	Not known	Known
Ownership appraisal		
Perceived ownership	2,51[e]	2,41
Amount of private implementation	Lower	Higher

[a] Average river dice number of 5,45 and average rain dice number of 4,45.
[b] Average river dice number of 8 and average rain dice number of 5,0625.
[c] Statistically significantly higher than the threat of the all information scenario (T-test, p-value=0.046).
[d] The same distribution of homeowner types was used for the games, thus income differences were the same.
[d] Statistically insignificantly higher than the ownership of the all information scenario (T-test, p-value=0.539).

4.3.2 Conclusion Scenarios

In summary, to partially answer sub-research question 3 and 4, the limited information scenario led to fewer flood measures implemented compared to the all information scenario, with a notable decrease in the use of self-rising bulkheads, automatic steel walls and waterproof walls & floors. In the limited information scenario, there was a slight shift in participant distribution towards the NbS area and away from the dike and farmland area, though this difference was minimal. Additionally, participants in the limited information scenario allocated more funds toward the direct acquisition of satisfaction while also saving more within the game. Higher perceived threat was noted in the limited information scenario despite lower amounts of floods happening. Income and ownership values remained consistent across scenarios.

4.4 Rounds

This subchapter presents data on private flood measures implemented in different rounds. Initially, there were five scheduled rounds for each game session. However, some games extended beyond the allocated time, leading to incomplete rounds. Fortunately, this did not affect the data, as every game managed to complete at least one full round, including the possibility for players to relocate. This ensured that players experienced all game elements and had the opportunity to execute their actions.

Table 20 compiles all games with their respective private implementations. In round 1, most private measures were acquired. Only the self-rising bulkhead and waterproof walls & floors were purchased more in round 3 than in round 1, which is the second-highest round for private implementation. During this round, a climate change event occurred, raising flood risk in the game. To simulate this, the protection levels of public flood measures were reduced.

Table 20: Number of private implementations ordered by rounds (all games)

	Round 1 (7 games)	Round 2 (6 games)	Round 3 (6 games)	Round 4 (5 games)	Round 5 (5 games)
Green garden	8	6	3	4	2
Automatic steel walls	5	2	2	0	1
Water pump	9	2	1	0	0
Self-rising bulkhead	2	7	8	1	1
Rise ground level	9	2	0	6	1
Waterproof walls & floors	2	1	3	1	2
Sandbags	8	1	6	6	4
Rain barrel	7	3	2	4	1
Total	50	24	25	22	12

The green boxes represents in which round a specific private measure was implemented the most. For the total the green box represents the round in which the most private measures were implemented.

4.4.1 Effect of the Rounds on the Appraisals

In Table 21, the values of the appraisal ordered by rounds can be found.

Table 21: Coping, threat and ownership appraisal values ordered by rounds

	Coping appraisal (spendable income)[a]	Threat appraisal (in-game question 1)[b,c]	Ownership appraisal (in-game question 2)[c,d]	Total amount of private implementations
Round 1 (N=53)	35.811	2,44	2,45	50
Round 2 (N=52)	31.969	2,09	2,32	24
Round 3 (N=43)	27.697	2,30	2,68	25
Round 4 (N=36)	33.624	2,19	2,44	22
Round 5 (N=36)	37.296	2,12	2,36	12

[a] *Unit used for average spendable income is the in-game currency, reflecting the euro.*
[c] *Questions are asked after a player had the opportunity to purchase private measures.*
[b,d] *The unit (likert scale questions) used for the threat and ownership appraisals can be found in Chapter 3.3.2.*

In Table 21, it is observed that the perceived threat had its highest values in round 1. Moving on to round 3, we find that it featured the second-highest perception of threat in the game, following round 1. Additionally, one can observe that the ownership appraisal tends to exhibit a consistent pattern across rounds. However, round 3 stands as an exception, as it features the highest recorded ownership appraisal among all the rounds. Lastly, it becomes evident that players had the most money available for private measures in round 1 and round 5. In round 1, available funds were primarily used for purchasing private measures. In round 5, players predominantly opted to either invest in the direct purchase of satisfaction (24 out of 36 players who participated in round 5) or save it for additional satisfaction at the end of the game. Only 7 out of 36 players acquired a private measure in the final round. The players mainly saved their money in round 3, as spendable income is significantly bigger in both round 4 and 5 compared to round 3. In round 3, only 8 out of 43 players purchased satisfaction directly, and although 25 private measures were acquired in this round, the average expenditure on private measures was the lowest among all the rounds (10.580).

4.4.2 Conclusion Rounds

In summary, to partially answer sub-questions 3 and 4, most private measures were acquired in round 1, and the second-highest in round 3. Also, threat, coping, and ownership appraisals were high in round 1, while threat and ownership appraisals were high in round 3.

4.5 Flood Experience

In this subchapter, the examination revolves around the adoption of private measures, taking into account the presence or absence of previous flood events. This is done as we expect from the PMT (*see* Chapter 2.3.2) that differences in flood experience influences taking private measures. To test this, the rounds are categorized into two groups: "rounds with flood experience" and "rounds without flood experience" (these include round 1 where flood events have not yet transpired). To comprehend the dynamics, the analysis relies on percentages. Specifically, it includes an examination of 73 rounds with flood experience and 147 rounds without flood experience across all games. However, in some instances of flood experience, 8 data rows lack information for the subsequent round due to player exits. To address this, an assumption is made, and 65 data rows are considered for rounds with flood experience. The detailed results are presented in Table 22.

More private implementations were found in rounds without flood experience (46+50) compared to those with experience (37). To understand this further, the percentages are considered. Including round 1, a slightly higher percentage took measures without flood experience (56.9% vs. 65.3%), with a minimal 8.4% difference. Excluding round 1, the percentage of measures with flood experience surpasses those without (56.9% vs. 48.9%), albeit with a slight 8% difference. Notably, following a previous round's flood, players tend to favour cost-effective, one-time solutions like sandbags over pricier options like ground elevation or a green garden.

Table 22: Number of private implementations considering flood or no flood in the previous round

	Implementations with flood experience		**Implementations no flood experience**		
	Implementations	*Percentage of total amount of instances**	*Implementations excluding round 1*	*Implementations in first round*	*Percentage of total amount of instances***
Green garden	4	6,2%	11	8	12,9%
Automatic steel walls	3	4,6%	2	5	4,8%
Water pump	1	1,5%	2	9	7,5%
Self-rising bulkhead	7	10,8%	9	2	7,5%
Rise ground level	3	4,6%	7	9	10,9%
Waterproof walls & floors	3	4,6%	4	2	4,1%
Sandbags	13	20,0%	4	8	8,2%
Rain barrel	3	4,6%	7	7	9,5%
Total	37	56,9%	46 (48,9%)***	50	65,3%

** Percentage is calculated by dividing the number of implementations by number of data rows (65) times 100.*
*** Percentage is calculated by dividing the number of implementations by number of data rows (147) times 100.*
**** Percentage is calculated by dividing the number of implementations by number of data rows (94) times 100.*

4.5.1 Effect of the Flood Experience on the Threat and Ownership Appraisals

To evaluate the potential impact of flood experience on the average threat and ownership appraisals, an Independent T-test is conducted. Table 23 presents the mean values of the threat and ownership appraisals two groups: rounds following flood experience and rounds following no flood experience (including round 1). The results of the T-test indicate that there is no statistically significant difference between these means. This finding suggests that the threat and ownership appraisals remain relatively consistent, regardless of whether participants have experienced a flood or not.

Table 23: Flood risk perception of players after flood or no flood in the previous round

	Mean appraisal, round after flood experience	**Mean appraisal, round after no flood experience**	**p-value T-test***
Threat appraisal	2,23	2,25	0.916
Ownership appraisal	2,48	2,43	0.752

* H_a $\mu 1 \neq \mu 2$

4.5.2 Conclusion Flood Experience

To recap and to partially answer sub-question 3 and 4 no substantial difference between having or not having flood experience is observed in the adoption rate of private implementations. Additionally, it is observed that the threat and ownership appraisal were consistent no matter if the participants had flood experience or not. However, participants with flood experience tended to favour cost-effective, one-time solutions like sandbags over pricier options like ground elevation or a green garden.

4.6 Relocation

In this subchapter, data regarding game-related house relocation is presented. Players could move to a different house starting from round 2 to enhance their winning chances. They could select any available house based on their financial capacity, including those in their current area.

Table 24 presents the destinations players mostly relocated to. Individuals who initially resided in the farmland area moved four times to the NbS area and 4 times to the dike area. No one left the nature-based solution area, which also happened to be the destination where participants relocated the most.

Table 24: Origin and destination of relocation events

Destination → Origin ↓	**Nature-based solutions**	**Dike**	**Farmland**	**Total**
Nature-based solutions	0x	0x	0x	0x
Dike	3x	1x	1x	5x
Farmland	4x	4x	0x	8x
Total	7x	5x	1x	13x

While the game was being played, the game facilitator recorded the specific reasons for each player's decision to relocate. These reasons were categorized into six distinct factors, outlined in Table 25. The primary motivation for a player to relocate stemmed from the desire to reside in an area with better flood protection. Furthermore, one player was influenced by the visual representations employed in the game to depict specific houses. No specific gameplay element was linked to this aspect, yet it managed to impact a player's decision to relocate.

Table 25: Motivation of players to relocate in the game

Motivation	**Times mentioned by players that relocated**
1. Player wants to increase satisfaction.	4x
2. Player had enough savings to relocate.	2x
3. Player considers the chance of flooding too high in the previous area and therefore wants to relocate to a better protected area.	6x
4. The house the player bought had already implemented private measures.	3x
5. The player had too high expenses and wanted to live to be able to afford other things (increase savings, implement measures or increase satisfaction directly).	4x
6. Attracted by visualization (figure) of the house	1x

4.6.1 Effect of Relocation on the Appraisals

In order to assess whether there exists a statistically significant disparity between players' threat and ownership appraisals when they opt for relocation, a paired t-test is conducted. This examination focused on comparing the threat and ownership values from the round preceding a player's move to the round following the player's move. The results of this analysis are presented in Table 26. These findings indicate that players have a statistically significant lower perceived threat and ownership after relocation.

Table 26:Threat and ownership differences between before and after relocation

	Mean before	Mean after	Paired T-test*
Threat appraisal	2.91	1.82	0.016**
Ownership appraisal	3.09	2.00	0.030**

With the mean values the alternative hypothesis for the paired T-tests is formulated. Example threat appraisal: H_a μ before relocation – after relocation < 0
*** A significant difference is observed (p < 0.05).*

To examine whether there are statistically significant differences in the threat appraisal and ownership appraisal across different areas, an ANOVA test is conducted. The results of this analysis revealed a p-value of less than 0.001 for both the threat and ownership appraisal. These low p-values signify that there are statistically significant differences in the means of the areas for both appraisals. To pinpoint these significant differences among the areas for the threat and ownership appraisal, a post-hoc test for pairwise comparisons is conducted. Given the utilization of Welch's ANOVA, the Games-Howell multiple comparisons method is applied for this analysis. In Table 27 the results are shown.

Table 27: Games-Howell Post-Hoc Tests for threat appraisal (Q1) and ownership appraisal (Q2) concerning areas

	Mean	NbS	Dike	Farmland
Threat appraisal (question 1)				
NbS	1.95	-	0.999	< .001*
Dike	1.96		-	< .001*
Farmland	3.16			-
Ownership appraisal (question 2)				
NbS	2.11	-	0.595	< .001*
Dike	2.24		-	< .001*
Farmland	3.29			-

** A significant difference is observed (p < 0.05).*

Based on the findings presented in Table 27, it is evident that players in the NbS and dike area perceive significantly lower levels of threat compared to players in the farmland area. Furthermore, there is no statistically significant difference in perceived threat between players in the NbS and the dike area themselves. Likewise, in terms of ownership, a similar pattern emerges. Players in the NbS and dike area report significantly less responsibility than players in the farmland area, while there is no statistically significant difference in perceived responsibility among players within the NbS and dike area.

4.6.2 Conclusion Relocation

In summary, to partially answer sub-question 3 and 4 the majority of relocations occurred from the farmland area to either the dike or NbS area. The primary motivation for relocating was the need for improved flood protection. Moreover, participants who moved from farmland to either the dike or NbS area had significantly higher threat and ownership values before their relocation, in contrast to their values after the move.

4.7 Post-Survey and Debriefing

This subchapter discusses the acquired data from the post-survey and relates it to the game data. Table 28 displays responses to the preferred private flooding measure in the game. The first column shows the frequency of each measure mentioned, while the second column ranks them accordingly. This ranking can be compared with the observed ranking within the game. "Green garden" is the most preferred choice, with "rain barrel" and "raising ground level" rising in post-game rankings. Conversely, "waterproof walls & floors" and "sandbags" decline significantly in preference and are mentioned less. Notably, although raising the ground level costs the most in the game, it might still be considered infeasible for realistic homes in the Netherlands. Many participants indicated that the cost seemed somewhat unrealistically low for homes in the Netherlands. While the prices are based on realistic values, the minimum feasible cost was chosen for this measure to enhance gameplayability.

In the debriefing multiple players declared that they chose private measures which were more familiar to them (for both the limited and all information scenario). These were in general the sandbag and the green garden option. The self-rising bulkhead was less recognized. Moreover, comments were frequently made about the green garden, highlighting its water absorption and aesthetic benefits, especially in urban areas with limited greenery. Participants additionally noted the rain barrel and its environmentally friendly nature of being able to reuse water.

Table 28: Preferences for private flood implementations post and in-game

	Number of times listed as preferred	Ranking post-game preferences	Ranking in-game preferences
Green garden	26	1st	2nd
Automatic steel walls	10	4th	7th
Water pump	8	5th	6th
Self-rising bulkhead	12	3rd	3rd
Rise ground level	18	2nd	4th
Waterproof walls & floors	7	6th	8th
Sandbags	10	4th	1st
Rain barrel	18	2nd	5th

When examining the preference for the public measure (see Table 29), it can be observed that these preferences are aligned with the in-game preferences. The dike is most frequently indicated as the favourite, followed by the NbS area in second place.The farmland area is least desired and ranks last. Participants indicated that the preference for the dike area primarily stems from familiarity with the measure. However, they acknowledged that NbS is an environmentally friendly option that enhances quality of life. Nonetheless, participants also noted reduced confidence in NbS during severe river flooding scenarios, with the greater trust placed in an area protected by a dike or other “grey” engineering schemes (post-survey & debriefing).

Table 29:Preferences for public flood measures post and in-game

	Dike	**Nature-based solutions**	**Farmland**
Position 1	27x	17x	3x
Position 2	14x	28x	5x
Position 3	6x	2x	39x
In-game ranking	1st	2nd	3rd

4.7.1 Conclusion Post-survey and Debriefing

In summary, to partially answer sub-question 3 and 4, post-game, the most preferred private flood measures were the green garden, rain barrel, and raising ground level. Players indicated familiarity, aesthetic benefits, and environmental friendliness as factors influencing their choices. The dike area emerged as the most preferred, attributed to familiarity. Players also expressed reduced confidence in NbS areas during severe river flooding scenarios.

5. Discussion

In this chapter, the analysis results will be explained and interpreted. A detailed interpretation of the results will be given, structured the same as Chapter 4. Beginning with a reflection on the translation between in-game activities to real world circumstances, followed by the interpretation of the profiles and consequently with homeowner types, scenarios, rounds, flood experience, relocation and the post-survey and debriefing. To finalize the chapter, a brief recap is provided of the key findings of the research.

5.1 Interpretation of the Results

5.1.1 From In-Game Activities to Reality

To translate between the observations made within the serious game and the conclusions drawn for real-world applications, a reflection is conducted to assess the transition from in-game activities to real-life scenarios.

This evaluation begins by verifying the game's credibility in mirroring real-world situations, achieved by incorporating the key variables outlined in Chapter 2 directly into the serious game. By integrating the fundamental principles of the PMT and the Tiebout model into the serious game, we aimed to capture participants' preferences and motivations more accurately, thus ensuring a closer alignment with real-world circumstances. This is also reflected in the different scenarios played, where the limited information scenario highlights the current real world situation by providing no information on the risk reduction effect of private flood measures. Additionally, the surveys followed close alignment with the game and previous questions used in research concerning profiling (Franceschinis et al., 2021), ensuring relevant and appropriate data collection.

Due to the fact the serious game closely resembled real world circumstances as much as possible and the participants of the serious game were either present (municipality) or future homeowners (students), the identified profiling of these participants and the distinctions in their in-game actions based on these profiles can be associated with real-life homeowners. Additionally, as the homeowner types used in the game mirror the distribution in financial circumstances in the Netherlands and these categories are constructed using actual income and expenditure figures, representing an aggregate over a span of 3 to 5 years, in-game actions based on these homeowner types can be associated with real-life homeowners.

Nonetheless, despite the serious game's attempt to emulate real-world situations, it inherently remains a simplification of reality. Consequently, this research does not encompass all concepts of human behaviour, leaving certain concepts omitted or unmeasured. Notably, intangible factors like psychological stress, wishful thinking, denial, and fatalism were omitted from consideration. Consequently, it is conceivable that certain conclusions pertaining to these factors may not encompass the full spectrum of the narrative.

5.1.2 Profiles

The data indicates the existence of three distinct attitude profiles within the population regarding flood-related matters: “Cautious Optimists”, ”Informed Preparers”, and “Cautious Realists”. With respect to “Informed Preparers”:

- “Cautious Optimists” have limited experience and knowledge about flooding but maintain an optimistic view regarding the likelihood of future floods and damage.
- “Informed Preparers” possess knowledge about flood-related topics, have encountered flooding, and believe in the high likelihood of future floods and damage.
- “Cautious Realists”, similar to “Cautious Optimists”, lack experience and knowledge but hold a more pessimistic outlook regarding future floods and damage.

The categorization of the profiles differs from that used by Franceschinis et al. (2021). This discrepancy arises from variations in the perceived effectiveness regarding flood protection of the classes between this study and theirs. In this research, no statistically significant difference between the profiles was observed regarding perceived effectiveness. However, in the research of Franceschinis et al. (2021), a difference between classes was observed concerning trust in structural flood protection, which included the parameter effectiveness of the flood protection. In Franceschinis et al. research, the class with flood experience and a pessimistic view that floods will happen in the future is considered to have low trust in structural flood protection. Given these dissimilarities, a different labelling for the groups in this research was found to be more fitting. However, it's worth noting in Franceschinis et al.'s second Latent Class Cluster model, the group with no knowledge tends to exhibit lower trust in flood protection when compared to the group with knowledge. A similar pattern emerges in this study, although it does not reach statistical significance. Specifically, the "Cautious realists" profile, which possesses minimal knowledge, tends to have the lowest perceived effectiveness compared to the other profiles. In contrast, the "Informed Preparers" profile, characterized by having knowledge, tends to have the highest perceived effectiveness. This observation suggests a strong influence of knowledge on an individual's trust and perceived effectiveness concerning both public and private flood protection measures. Importantly, however, the research of Franceschinis et al. (2021) identified that this difference in knowledge was also accompanied with flood experience differences and different living areas, which perhaps could also explain this observation.

Private Flood Implementations

Data on private measures, ordered by profiles, suggests that those with limited acquiring of knowledge, limited flood experience and who anticipate the worst (cautious realists) tend to invest the most in private protections. Conversely, those with limited acquiring of knowledge and limited flood experience but an optimistic outlook (cautious optimists) are the least inclined to invest in private protection. The key distinction between these profiles lies in their outlook on future floods, with a positive perspective leading to less private implementation. This is similar to the research of Bodoque et al. (2016) and Martens et al. (2009), who found that their identified groups of citizens significantly differed in terms of risk perception and awareness. However, increasing knowledge, especially about climate change, which indicates more frequent and severe floods, could perhaps shift this perspective. This is supported by the data, showing that individuals with more acquiring of knowledge, more flood experience, and an expectation of future floods (informed preparers) recognize the need for additional private flood protection, as evidenced by the second-highest implementation rate.

This reasoning for why cautious optimists buy the least amount of private measures can also be reflected by using the PMT framework. Based on the data, this particular profile exhibited the lowest perceived threat among all profiles, resulting in a reduced inclination toward the protective response route. This lower threat perception may be attributed to their optimistic perspective and limited acquisition of knowledge about flooding. In contrast, cautious realists and informed preparers both reported similar higher levels of perceived threat compared to cautious optimists. These profiles tend to have a more pessimistic outlook, with informed preparers acquiring more knowledge and having more experience with flooding. Interestingly, cautious realists had the highest level of private implementation (higher inclination towards the protective response route), suggesting that a heightened perceived threat is associated with increased implementation. However, in cases where there is limited acquiring of knowledge and limited flood experience, there might be an overestimation of the necessary amount of private measures. This is evident in the fact that informed preparers, exhibiting the same perceived threat level as cautious realists, despite acquiring more knowledge and having more flood experience, implemented fewer private measures.

Overall, these findings further advance our understanding of the relationship between worry and climate change beliefs on household adaptations, which the study of Noll et al. (2022) first highlighted.

5.1.3 Homeowner Types

The data suggests that primarily medium-welfare homeowner types make the most purchases of private measures. Additionally, the data suggests that higher welfare homeowners are more likely to purchase the more expensive and more satisfaction increasing private measures. This is as expected from the PMT as these homeowners have the financial capabilities (coping ability) to do so. In contrast, low welfare homeowners don’t have the financial capabilities to purchase such measures but opt to purchase affordable but effective measures such as sandbags. In any case, the adoption of private measures was about the same for both types. This suggests that the coping appraisal (financial capabilities), affects the type of measure being bought, but does not increase the inclination towards the protective route. It is believed that higher welfare homeowners did not want to buy more private measures as the perceived threat and ownership became lower due to the purchase of highly effective and more expensive measures. It's conceivable that these individuals perceived themselves as sufficiently shielded due to the implementation of these measures. This presumption is substantiated by the elevated acquisition of direct satisfaction, a figure considerably higher than that of other types.

Concerning the high welfare homeowner type, they did not conform to the expected pattern of the PMT. Despite all three appraisals being notably high in comparison to the other homeowner types, this hasn't translated into higher adoption of private measures compared to the other homeowner types. To understand this, it is necessary to look at the average spending towards private measures and their savings amount. Here, it's apparent that their spending is exceptionally elevated, suggesting the acquisition of particularly effective measures. This implies that players might have felt adequately safeguarded due to the acquisition of these costly measures. Furthermore, these people did not allocate their remaining funds toward the acquisition of direct satisfaction. Instead, they chose to preserve a substantial portion of this money, with the goal of accumulating additional satisfaction at the end of the game. All five players, in comparison to other homeowner types, have managed to preserve a noteworthy sum of money by the game's conclusion. While the very high welfare type inherently possesses a substantial reserve of funds, this particular type has managed to accumulate close to the same amount as the very high welfare type, facilitated by the strategic decision to save. With all five players, all adhering to this saving strategy, the result indicates a preference towards saving rather than the implementation of private measures. This is in line with the research of Ezekiel (1942), who found that people save more than they invest.

Regarding the preferred public flood measure, the data indicates that individuals with lower welfare tend to reside in the game's most costly yet well-protected areas. Conversely, those with higher welfare profiles tend to opt for middle-of-the-road options, avoiding both the most and least expensive and the most and least protective areas. This highlights a significant trend in participants' selections, influenced by their homeowner type. Participants with lower incomes seem inclined to live in areas with higher protection, even if it means paying more for it. The potential cost savings from not moving to a better-protected area do not seem to justify the expense of private protection. Conversely, individuals with higher incomes tend to settle in less protected areas compared to the nature-based solution area. They may allocate the money saved by choosing a less secure area to invest in private protection measures or enhance their overall satisfaction in other ways. Furthermore, what stands out about the data concerning preferred residency area is that the same homeowner types can mostly be found in the same residency area, which is in line with the statement made by Alonso (1964), which stated that residential areas can become differentiated based on factors such as income, ethnicity and other demographic characteristics of individuals. Overall, the data suggests that "grey solutions" like dikes are the most favoured public choice. This preference may stem from participants' familiarity with the measure and their expressed lack of confidence in NbS (the overall better-protected area) during severe river flooding scenarios.

5.1.4 Scenarios

Given the evident disparity in private implementations between the all information scenario (83 implementations) and the limited information scenario (50 implementations), and considering that the simulated probabilities of flooding were higher in the all information scenario compared to the limited information scenario, it is projected by the PMT that the values of both threat and ownership appraisal would exhibit lower readings in the limited information scenario in contrast to the all information scenario. However, the limited information scenario had statistically significant higher threat appraisal values and the ownership appraisal remained the same compared to the all information scenario (average ownership was higher but not statistically significant). This indicates that the difference in scenarios (the provision of information regarding the effectiveness of private measures), has a notable influence on the coping appraisal, leading to a reduced inclination toward a protective response. This influence can be elucidated by examining the coping appraisal question: "Can I take effective action that is affordable?" In this context, the absence of information regarding effectiveness raises doubts about one's ability to take effective action, consequently diminishing coping ability. Furthermore, despite fewer floods occurring, a heightened perception of threat was observed in the limited information scenario. This suggests that the provision of information concerning the effectiveness of a private measure heightened the perceived threat, but decreased the coping ability. This indicates, as the framework of PMT highlights, that the factors influencing one appraisal are also interacting with the other appraisals. Moreover, another perspective of the lower implementation of private measures in the limited information scenario could be that players were inclined to prioritize increasing their satisfaction with certainty. Since the protection values were unknown, players were more likely to opt for choices that guaranteed immediate satisfaction rather than investing in protection that would shield them from potential costs and satisfaction losses. Ultimately, these findings align with the conclusions of Suijkens (2022), whose research asserted that providing more information about the relative risk reduction effect of private measures leads to increased adoption of private flood protection measures.

Examining the data regarding private preferences across scenarios, it's evident that self-rising bulkheads, automatic walls, and waterproof walls and floors are less frequently chosen in the limited information scenario but have significantly higher adoption rates in the all information scenario. The limited adoption of these measures in the limited information scenario may be attributed to their unfamiliarity. In this scenario, participants had access only to images and text descriptions of the measures without specific data on their effectiveness. Consequently, participants had to make assumptions based on these descriptions, images and their own experience with these measures regarding how well these private measures protected against floods relative to their costs. The results suggest a negative outcome for these measures, implying that players might have thought other measures were more cost-effective options to enhance their chances of winning the game. This preference is further supported by in-game discussions where the self-rising bulkhead option was considered unfamiliar. Additionally, two of these private measures do not provide any satisfaction, which contradicts the game's ultimate goal of increasing satisfaction. Analysing the waterproof walls and floors measure, it falls into the category of more expensive options. Players are likely to compare it with alternative choices like raising the ground level and having a green garden, which offer greater satisfaction. This comparison likely resulted in fewer purchases of waterproof walls and floors. Conversely, in the all information scenario, specific protection values were provided, eliminating the need for assumptions. In the game, the self-rising bulkhead offered the most cost-effective permanent river protection, which likely explains its significantly higher adoption in this scenario.

Regarding public flood measure preferences, the data slightly indicates that individuals lacking information about the effectiveness of private measures were more inclined to reside in the best-protected area compared to those with this knowledge. This suggests that in the absence of knowledge about private measure protection levels, individuals needed to place greater trust in the public measure to avoid flooding. Consequently, they opted for safety and were more likely to choose the best-protected area

5.1.5 Rounds

The data reveals that the majority of private measures were acquired during the initial opportunity to purchase them, even before the possibility of a flood event. This trend may be attributed to the central theme of flooding in the game. Since players were introduced to the game without prior experience of the extent of flood probabilities, their perceived anticipation of flood risk might have been heightened in the first round, prompting a greater demand for private measures as a precautionary safety measure. This observation suggests that players may have overestimated the risk of flooding, resulting in the purchase of multiple measures. This suspicion is further supported by the fact that threat values were at their highest in the first round and ownership and coping values were one of the highest in the first round. As these threat and ownership assessments were made after private measure purchases, it's plausible that the actual values in round 1 of these appraisals were even higher. Moreover, although not explicitly mentioned in the game instructions or debriefing, players might have believed that acquiring measures would improve their chances of winning the game. Another possibility is that players aimed to minimize their flood risk as quickly as possible, even when the flood risk was low in the initial rounds. This strategy would eliminate the need for additional purchases in later rounds if they chose not to move or did not perceive the increasing flood risk in subsequent rounds as a significant concern. Collectively, these observations suggests that game design has influenced the in-game behaviour in the first round and therefore the first round actions may not be representative for real world behaviour.

However, the data does imply a correlation between the increase in flood probabilities and a higher number of private measures being purchased. Notably, in round 3, flood probabilities for river and rain flooding were elevated due to reductions in the protection levels of public measures. Interestingly, the second-highest number of private measures was acquired in round 3. This pattern suggests that as flood probabilities rise, there is an increased tendency for individuals to adopt private flood protection measures. This observation gains further support from the elevated threat and ownership values observed in round 3 compared to the other rounds. Following the PMT, the perception of threat increased as a result of the heightened flood risk. Concurrently, the evaluation of ownership values rose because this heightened flood risk was achieved by decreasing the protection levels of public measures. As the ownership values are acquired by measuring the trust in public measures these values increase.

5.1.6 Flood experience

The findings regarding the impact of flood experience on the amount of private implementation indicate that, in general, people do not significantly bear in mind whether a flood has occurred in the past when considering private implementation measures. Additionally, threat and ownership values were considered to be the same with or without flood experience. However, it is noteworthy that when individuals did have past flood experiences, there was a preference for more familiar, one-off and cost-effective private solutions. This suggests that although the amount of ownership and risk perception are the same, flood experience influences the choice of type of private measure, aligning with the framework of PMT which includes flood experience as a factor which impacts the protective route response. This builds on the research conducted by Venkataramanan et al. (2020), which suggests that prior flood experiences can influence attitudes and motivations related to private implementation.

5.1.7 Relocation

The data regarding relocation suggests that people place a significant value on the area's inherent protection and, as a result, relocate to better protected areas if this is deemed insufficient. When people moved from an area with lower flood protection to an area with higher flood protection, threat and ownership values were significantly higher in the less protected area. This emphasises that the perceived threat and the ownership to do something about this threat might have influenced the relocation of multiple people. Additionally, it emphasizes that the information regarding the effectiveness of the public measure has a significant influence on the choice of public measure.

When looking at the reasoning behind moving, multiple reasons indirectly relate to either increasing satisfaction or seeking extra flood protection. All in all, the primary reason for a player's decision to relocate hinged on the level of protection an area provided, which follows the assumption of the Tiebout model that individuals choose to live in communities that provide the level of public goods and services they desire, in this case, the protection level of the area.

5.1.8 Post-Survey and Debriefing

From the debriefing and post-game survey several measures with environmentally conscious elements gained prominence in preferences post-game. The rain barrel and the green garden measures, which contribute to water reuse and aesthetic appeal, were particularly more intriguing to participants. This suggests the importance of personal or societal benefits of private flood measures besides flood protection and could be seen as an additional motivator for private implementation besides the factors in the PMT framework.

While rising the ground level was also highly favoured in the post-survey results, this inclination may have stemmed from the fact that the question of the survey pertained to in-game preferences. This measure provided substantial in-game flood protection and satisfaction. Despite being the priciest in-game option, the cost appeared unrealistically low for real-world Dutch homes. Given the in-game preferences were asked in the survey, post-game inclinations towards this measure persisted. However, given that many participants found these prices unrealistically low, the post-survey preference likely differs from what is the case.

5.2 Conclusion of the Discussion

In summary, the study reveals important insights into flood-related decision-making. We identified three attitude profiles among participants and found that knowledge and outlook influence private measure adoption. Homeowner types played a significant role in the adoption of private measures, with medium-welfare homeowners making the most purchases, while higher-welfare homeowners invested in more expensive options. The provision of information regarding the effectiveness of private measures also influences private measure adoption, with no information available negatively affecting the perceived threat and coping ability of homeowners and thus decreasing the adoption rate of private implementations. Flood experience impacts the choice of private measures, while relocation decisions are driven by perceived protection levels. Post-game preferences highlight the importance of environmentally conscious elements. These findings offer valuable guidance for flood risk management and communication strategies.

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6. Conclusion & Recommendations

First, in this concluding chapter, the research findings will be summarized, aligning them with the research objectives and questions, which will be restated. Subsequently, the value and contributions of these findings to the field of study will be highlighted. Finally, the chapter will critically assess the study's limitations and propose opportunities for future research, providing a comprehensive wrap-up of the research journey and its implications.

The primary aim of this research was to acquire a comprehensive understanding of homeowners' preferences regarding public and private flooding measures. Furthermore, the research aimed to uncover the motivations behind homeowners' decisions to take specific actions or abstain from taking action (using PMT). These actions included the adoption of private flood protection measures and the selection of residency locations in relation to the existing public flood protection measures that were already in place. As this research segmented homeowners based on their income levels and additionally categorized them into different profiles, each reflecting a unique attitude towards flood-related topics, insights concerning preferences towards private and public flood protection precisely tailored to homeowner types and profiles are aimed to be found. The main research question and sub-questions stated:

Main research question:

What are the profiles of homeowners regarding attitudes towards flooding and what are homeowners preferences and motivations towards public and private flood protection measures for floods?

Sub-questions:

1. *What are the key concepts that drive the behaviour of homeowners in relation to their residency location, flood risk and the adoption of private flood protection measures?*
2. *Which profiles can be identified with regard to attitudes towards flooding and what differences can be identified between profiles regarding private implementation?*
3. *How do in-game choices for public and private flood protection vary among homeowner types, evolve in response to in-game flood experience, and relate to players' preferences?*
4. *What in-game strategies motivated the homeowner types to take protective measures and relocate?*

To be able to answer the main research question, sub-question 1 was formulated to understand the key concepts behind the behaviour of homeowners. This particular sub-question has been addressed in Chapter 2, with the formulation of key variables.

Subject to sub-question 2, the data indicates the existence of three distinct attitude profiles within the population regarding flood-related matters: “Cautious Optimists”, ”Informed Preparers”, and “Cautious Realists”. With respect to “Informed Preparers”:

- “Cautious Optimists” have limited experience and knowledge about flooding but maintain an optimistic view regarding the likelihood of future floods and damage.
- “Informed Preparers” possess knowledge about flood-related topics, have encountered flooding, and believe in the high likelihood of future floods and damage.

- “Cautious Realists”, similar to “Cautious Optimists”, lack experience and knowledge but hold a more pessimistic outlook regarding future floods and damage.

By profiling homeowners into three distinct attitude profiles this research has shown that people with a positive outlook on future floodings are less inclined to take the private protective response compared to people with a pessimistic outlook. Increasing knowledge, especially about climate change impacting flood probabilities, which indicates more frequent and severe floods, could perhaps shift this outlook by increasing the perceived threat and thus increasing private implementation.

Subject to sub-question 3 and 4, the data indicates that medium-welfare homeowners purchase the most private flood measures. Higher welfare homeowners prefer more expensive and highly effective private measures, while lower welfare homeowners opt for affordable but effective options like sandbags. The adoption of private measures did not increase with higher income, suggesting that the coping appraisal (financial capabilities), affects the type of measure being bought, but does not increase the inclination towards the protective route. Additionally, it was found for high welfare homeowners that there is more preference for saving rather than the implementation of private measures. When considering the provision of effectiveness information regarding private measures, the data suggests that fewer private measures are acquired when no information is available about the effectiveness of these measures, negatively affecting the perceived threat and coping ability of homeowners. This also highlights why self-rising bulkheads, automatic walls, and waterproof walls and floors were less popular when no information was given, as unfamiliarity caused less adoption. In general, homeowners were motivated to implement private measures when they simultaneously perceived high levels of threat, possessed coping abilities, and took ownership of the risk.

Regarding public measures, the data indicates that areas with dike infrastructure are the most preferred, closely followed by areas with a Nature-based Solution (NbS). High-welfare homeowners more often opt for areas with “grey” solutions, while low welfare homeowners tend to favour NbS areas. Regarding flood experience, limited influence on the amount of private implementation was found, but individuals who had past flood experiences showed a preference for more familiar and cost-effective private solutions. Relocation decisions were influenced by the perceived threat and the level of protection in an area. Post-game preferences highlighted environmentally conscious measures like rain barrels and green gardens, suggesting additional personal and societal motivators for private implementation beyond flood protection.

Relating this to the real-world: there is a general preference for private measures that offer environmental benefits, personal advantages such as aesthetics, and societal benefits. Interestingly, individuals with higher financial means tend to invest in more expensive and effective measures but choose to live in areas protected by "grey" solutions, which offer less pluvial flood protection compared to Nature-based Solutions (NbS). Conversely, those with limited financial resources choose less expensive but cost-effective measures and prioritize residing in the best-protected areas, often protected by NbS. Furthermore, the familiarity and cost-effectiveness of flood protection measures significantly influence homeowners' preferences for public or private options. For example, “grey” solutions are favoured due to their familiarity, while there is less trust in NbS regarding river flood protection.

6.1 Practical Recommendations

Practical applications to apply the research findings into the real world could be the improvement of flood management and communication strategies regarding private flood measures. This research highlights that the present strategy of increasing awareness of flood risk among the public (Suijkens, 2022) is not sufficient enough to increase private flood implementation. In order to increase the acquisition rate of private implementation this research suggests to simultaneously include factors such as the risk reduction effect of measures, personal and societal benefits of measures and general private flood measure knowledge in the communication strategies. This research suggests that the combination of these factors, including the strategy of increasing awareness can increase the adoption rate of private flood measures compared to only focussing on one factor at the time. This increase in adoption can be attributed to several factors. Firstly, homeowners are now informed about the risk reduction effect associated with private measures, which enhances their ability to cope with flood risks. Secondly, the ongoing effort to raise awareness about flood risks through education on climate change and its impact on flood probabilities is likely to heighten homeowners' perception of the threats posed by floods. Although some may argue that this heightened perception of threat might cause unnecessary fear, scientific evidence supports the fact that climate change is indeed increasing the probability of floods in the coming years. Therefore, fostering an elevated sense of threat among individuals is not only warranted but crucial for the safety of homeowners. Thirdly, actively promoting private flood protection measures and their personal and societal advantages can increase homeowners' familiarity with these options and motivate them to invest in such measures. Ultimately, the combination of these three approaches in new communication strategies can heighten the adoption rate of private implementation.

Another practical application could involve tackling the found disparity between high-income homeowners, who can afford costly and highly efficient measures, and low-income homeowners, who are limited to less expensive and less effective options due to budget constraints. Implementing approaches such as subsidies or collaborative initiatives aimed at providing affordable access to these more effective solutions for low-income homeowners has the potential to address and rectify this inequality.

Lastly, by discussing and taking into account, factors that extend beyond the used PMT framework such as cost-effectiveness, familiarity, knowledge, outlook on future floods and personal and societal benefits in future scientific research a better understanding of the reasoning behind human behaviour regarding public and private flood protection can be established.

6.2 Limitations

While this research has provided valuable insights into the behaviour of homeowners regarding preferences and motivations for public and private flood measures, it is important to acknowledge the limitations that have inevitably shaped the scope and applicability of the findings. Recognizing these limitations is crucial for a comprehensive understanding of the study's context and potential implications. In this section, the discussion will revolve around the key limitations encountered during the course of this research, shedding light on the constraints and boundaries that may have influenced the outcomes and interpretations of the study.

One key observation is through the organization of two distinct game sessions, one hosted at IHE-Delft and the other in the Nissewaard municipality, the research sample encompassed notably different participant groups. The IHE-Delft session primarily drew students with a strong background in flood-related subjects, given their academic interests in water-related fields. In contrast, the municipality session mainly attracted homeowners who held positions as officials but possessed limited specialized knowledge concerning flooding. This divergence in participant profiles raises considerations about the representativeness of the sample, potentially introducing population specification errors, particularly evident in the IHE-Delft session, where the majority were students. Additionally, there is a possibility of selection bias, as those inclined toward serious gaming or with a specific interest in flood-related topics were more likely to participate, especially in the IHE-Delft session. To relate this to the outcome of this research, it might be possible that the data from students of IHE-Delft may not be representative of real homeowners as these students may be more or less inclined to implement private measures due to their interest and experience in flood-related topics.

A second observation is the small sample size of 54, from which it can be asserted that the accuracy and margin of error are not optimal. In Franceschinis et al.'s (2021) research, a total sample size of 420 was employed, and studies have indicated that a minimum sample size of 300 is preferred (Wurpts & Geiser, 2014) for Latent Class Analysis, used in this research. Consequently, it can be inferred that with a larger sample size, better participant classification might have been achievable in this study, resulting in potentially better distinction between the 3 classes found or even identification of more distinct profiles. Identifying more distinct profiles, however, is doubtful, as the study of Franceschinis et al. (2021) also found three classes, with an adequate sample size.

A third observation refers to the used theory and methodology. In this research, intangible factors such as psychological stress, wishful thinking, denial and fatalism were not used in the interpretation of the results. However, these factors could additionally explain which preferences were present among homeowners but were unable to perform due to their limitations set by their social environment and access to resources and knowledge.

Lastly, game design and the interpretations of the results were built on the assumptions made by the Tiebout model and PMT. Public preferences were based on relocation data and adoption rates were explained through the appraisals. Consequently, these assumptions, encompassing elements like complete information, perfect mobility, and the influence of fear, ownership, and coping appeals, as per theory, may not necessarily align with real-world behaviours. As a result, deriving meaningful conclusions from them can be challenging.

6.3 Future Research

To build and enhance the impacts of this research on communication strategies and the acquisition of private measures, future research can focus on the following things:

Enhancing the serious game. This could involve transitioning it into a digital format. This modification would enable participants to direct their focus towards the decision-making process regarding their disposable income. They would no longer need to concern themselves with the origins of this income value. Moreover, it may be beneficial to rephrase the game's questions and present them before introducing private measures. Currently, posing these questions after the acquisition of private measures might have led to an underestimation of perceived threats and ownership assessments. Additionally, it is advisable to market the game solely as an economic decision-making game without introducing concepts such as flood risk and flood protection in promotional materials. This precaution is necessary to prevent players from forming the impression that acquiring private protective measures or residing in the most secure area is a prerequisite for winning the game. To further enrich the gaming experience, one could consider introducing new events and scenarios. These additions could encompass activities like subsidizing private measures or revealing the effectiveness of a measure within a limited information scenario. Such inclusions would allow for the assessment of their impact on adoption rates in simulated environments. Another valuable avenue to explore involves creating a game where players have unrestricted financial capabilities. This approach could yield a more comprehensive understanding of participants' “true” preferences. Lastly, in-game elements, such as house pictures that have no impact on gameplay, should be visually identical to prevent any behavioural discrepancies influenced by these game elements.

If the game transitions into a digital format, it opens up the possibility to introduce a wider array of game mechanics. These mechanics could serve to challenge the assumptions that underlie the current game design. For instance, these assumptions may revolve around concepts like the proposed price fluctuations of houses situated near flood-prone areas or the premiums attached to houses located near environmental amenities, as discussed in Mutlu et al. (2023). One way to explore these assumptions is by initially setting all house prices in the game at the same level and allowing players themselves to influence these prices based on certain factors. These factors could include variables such as proximity to rivers, access to nature amenities, and flood protection measures, which would necessitate the inclusion of ecological, personal, and social benefits within the game's mechanics. By incorporating a housing market mechanism within the game, researchers would gain the ability to observe which specific houses rise in value and which do not. This would provide valuable insights into whether the initial assumptions hold true and which factors significantly influence players' preferences for their ideal residential locations.

Furthermore, broadening the satisfaction aspect of the game could involve introducing specific options designed to boost satisfaction. This approach would offer a more detailed understanding of which specific actions players favour over private implementation thereby potentially informing more effective flood management and communication strategies.

Moreover, future research could address the interpretation issues of not including intangible factors by including these factors and addressing the “true” preferences of homeowners without their limitations. Additionally, although this research addresses the key aspects of the PMT, a more in-depth perspective of the PMT could be gathered by making use of Structural Equation Modelling (SEM). With this technique, indirect and direct effects, such as demographics, flood experience, climate-related beliefs and confidence could be included that affect the preference and adoption of private measures. Additionally, to further build on this research, the assumptions of the PMT and Tiebout model should be tested in real-world simulated situations. In this way, verification of the assumptions of the Tiebout model and PMT can provide better foundation to the given conclusions.

Lastly, in future research, it would be advantageous to direct attention towards actual homeowners currently residing in flood-prone regions as the new sample group. The rationale behind this approach lies in the research's goal of addressing the often underestimated urgency among homeowners in such areas to safeguard themselves against flooding risks. The absence of this specific sample group in the current study suggests that the findings related to motivating factors and preferences regarding both public and private mitigation measures might differ. By incorporating homeowners who currently reside in flood-prone areas as part of the new research, researchers could potentially gain fresh insights. These insights would be instrumental in developing more effective strategies to promote the adoption of private mitigation measures among this specific demographic and decrease the likelihood of potential damages and human loss.

6.4 Closing Remarks

In closing, this chapter has summarized the key findings, emphasized the contributions to the field, and critically evaluated the limitations of the research. The study delved into homeowner preferences regarding flood mitigation measures and the motivations guiding their choices. The outcomes indicated a preference for private measures offering environmental, personal, and societal benefits. Notably, financial means influenced choices, with higher-income individuals opting for effective but expensive private measures, while low-income homeowners prioritized cost-effective options. Furthermore, three distinct attitude profiles – Cautious Optimists, Informed Preparers, and Cautious Realists – are identified. These profiles revealed that those with a positive outlook on future floods are less likely to adopt private protection, but increasing climate change knowledge could shift this perspective. Additionally, this research found by interpreting the results with the Protection Motivation Theory (PMT) framework, that lack of information regarding the risk reduction effect of measures negatively impacts the coping abilities of homeowners and decreases private implementation. Furthermore, this research highlights the importance of simultaneously increasing the threat perception, coping abilities, and ownership of risk in motivating private protection.

To address the urgency of private measure adoption, this research points to various practical recommendations. These include enhancing communication strategies by including information provision about the risk reduction effect of private measures, and thus improving the coping ability of homeowners. Additionally, addressing inequalities between high and low income homeowners by implementing subsidies or collaborative initiatives to make highly efficient flood protection measures more accessible to those with limited budgets. Lastly, in future scientific research, it would be advantageous to consider factors beyond the used PMT framework, such as cost-effectiveness, familiarity, knowledge, outlook on future floods, and personal and societal benefits, to gain a more comprehensive understanding of human behaviour in relation to public and private flood protection.

While our research provided valuable insights, it also faced limitations, including variations within the sample and concerns related to sample size. Moreover, we did not explore intangible factors like psychological stress, wishful thinking, denial, and fatalism in interpreting the results. To gain a deeper understanding of homeowners' motivations, future research could incorporate these factors and employ analytical techniques like Structural Equation Modelling, offering a more comprehensive perspective on the Protection Motivation Theory. Future studies can also build on the insights of this research by enhancing the serious game, exploring digital formats, and targeting actual homeowners in flood-prone areas. These steps can deepen our understanding and improve flood risk management strategies, ultimately mitigating losses and ensuring safer communities.

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Appendix A: Game description

In Figure 13 an overview is provided of the serious game used for this research. The game is consists of 4 stages, where the run-through of the stages is considered to be one round. In total the game has 5 rounds and below each stage will be explained. The goal of the participants is to maximize their satisfaction to win the game.

Stage 1: House Choice

This stage is performed once in round one, after which the following rounds will consist only of stage 2 to 4. In this stage, where the participants are given the role of a homeowner, participants need to choose a house to live in. Homeowners have a certain income, living costs, starting savings and maximum amount of mortgage allowed. Additionally, they have a preference for a certain house rating. With this information and the three different possible communities of living, a participant needs to choose where to live. Houses have certain prices and protection levels and the communities also has different protection levels and taxes, which can influence the decision-making. A homeowner takes on a mortgage in order to buy a house and when all participants have chosen a house to live in, the game will continue to the next stage. A more in-depth description of this stage and what to do as a facilitator and participant can be found in the manual.

Stage 2: Spending Choice

In the first round this stage will follow the house choice. Subsequently, this stage will be the first in the upcoming rounds. In this stage homeowners are instructed to distribution their spendable income into three possible options:

1. **Spending it on private measures**: The homeowners are able to buy private flooding measures to increase their protection against pluvial and fluvial flooding events happening in stage 4 of each round. This protection is in addition to the public flood protection already available in the community that the homeowner lives in.
2. **Spending it on goods and services:** The homeowners have the opportunity to spend money to increase their satisfaction with one or more points. Buying this represents going on vacation, installing solar panels , buying a new tv etc. Additionally, homeowners could opt to not spend their money and save it. At the end of the game, the amount of money in savings will then be transferred to satisfaction points. If a homeowner has taken damage from a flood, they are required to repair their house. The amount of money needed for the repairs depends on the amount of damage taken.
3. **Spending it on relocating:** From the second round onwards, homeowners are allowed to move to a different house, in the same or another community. They will sell their current house either to the bank or another homeowner and pay or take a new mortgage to purchase the new house they want to live in.

After this round, stage 3 will begin. A more in-depth description of stage 2 and what to do as a facilitator and participant can be found in the manual.

Stage 3: Participants Filling in Questions

In this stage, before determining whether a flood occurs in stage 4, participants are asked to fill in two questions regarding their flood risk perception and trust in the public protection in their community. These questions relate to the threat and ownership appraisal and allow the research to determine why participants made certain choices during the game. A more in-depth description of stage 3 and what to do as a facilitator and participant can be found in the manual. After each participant has completed the filling in the questions, it is determined in stage 4 whether a pluvial and/or fluvial flooding will occur.

Stage 4: Flooding Event

In this stage it is determined whether a fluvial and/or pluvial flood happens. If a flood happens the protection level of both the public and private flooding measures implemented are of importance to determine if a homeowner will sustain damage. The events that happen during a fluvial and pluvial flood are different, therefore below they are discussed separately. In the game itself fluvial and pluvial floods are explained as river and rain floods respectively. This is done to make the game as understandable as possible.

1. **Fluvial flood:** To determine whether a fluvial flood will occur in one of the communities, two six-sided dice are rolled by the facilitator. The summed value of these dice determines how much water will flow through the river in that round. Due to different public measures being implemented in the communities, each area can hold different amounts of water. In this game, this number is based on the flood risk probabilities found for the public measures. The more water in the river that the public measure cannot hold back, the more water will flow through the streets of the community. This means each number above the protection of the public measure is a volume of water that enters the area. If the houses in the community are not protected against the overflowing volumes of water with private flood measures, they will suffer damage and lose satisfaction. One point of damage and satisfaction for each volume of water against which the homeowner could not protect itself. Moreover, because the community is then flooded, one satisfaction point is lost and house discounts are applied which can be disadvantageous to homeowners wishing to relocate.
2. **Pluvial flood:** Unlike fluvial floods, pluvial floods are less impactful but are more common. For this reason, in the game, there is only either flooding or no flooding concerning pluvial flooding. To determine if a pluvial flood will occur in one of the communities, a 10-sided dice is rolled by the facilitator. However, this time, there is no flood volume. A community is either flooded by a pluvial flood or not. Similarly, the houses in the community are also either protected or not. If the community is flooded it will lead to house discounts, but no satisfaction will be lost by the homeowners. If, however, a homeowner is not protected against pluvial flooding with a private measure and the community is flooded, the homeowner will lose one satisfaction point and suffer one damage.

Table 30 shows all probabilities of flooding with regard to the public measures. In the game, for fluvial flooding, not the actual probabilities, but the difference in probability between the public measures is considered. This means that, in the game, the probability of flooding in the unprotected area is 5 times higher than in the area with an NbS or "Grey" solution. The actual probabilities are thus not used to emphasis flood risk as utilizing the actual probabilities would substantially limit the occurrence of floods within the game. This means the difference in probability is used in order to support the game mechanics and playability. The actual probabilities will be emphasised while explaining the rules of the game for participants. Two six-sided dice are used to determine if a fluvial flood will happen. This means in order to use the difference in flood probability, NbS and "grey" must have a 5 times less chance to be flooded compared to the farmland area. This results in a combined dice value of 11 or higher to be flooded in the NbS and dike area (yielding a 8,34% chance of being flooded) and a combined dice value of 8 or higher to be flooded in the unprotected area (yielding a 41,67% chance of being flooded).

For pluvial flooding, a single 10-sided die was employed to replicate the actual flood probabilities associated with pluvial flooding. Similarly to the approach taken with fluvial flooding, the decision was made to concentrate on the disparity in probabilities rather than the precise likelihoods. This choice was driven by the same rationale - to underscore flood risks and enhance the functionality and enjoyment of the game. Consequently, the outcome was that the game mirrored the difference in probability rather than the actual probabilities. This was translated into the game dynamics in the following manner: the farmland and NbS area were afforded protection up to a die value of 8, while the dike area had protection up to a die value of 6. This adjustment has the effect of doubling the likelihood of encountering a pluvial flood within the game areas compared to real-world conditions. This corresponds to a 20% chance of flooding in the game's farmland and NbS regions, and a 40% chance in the dike area.

Table 30: Flood probabilities

Area	Chance of river (fluvial) flood	Chance of rain(pluvial) flood
NBS protected	1:250 year	1:10 year
Dike protected	1:250 year	1:5 year
Unprotected (Farmland)	1:50 year	1:10 year

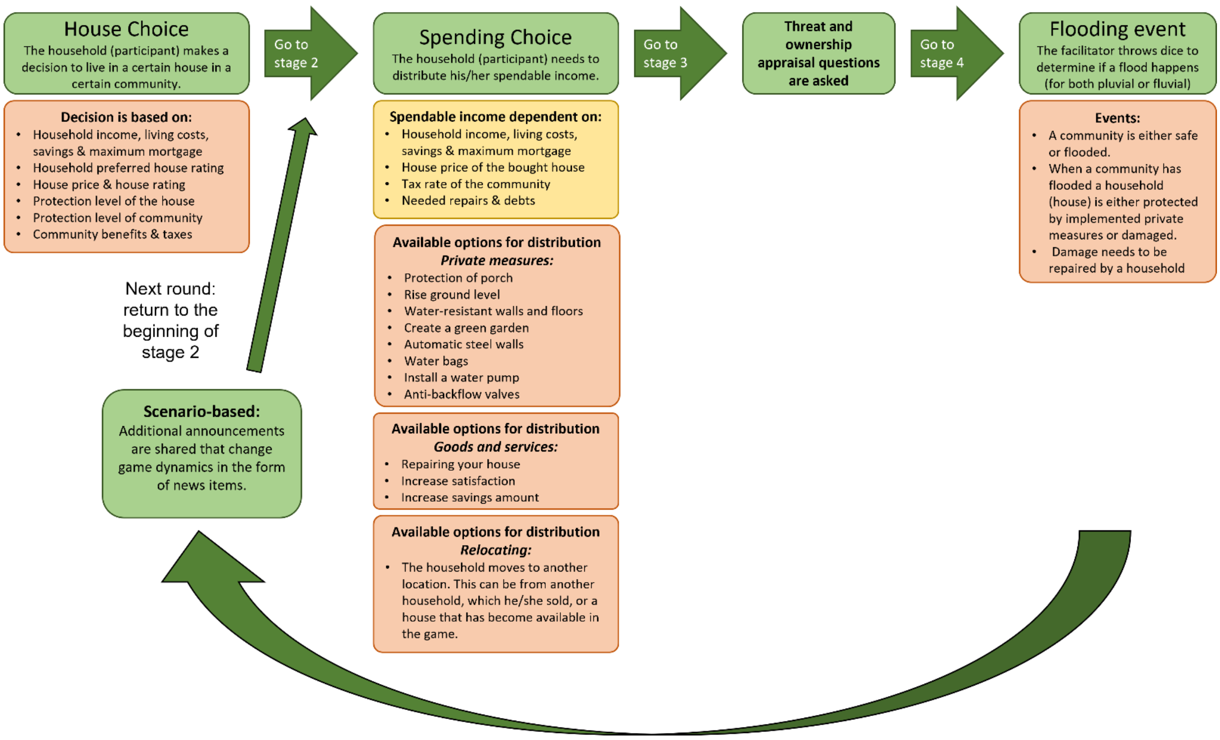

Figure 13: Procedure of a turn of the serious game

Appendix B: Game Elements

In Table 31 all game elements of "Where We Move" are described and their dependencies is given and explained. The dependencies are viewed from the game design perspective and not the players perspective.

Table 31: Game elements with their dependence and description

Game Element	Dependence	Description
Player		
Income	Independent; given	This is the income a homeowner receives each round.
Living costs	Dependent; income	This is the living cost a homeowner must pay each round. It is assumed that the more a homeowner earns (income), the higher the standard of living, resulting in higher living costs.
Max mortgage	Dependent; income	This is the maximum mortgage a homeowner can take. This also means when a homeowner has higher income, they can afford a higher mortgage.
Starting savings	Dependent; income	This is the starting capital of a homeowner. It is assumed that a homeowner with a higher income has a higher start capital.
Savings	Dependent; homeowner actions, mortgage left	This is the amount of savings a homeowner has during the game. This depends on how the homeowner will distribute their spendable income (paying debt, paying measures, paying for satisfaction, increasing savings or buying a new house). At the end of the game, a homeowner will acquire additional satisfaction points corresponding to the amount saved. From these savings, however, the mortgage remaining needs to be deducted.
Increase satisfaction	Dependent; income	This is the value for a homeowner to increase its satisfaction. Buying this represents going on vacation, installing solar panels , buying a new tv etc. It is assumed that it is more expensive for a wealthy homeowner to increase its satisfaction.
Preferred house rating	Dependent; income	This is the rating a homeowner looks for in a house. This rating represents all the qualities a homeowner wants in a house. It is assumed that wealthier homeowners have higher requirements for their house and therefore prefer houses that have higher ratings.
Start Mortgage	Dependent; Max mortgage, savings, house price and homeowner actions	This is the mortgage a homeowner has taken on for purchasing a house. This value is at most the savings plus the maximum mortgage of the homeowner.
Round Mortgage	Dependent; Start mortgage	This is the mortgage the homeowner needs to pay each round and is 10% of the start mortgage.
Mortgage	Dependent; number of	This is the mortgage that is still left after paying off

Left	rounds and Round mortgage	mortgage each round. It depends on how long the homeowner has owned the house and how much each round is paid off.
Spendable income	Dependent; Income, living costs, round mortgage, savings, taxes and repairs	This is the amount of money a homeowner is able to spend in a round. How high their mortgage, income, living cost, taxes, savings and required house repairs costs are influence how much spendable income a homeowner has.
Debt	Dependent; spendable income	This is the amount of money a homeowner is unable to pay in a round and can accumulate if it is not paid off. How high their mortgage, income, living cost, taxes, savings and required house repairs costs (spendable income) are influence whether there is a debt.
Relocating	Dependent; Spendable income, savings, house price, house rating, implemented measures and address	This is the possibility to relocate to another house in the same community or another one. Where a homeowner will move to depends on how much spendable income and savings they have and whether the house price, rating, implemented measures and address will positively affect their satisfaction. When a homeowner relocates a homeowners loses satisfaction, as moving is considered stressful.
Satisfaction	Dependent; spendable income, debt, relocating, preferred and actual house rating, savings, flooding, increasing satisfaction.	This is the value that needs to be maximized to win the game. Satisfaction can be increased or decreased by relocating, being flooded, increasing satisfaction, obtaining a higher house rating, having debt and by increasing their savings. These factors can be influenced by the spendable income.
House		
Address	Dependent; community	This is the address of a house. Houses in the NbS area will start with a N. Houses in the “Grey” solutions area will start with a D (dike) and house in the unprotected area will start with a U.
Owner history	Dependent; homeowners actions	This is the history of who has owned this house. Homeowners are able to buy this house and acquire ownership.
House price	Independent; given	This is the price a homeowner needs to pay for purchasing the house. In each community has three types of houses, cheaper houses, average houses and more expensive houses.
House rating	Dependent; House price and community	This is the rating a house has been given. It is assumed that a more expensive house has a higher house rating and that if a house is in a community that has protection the rating is also higher.
Implemented measures	Dependent; Round, homeowner actions, Protection level against pluvial and fluvial of private measure and price of private measure, flood risk perception and public	This represents which private measures are taken for this house. This means a private measure is applied to the house and not the homeowner. Homeowners are able to purchase private measures (and buy them depending on their price and protection level) and in future rounds houses will become available in the market which already have measures implemented (for game balance).

	flood protection	If a homeowner implements a measure depends on their perception of flood risk and what their level of public protection is.
Pluvial protection	Dependent; implemented measures	This represents if the house is protected against pluvial flooding. In the game this will be explained as a rain flooding to keep it understandable for the players. A house is either protected or not protected against it.
Fluvial protection	Dependent; implemented measures	This represents how much the house is protected against fluvial flooding. In the game this will be explained as river flooding to keep it understandable for the players. Houses can have different gradations of protection against different volumes of water.
	Community	
Type of community	Independent; Given	There are three types of communities, a NbS area, a “Grey” solutions area and a unprotected area.
Taxes	Dependent; Community, house capacity, citizens size	This is the amount of tax a homeowner needs to pay each round to live in a certain community. Taxes differ from communities and amount of homeowners living there.
Citizens size	Dependent; Homeowner actions	This is the amount of homeowners living in a certain community. This depends where homeowners choose to live.
Public protection level	Dependent; Community	This is the amount of protection the community has against pluvial and fluvial flooding and is dependent on the type of community.
House capacity	Dependent; Community	This is the amount of houses a community has. The NbS area needs more space for its public flooding measure and therefore less room is available for housing. Unprotected and “Grey” solutions areas are assumed to have the same amount of space for housing.
House discount due to flood	Dependent; Public protection level, rounds and pluvial or pluvial floods	This is the amount of discount that is applied to a house in a community that has been flooded by a pluvial or fluvial flood. This discount decreases every round, when no flood happens until it disappears.
	Private flooding measures	
Protection level Pluvial	Dependent; private measure price	This represents if the measure protects a house against pluvial flooding. In the game this will be explained as a rain flooding to keep it understandable for the players. A measure can either protected or not protected against it.
Protection level Fluvial	Dependent; private measure price	This represents how much the measure protects a house against fluvial flooding. In the game this will be explained as river flooding to keep it understandable for the players. Measures can have different gradations of protection against different volumes of water.
Private measure price	Independent; Given	This is the price a homeowner has to pay to purchase the measure. In real-life most of the more expensive measures offer more protection than less expensive ones.

Floodings		
Flood dice Pluvial	Independent: Given	The roll of the dice and the probability of falling onto a certain number represents the probability of a pluvial flood happening. This is based on real probabilities.
Flood dice Fluvial	Independent: Given	The roll of the dice and the probability of falling onto a certain number represents the flood volume present in the river. The volume that causes a flood is based on real probabilities compared to the implemented public measures.
Pluvial flood	Dependent; Flood dice pluvial, public protection level and implemented private measures	If the number rolled on the dice is higher than the protection level of the community, the community is flooded and results in house discounts. If the house does not have protection against pluvial flooding, the house is damaged and needs to be repaired.
Fluvial flood	Dependent; Flood dice fluvial, public protection level and implemented private measures	If the number rolled on the dice is higher than the protection level of the community, the community is flooded and results in house discounts. If the number is higher than the protection level of the homeowner, the house is damaged and needs to be repaired.
Damage	Dependent; Pluvial and fluvial floods and public protection level and implemented private measures	The damage on a house of a fluvial flood depend whether the house is protected against pluvial flooding or not (in the case the community does not offer enough protection). If not, the damage is considered to be less impactful compared to fluvial flooding, but is present. 1 damage is given to the house. The damage on a house of a fluvial flood depend whether the community and the house protection are higher than the flood volume. How much higher the flood volume is compared to the protection is seen as damage.
House repair	Dependent; Damage	This represents how much repairs a house has to undertake. This is influenced by how much damage the house has endured.
Flood risk perception	Dependent; Flood dice Pluvial, Flood dice Fluvial, Private protection level, Public protection level	This represents how much the participant thinks he will get flooded. This depends on what the values of the dices are and how much protection he has privately and publicly.

Appendix C: Private Measures

Green garden: Creating a green garden space can help your garden soak up more water during longer periods of rain. This can help in, for example urban areas. This means that in the game this measure will only help with pluvial floodings. As making your garden more beautiful with nature this is considered to increase the satisfaction of a participant (in the game).

Automatic steel walls: Steel walls will automatically rise when a flood is detected. This will shut the water out of your house. This means that in the game this measure will help during fluvial floodings and because it is a quite effective measure it will also offer pluvial protection. However, as a steel wall isn’t really a nice thing look at it won’t offer satisfaction for a participant (in the game).

Install a water pump: A water pump can help you to remove excess water from your basement or garden. It is not fast enough to remove water from an actual flood. This means that in the game this measure will only help with pluvial floodings. However, as a steel wall isn’t really a nice thing look at it won’t offer satisfaction for a participant (in the game). However, as a water pump isn’t really a thing you will see and only takes up space, it won’t offer satisfaction for a participant (in the game).

Anti-backflow valves: When there is a lot of excess water, the sewage system might overflow. With anti-backflow valves, you will protect your home against the water from the sewage system. This relates to pluvial flooding and therefore in the game this measure will only help with pluvial flooding. However, as an anti-backflow valve isn’t really a thing you will see and only takes up space, it won’t offer satisfaction for a participant (in the game).

Rise ground level: To rise the ground level of your house is an expensive, but incredibly effective way to protect your house from flood water. It essentially moves your house higher from the ground, meaning you are protected against higher levels of water. This means that in the game this measure will help during fluvial floodings and because it is a quite effective measure it will also offer pluvial protection. However, as this measure is quite drastic and will protect a house in a significant way, the measure is considered to increase the satisfaction of a participant (in the game).

Water resistant walls & floors: There exist walling and floors that are not easily damaged by water and will protect the structure underneath. If a flood does happen, this will lessen the damage the water does. This means that in the game this measure will help during fluvial floodings and because it is a quite effective measure it will also offer pluvial protection. However, as this measure is quite drastic and will protect a house for both types of flooding, the measure is considered to increase the satisfaction of a participant (in the game).

Water bags: When a flood is happening, you can use these water bags to protect your doors and house. It is a cheaper alternative, but cannot be used again once they are used. This means that in the game this measure will help during fluvial floodings. However, as they cannot be used again after use, in the game you have to buy them every round to make use of them. In addition, they do not offer any additional satisfaction to the participants (in the game).

Underground rain barrel: Rain barrels are typically connected to gutter downspouts and collect the runoff from roofs. You can use this stored water for non-potable uses such as watering the lawn and gardens or washing your car. This means that in the game this measure will only help with pluvial floodings, as it is not able to the volume of water of a fluvial flood. As a rain barrel as many side benefits this is considered to increase the satisfaction of a participant (in the game).

In Table 32 an overview is given of the in-game advantages each private measure gives.

Table 32: Private measures and their advantages in-game

Private measure	**River protection**	**Rain protection**	**Satisfaction increase**	**Price**
Green Garden	0	Yes	+2	20.000
Automatic steel walls	+1	Yes	0	12.000
Install a water pump	0	Yes	0	6.000
Self-rising bulkhead	+1	No	0	8.000
Rise ground level	+2	Yes	+3	35.000
Water-resistant walls & floors	+1	Yes	+1	20.000
Sandbags	+1	No	0	3.000
Underground rain barrel	0	Yes	+1	11.000

Appendix D: Organizing Game sessions and Inviting Participants

To gather the data from the serious game, gaming sessions are organised. These sessions were targeted and promoted for students on the TU Delft. Students are chosen as the participants, due to time constraints and because this study will function as a test for future research using this serious game. Moreover, there was the option of having the game played by people involved in the Grensmaas project and water safety, but it was decided to first use a controlled setting (students) to pinpoint areas for enhancement before introducing it to the actual homeowners (the final target group) living in a flood prone area, ensuring a safe testing environment. In the end, one session was organised at one specific faculty (IHE-Delft). However, each type of student, not depended on faculty, was allowed to come to the session to maximize turnout (mostly IHE-Delft students participated). The option existed to give a gift voucher to people who participate in order to increase attendance even more, however, this was waived as it contradicts the research culture of serious gaming projects. Food and drinks, however, were offered to offer more appeal to the event. For promoting the event study associations and teachers were contacted. This allowed the research to spread the word about the event on the communication channels of the study associations and teachers. These channels were for example, websites, social media accounts, Brightspace pages and during lectures. Regarding the promotion material, minimal information was shared about the topic of the serious game and no knowledge was given about flood protection measures. This was done in order to minimize given knowledge on the topic which could influence the answers given in the pre-survey. In Figure 14 a poster can be seen which was used as promotion material. However, the player did know that the game was about flood risk and flood protection. For the event itself, a maximum of 3 tables were present, where each table consisted of between 6 and 8 students. Each table had one facilitator to explain the game. Facilitators were close friends of the researcher and were trained by a facilitator manual and a meeting discussing the facilitation of the event.

Figure 14: Poster used for session at Applied Sciences, similar posters used for the other sessions.

Following the initial three games, the participant count remained notably low. As a result, deriving impactful and conclusive insights from the data would have proven to be challenging. Consequently, a decision was made to arrange an additional four sessions in collaboration with the Nissewaard municipality. This shift in the target group led to the participation of actual homeowners in the game, albeit those not residing in high-risk flood areas. This aspect didn't pose an issue for the profiling process, given that their responses to the pre-game survey were the determining factor. Through a connection within the municipality, four more sessions were successfully organized, each involving one table of participants. This cumulative effort resulted in 53 individuals eventually participating in the game. While a larger participant pool was initially desired, constraints on time prompted the decision to analyse the data from this group.

Appendix E: Pre-Game Survey

Introduction

Thank you for participating in the pre-game survey! Your input is of great importance for formulating appropriate flood risk management and communication strategies in the future. We want to ask you a few questions to get an understanding of the attitudes of our respondents. The survey consists of 11 questions and will only take a few minutes of your time. All your data will be handled with care and analysed anonymously according to the signed consent form: Letter of consent

Q1 Please fill in the player number (+letter) you have been assigned.

Q2 At which faculty or institute do you study, or are mostly affiliated?

- ○ TU Delft, Technology, Policy & Management
- ○ TU Delft, Civil Engineering & Geosciences
- ○ TU Delft, Architecture
- ○ IHE-Delft, Institute for Water Education
- ○ Rotterdam University of Applied Sciences
- ○ Other

Q3 What is the highest level of education you have completed?

- ○ High school
- ○ BSc
- ○ MSc
- ○ PhD
- ○ Other

Flood experience

Q4 Have you ever personally experienced any type of flood? (e.g. coastal, river or rain flood)

- ◯ No, I **do not** have a flood experience
- ◯ Yes, but **without** disruptions or damages
- ◯ Yes, with **minor** disruptions or damages
- ◯ Yes, with **some** disruptions or damages
- ◯ Yes, with **serious** disruptions or damages

Q5 How often do you actively listen or read information about floods from the following sources?

	Never	Rarely	Sometimes	Often	Always
Government (i.e. official letters, warnings, announcements etc.)	◯	◯	◯	◯	◯
Scientific (i.e. academic reports or publications)	◯	◯	◯	◯	◯
General media (i.e. news, TV and radio)	◯	◯	◯	◯	◯
Social network or media (i,e, friends, family and colleagues)	◯	◯	◯	◯	◯

Flood related questions

Q6 How **likely** do you consider a flood event to happen to you in the next 5 to 10 years?

- ◯ Very unlikely
- ◯ Unlikely
- ◯ Neutral
- ◯ Likely
- ◯ Very likely

Q7 To what extent do you believe climate change will **increase your likelihood or chance of being flooded** in the next 5 to 10 years?

- ◯ No increase at all
- ◯ A little increase
- ◯ A moderate increase
- ◯ A big increase
- ◯ An extreme increase

Q8 To what extent do you **believe you will get damaged** in the event of a major flood in the next 5 to 10 years?

- ◯ I certainly won't get any damage
- ◯ I won't get damage
- ◯ I might suffer minor damage
- ◯ I will suffer minor damage
- ◯ I will get seriously damaged

Q9 Whom do you consider to be responsible for providing/having flood protection?

- ◯ Public authorities are completely responsible for flood protection
- ◯ Public authorities are responsible and citizens somewhat responsible for flood protection
- ◯ Public authorities and citizens are equally responsible for flood protection
- ◯ Citizens are responsible and public authorities are somewhat responsible for flood protection
- ◯ Citizens are completely responsible for flood protection

Public & private measures

Please answer the following questions about public & private flood measures by a range of 1 (not at all effective) to 5 (extremely effective). If you do not know anything about the public or private flooding measure please fill in "I don't know".

Q10 How **effective** do you believe the following public flood measures are against floods?

	Not at all effective	Slightly effective	Moderately effective	Very effective	Extremely effective	I don't know
Nature-based solutions such as vegetated flood retention areas	○	○	○	○	○	○
Civil engineering flood defences such as dikes	○	○	○	○	○	○
Farmland	○	○	○	○	○	○

Q11 How **effective** do you believe the following private flood measures are against floods?

	Not at all effective	Slightly effective	Moderately effective	Very effective	Extremely effective	I don't know
Green garden	○	○	○	○	○	○
Automatic steel walls	○	○	○	○	○	○
Installing a waterpump	○	○	○	○	○	○
Self-rising bulkhead	○	○	○	○	○	○
Rising ground level	○	○	○	○	○	○
Water resistant walls & floors	○	○	○	○	○	○
Sandbags	○	○	○	○	○	○
Underground rain barrel	○	○	○	○	○	○

Appendix F: Post-Game Survey

Introduction

Thank you for participating in the post-game survey! The survey consists of 12 questions about your game experience with flood risk and protection and will only take a few minutes of your time. All your data will be handled with care and analysed anonymously according to the signed consent form: Letter of consent

Game experience

Q1 Please fill in the player number (+letter) you have been assigned.

Q2 Did you overall feel safe from flooding in the game?

- ◯ Very unsafe
- ◯ Unsafe
- ◯ Neutral
- ◯ Safe
- ◯ Very safe

Q3 What game actions did you focus on for your game (strategy)?

- ◯ I focused on financial stability (increasing savings).
- ◯ I focused on being safe (moving to a more safe community and implementing private measures).
- ◯ I focused on directly increasing my well-being (directly increasing your satisfaction).
- ◯ I focused on all the above at the same time.
- ◯ Other, please explain:

Flood protection questions

Please answer the following questions concerning public flood protection.

Q4 Regardless of your game role and actions, which of the following public flood protection areas would you have preferred to live in? Rank the areas from most to least preferred to live in.

- The area is protected by a dike.
- The area is protected by a nature-based solution.
- The area is protected by farmland.

Q5 Please shortly explain why.

Please answer the following questions about public flood protection by a range of 1 (not at all) to 5 (extremely). If you do not know anything about the public measure please fill in "I don't know".

Q6 From your game experience, how **effective** do you believe the following public measures are against floods?

	Not at all effective	Slightly effective	Moderately effective	Very effective	Extremely effective	I don't know
Nature-based solutions	○	○	○	○	○	○
Dikes and other civil engineering flood defences	○	○	○	○	○	○
Farmland	○	○	○	○	○	○

Q7 From your game experience, how much **confidence** do you have in the following public measures to protect you?

	Not much confidence	Slight confidence	Moderate confidence	A lot of confidence	Extreme confidence	I don't know
Nature-based solutions	○	○	○	○	○	○
Dikes and other civil engineering flood defences	○	○	○	○	○	○
Farmland	○	○	○	○	○	○

Please answer the following questions concerning private flood protection.

Q8 From your game experience, which private measure(s) (maximum of 3) had your preference in the game?

- ☐ Green garden
- ☐ Automatic steel walls
- ☐ Install a water pump
- ☐ Self-rising bulkhead
- ☐ Rise ground level
- ☐ Water resistant walls & floors
- ☐ Sandbags
- ☐ Underground rain barrel

Q9 Please shortly explain why.

Please answer the following questions about private flood protection by a range of 1 (not at all) to 5 (extremely). If you do not know anything about the private flooding measure please fill in "I don't know".

Q10 From your game experience, how **effective** do you believe the following private measures are against floods?

	Not at all effective	Slightly effective	Moderately effective	Very effective	Extremely effective	I don't know
Green garden	◯	◯	◯	◯	◯	◯
Automatic steel walls	◯	◯	◯	◯	◯	◯
Install a water pump	◯	◯	◯	◯	◯	◯
Self-rising bulkhead	◯	◯	◯	◯	◯	◯
Rise ground level	◯	◯	◯	◯	◯	◯
Water resistant walls & floors	◯	◯	◯	◯	◯	◯
Sandbags	◯	◯	◯	◯	◯	◯
Underground rain barrel	◯	◯	◯	◯	◯	◯

Q11 From your game experience, how much **confidence** do you have in the following private measures to protect you?

	Not much confidence	Slight confidence	Moderate confidence	A lot of confidence	Extreme confidence	I don't know
Green garden	◯	◯	◯	◯	◯	◯
Automatic steel walls	◯	◯	◯	◯	◯	◯
Install a water pump	◯	◯	◯	◯	◯	◯
Self-rising bulkhead	◯	◯	◯	◯	◯	◯
Rise ground level	◯	◯	◯	◯	◯	◯
Water resistant walls & floors	◯	◯	◯	◯	◯	◯
Sandbags	◯	◯	◯	◯	◯	◯
Underground rain barrel	◯	◯	◯	◯	◯	◯

Q12 From your game experience, how do you think the following private flood measures **cost compared to its benefits**?

	Not at all costly	Slightly costly	Moderately costly	Very costly	Extremely costly	I don't know
Green garden	○	○	○	○	○	○
Automatic steel walls	○	○	○	○	○	○
Install a water pump	○	○	○	○	○	○
Self-rising bulkhead	○	○	○	○	○	○
Rise ground level	○	○	○	○	○	○
Water resistant walls & floors	○	○	○	○	○	○
Sandbags	○	○	○	○	○	○
Underground rain barrel	○	○	○	○	○	○

Appendix G: Debriefing

In Table 33, the debriefing questions are showed, which were used as guideline during the discussions.

Table 33: Debriefing questions

Blow off some steam
1. Did you like the game?
2. Did you feel the game was fair?
3. If you play the game again, would you take other actions?
4. Did you agree with the protection levels of the areas/public measures?
5. How did the floods influence your decisions?
Explore the game
1. How do you think the game relates to the real world?
2. Have you ever experienced flooding yourself?
3. In what ways is the game not realistic?
4. How would you implement the flooding?
Real-world actions
1. Why did you choose the measures you chose, what was your reasoning?
2. When buying a house, do you think you will think about possible flooding?
3. What kind of actions do you think you will take in the real world?
4. How do these choices differ from the game and why?
5. Do you think you might get flooded at some point?
6. How and who should prevent this?

Appendix H: ANOVA Test

Indicators

In Table 34, one can observe the means, medians and standard deviations of the different classes per indicator.

Table 34: Mean scores for each class on the indicators

	Class	Q4	Q5-1	Q5-2	Q5-3	Q5-4	Q6	Q7	Q8	Q9
Mean	*1 (N=25, 46,8%)*	1.84	2.44	2.40	2.92	2.64	2.56	2.72	2.36	2.28
	2 (N=13, 23,8%)	3.15	3.77	3.92	4.00	4.00	4.00	4.23	3.15	2.15
	3 (N=16, 29,4%)	2.38	2.63	2.56	3.44	2.88	3.94	4.13	3.25	2.44
Median	*1 (N=25, 46,8%)*	1	3	3	3	3	3	3	2	2
	2 (N=13, 23,8%)	4	4	4	4	4	4	4	3	2
	3 (N=16, 29,4%)	2.5	3	2	3	3	4	4	3	2
Std deviation	*1 (N=25, 46,8%)*	1.1	0.65	0.82	0.86	0.91	0.82	0.89	0.57	0.68
	2 (N=13, 23,8%)	1.3	0.73	0.86	0.71	0.91	0.71	0.44	0.56	0.56
	3 (N=16, 29,4%)	0.89	0.89	1.2	0.63	1.0	0.85	0.62	0.45	0.51

** Q4: Experience with floods, Q5-1: Knowledge obtained from government, Q5-2: Knowledge obtained from scientific resources, Q5-3: Knowledge obtained from general media, Q5-4: Knowledge obtained from social networks and media, Q6: Floods happening in the future, Q7: Climate change impact in the likelihood of flooding, Q8: Expected damage from potential flood, Q9: Responsibility for flood protection*

To determine whether the differences in mean scores on the indicators between profiles is considered to be significant, a One-Way ANOVA test is performed. In this analysis, the belonging to a certain profile (Class 1,2 or 3) is the grouping variable and the indicators (Q4 to Q9) are the dependent variables. To not worry about the analysis assumption of homogeneous variances, Welch's ANOVA test is conducted, as its statistical power is nearly equivalent to that of the Classic test (Fisher's ANOVA test) (Frost, 2017).

Table 35: Welch's ANOVA test for the indicators

Question	**F**	**p-value**
Q4: Experience	4.70	0.017*
Q5_1: Information	15.37	< .001*
Q5_2: Information	13.96	< .001*
Q5_3: Information	8.39	0.001*
Q5_4: Information	9.60	< .001*
Q6: Flood in future	20.40	< .001*
Q7: Climate change	26.06	< .001*
Q8: Threat	17.12	< .001*
Q9: Responsibility	1.01	0.375

**H0 can be rejected (p-value < 0.05), a significant difference is observed between the means of the profiles.*

Table 35 shows the results and provides evidence that there is statistical significance in the differences between at least one profile mean of the indicators. The sole exception lies in question 9, where the difference in means is not deemed significant.

Although the outcomes indicate inequality among class means, the statistical significance of particular differences between class means remains unknown. To identify significant differences between the classes, a post-hoc test for pairwise comparisons is conducted. Given the utilization of Welch's ANOVA, the Games-Howell multiple comparisons method is applied for this analysis.

Table 36: Post-Hoc test Games-Howell for the indicators

		Class 1	Class 2	Class 3
Q4: Experience				
Class 1	*p-value*	-	0.017*	0.215
Class 2	*p-value*		-	0.196
Class 3	*p-value*			-
Q5_1: Information				
Class 1	*p-value*	-	< .001*	0.754
Class 2	*p-value*		-	0.002*
Class 3	*p-value*			-
Q5_2: Information				
Class 1	*p-value*	-	< .001*	0.885
Class 2	*p-value*		-	0.004*
Class 3	*p-value*			-
Q5_3: Information				
Class 1	*p-value*	-	< .001*	0.081
Class 2	*p-value*		-	0.085
Class 3	*p-value*			-
Q5_4: Information				
Class 1	*p-value*	-	< .001*	0.737
Class 2	*p-value*		-	0.011*
Class 3	*p-value*			-
Q6: Flood in future				
Class 1	*p-value*	-	< .001*	< .001*
Class 2	*p-value*		-	0.975
Class 3	*p-value*			-

Q7: Climate change				
Class 1	*p-value*	-	< .001*	< .001*
Class 2	*p-value*		-	0.854
Class 3	*p-value*			-
Q8: Threat				
Class 1	*p-value*	-	< .001*	< .001*
Class 2	*p-value*		-	0.869
Class 3	*p-value*			-

** A significant difference (p-value < 0.05) is observed between these classes*

Based on the data presented in Table 36, it can be concluded that for question 4, only the mean scores of Class 1 and Class 2 exhibit statistically significant differences. In relation to question 5_1, 5_2, and 5_4, significant variations in mean scores are observed between Class 1 and Class 2, as well as between Class 2 and Class 3. As for question 5_3, significant disparities are noted between mean scores of Class 1 and Class 2. With respect to questions 6, 7, and 8, significant differences in mean scores are evident between Class 1 and Class 2, and also between Class 1 and Class 3. Notably, question 9 is excluded from this analysis, as the differences in mean scores for this question were previously found to lack significance in the Welch's ANOVA test.

Questions 10 and 11 of the Survey

Table 36 provides an overview of each class's evaluation of the effectiveness of both private and public flooding measures (question 10 and question 11 in the pre-game survey). The data in Table 36 highlights that, on the whole, Class 2's averages stand out as the highest when contrasted with the other two groups. This implies that this particular group assigns higher ratings to the efficacy of both private and public flood measures compared to Class 1 and Class 3. Nevertheless, the determination of whether these mean differences hold statistical significance remains unknown. To determine whether the differences in mean scores on question 10 and 11 between profiles is considered to be significant a One-Way ANOVA test is performed. To not worry about unequal variances, Welch’s ANOVA test is conducted.

Table 37: Each class's evaluation of the effectiveness of both public and private flooding measures (Q10 and Q11)

		Class 1 (N=25)	**Class 2 (N=13)**	**Class 3 (N=16)**
Public flooding measures				
Effectiveness NbS	*Mean*	3,32	3,62	2,81
	Std Deviation	0,90	0,51	1,54
Effectiveness dike	*Mean*	3,84	3,92	3,38
	Std Deviation	0,85	0,64	1,54
Effectiveness farmland	*Mean*	2,64	3,08	2,13
	Std Deviation	1,11	0,95	1,59

Private flooding measures				
Effectiveness green garden	*Mean*	2,80	2,77	2,06
	Std Deviation	0,82	0,73	1,24
Effectiveness automatic steel walls	*Mean*	2,76	3,23	2,63
	Std Deviation	1,27	1,09	1,26
Effectiveness water pump	*Mean*	2,56	3,38	2,50
	Std Deviation	1,16	0,77	1,32
Effectiveness self-rising bulkhead	*Mean*	2,52	2,46	1,31
	Std Deviation	1,30	1,76	1,66
Effectiveness rising ground level	*Mean*	3,20	3,15	2,44
	Std Deviation	1,23	1,21	1,71
*Effectiveness waterproof walls & floors***	*Mean*	2,76	3,67	2,31
	Std Deviation	1,01	1,07	1,40
*Effectiveness sandbags**	*Mean*	2,16	2,75	2,00
	Std Deviation	0,75	1,06	0,82
Effectiveness rain barrel	*Mean*	2,40	2,69	1,50
	Std Deviation	0,96	1,18	1,55

**Green is the highest observed considered effectiveness among the classes, yellow the in between and orange the least observed considered effectiveness among the classes.*
***For this question Class 2 had a sample size of 12 instead of 13. *

Table 38: Welch's ANOVA test for questions 10 and 11

Question	**F**	**p-value**
Q10_1: Effectiveness NbS	2.242	0.124
Q10_2: Effectiveness dike	0.815	0.453
Q10_3: Effectiveness farmland	2.051	0.147
Q11_1: Effectiveness green garden	2.308	0.118
Q11_2: Effectiveness automatic steel walls	1.082	0.352
Q11_3: Effectiveness water pump	4.308	0.022*
Q11_4: Effectiveness self-rising bulkhead	3.097	0.062
Q11_5: Effectiveness rising ground level	1.230	0.308
Q11_6: Effectiveness waterproof walls & floors	4.589	0.020*
Q11_7: Effectiveness sandbags	2.086	0.146
Q11_8: Effectiveness rain barrel	2.897	0.074

**H0 can be rejected (p-value < 0.05), a significant difference is observed between the means of the profiles.*

Table 38 provides evidence that there is no statistical significance in the differences between class means of questions 10 and 11. The sole exception lies in question 11_3 and 11_6, where the difference in means is deemed significant.

To identify the significant differences between the classes of questions 11_3 and 11_6, a post-hoc test for pairwise comparisons is conducted. Given the utilization of Welch's ANOVA, the Games-Howell multiple comparisons method is applied for this analysis.

Table 39: Post-Hoc test Games-Howell for question 11_3 and 11_6

		Class 1	**Class 2**	**Class 3**
Q11_3: Effectiveness water pump				
Class 1	*p-value*	-	0.034*	0.988
Class 2	*p-value*		-	0.081
Class 3	*p-value*			-
Q11_4: Effectiveness waterproof walls & floors				
Class 1	*p-value*	-	0.058	0.519
Class 2	*p-value*		-	0.020*
Class 3	*p-value*			-

** A significant difference (p-value < 0.05) is observed between these classes*

Based on the data presented in Table 39, it can be concluded that for question 11_3, only the mean scores of Class 1 and Class 2 exhibit statistically significant differences. In relation to question 11_4 significant variations in mean scores are observed between Class 2 and Class 3.