TU Delft Delft University of Technology

WAGENINGEN UNIVERSITY & RESEARCH

MSc MADE

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How to Map the Costs of Inaction?

The Role of Climate Risk Assessment in Amsterdam's Climate Governance Arenas

Thesis Report
Wageningen, the Netherlands;
14 January 2025

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Front page picture by Caroline Watson (2020).

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Abbreviations

CABF	Climate Adaptive Building Framework
CGA	Climate Governance Arena
CRA	Climate Risk Assessment
DGBC	Dutch Green Building Council
ECB	European Central Bank
EU	European Union
GIS	Geographic Information System
ICG	Integrated Climate Governance
INBO	Instituut voor Natuur- en Bosonderzoek
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
KNMI	Royal Netherlands Meteorological Institute
NKWK	Nationaal Kennis- en Innovatieprogramma Water en Klimaat
NWO	Nederlandse Organisatie voor Wetenschappelijk Onderzoek
PCR	Physical Climate Risks
PDOK	Publieke Dienstverlening Op de Kaart
SRQ	Sub-research question
TCFD	Task Force on Climate-related Financial Disclosures

Abstract

Climate risk assessment estimates the risk of physical climate hazards, and it is increasingly relevant for stakeholders involved in Dutch urban climate governance where floods, heat and drought are becoming more frequent and severe. However, its future role in climate governance and stakeholders' information needs. While previous research analyzed the role of technical tools in decision-making for climate adaptation, it does not identify the needs of the involved stakeholders. This research aims to contribute towards more effective and rapid implementation of urban climate adaptation measures in the Netherlands by identifying the role of climate risk assessment in the climate governance arena of Amsterdam as the case study. This is done by producing risk maps of Amsterdam's Watergraafsmeer area as sample and using them in eleven semi-structured interviews with advisory, financial and municipal stakeholders. Preference was found for methods that estimate the financial implications of hazards at the neighborhood scale because it supports the identification of risk hotspots, understanding the costs of inaction, and accelerating the implementation of adaptation measures. These findings enhance the understanding of stakeholder information needs in Dutch climate governance arenas and support further development of risk assessment tools that estimate the financial consequences of physical climate hazards.

Acknowledgments

Thank you to everyone who made this thesis possible.

First, I must express my gratitude to both of my supervisors, Maged and Mattijs. You supported me through the entire process, even when I did not give it all the time and attention that it deserved. Thank you for always pushing me to do better and for your wise advice that helped me get there.

Second, my research would not have been possible without the help of all the experts who agreed to be interviewed. Your expertise was invaluable, and I hope that this thesis will, in its own small way, help spread your knowledge.

Finally, I thank all my friends for showing interest in my work and helping me find a balance between research and free time.

Again, none of this would have been possible without your support.

Kuba Kowalski

Wageningen, January 2025

1. Introduction

Physical climate risks (PCR) — such as floods, droughts and heatwaves — are increasing in severity and frequency due to climate change and they are posing a greater threat to the quality of life and economic wellbeing in cities across the globe (Bulkeley & Betsill, 2003; IPCC, 2018). To combat this threat, private and public stakeholders meet in climate governance arenas (CGA) to decide about the development of policies and the implementation of climate change adaptation and mitigation measures in cities (Heinen, Arlati, and Knieling, 2021). CGA refers to the physical, virtual, or conceptual spaces where decision-makers such as municipal authorities, financial institutions, and advisory organizations interact according to established rules and dependencies to influence or implement climate-related policies (Dore, Lebel, and Molle, 2012).

Climate risk assessment (CRA) is an important decision-support tool for these stakeholders as it quantifies the exposure and vulnerability of locations and objects to climate hazards (IPCC, 2018; Figure 1). CRA is a rapidly evolving method that seeks to quantify interconnected, spatially dependent risks and to bridge the gap between technical analysis and policymaking. Despite significant technological advancements, it is uncertain whether these novel methods of assessment address the actual information needs of urban stakeholders and policymakers in addition to the political discourse which may influence their implementation (Hedlund, 2023). This insufficient understanding of stakeholder needs and constraints makes the role of CRA in CGAs uncertain and raises concerns about its effectiveness in supporting the implementation of climate adaptation measures in cities (Brown et al., 2018).

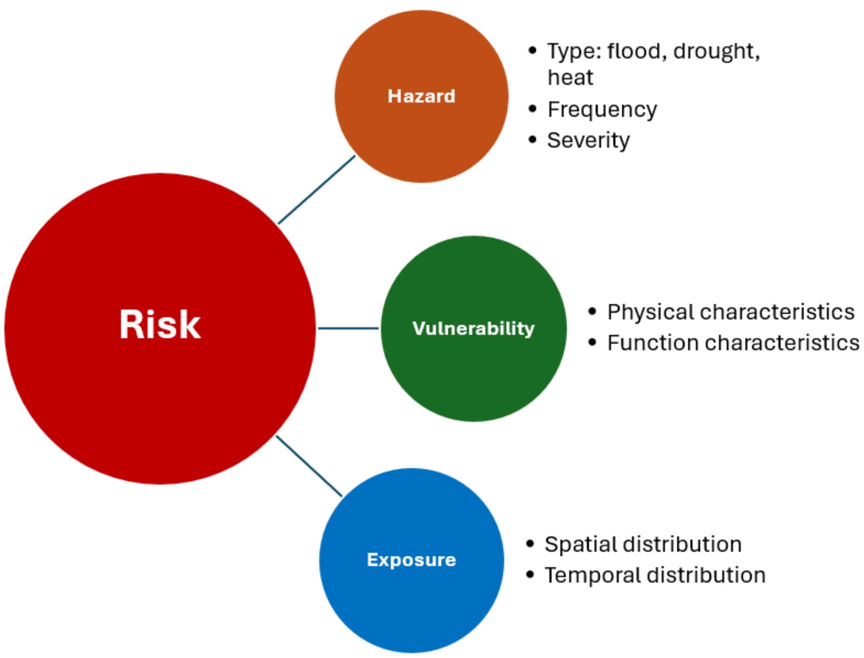

Figure 1. Climate risk and its components. Made by researcher.

1.1 The Challenges of Multi-Stakeholder Governance

In the European Union (EU), an important factor and challenge for the emerging role of CRA is the European Central Bank's Guide on Climate-Related and Environmental Risks which determines the needs of financial stakeholders. Citing "*sparse and heterogenous disclosure practices*" that are predominant in climate finance, the ECB established supervisory expectations for the assessment and disclosure of climate risks for among others real estate developers, investors, insurers and banks (European Central Bank, 2020, p.14). These actors are a key stakeholder group in urban climate governance due to their direct influence on the resilience of private spaces, contrasted with the government's power over public spaces (Heinen, Arlati, and Knieling, 2021). By forming a strict regulatory basis for the needs of these groups from CRA, the ECB guide also led to a mismatch between the current technological capabilities and what is needed to effectively support financial decision-making and fulfill the disclosure requirements. As found by Keenan (2019), financial stakeholders currently rely on propriety "black box" models and datasets with spatial and temporal gaps. These limitations are especially severe on extremely broad scales, such as continents where the most influential stakeholders operate, and fine scales where asset-level decisions are made. As such, CRA may lead to misinformed investment strategies being adopted by financial stakeholders which incentivize maladaptation to PCRs by relying on inaccurate estimates of risk. Furthermore, bridging the gap between CRA models and information that has utility for financial decision-making is difficult and requires understanding the needs of these stakeholders first. (Fiedler et al., 2021).

Dutch climate governance is distinct in the European Union due to its decentralized, multi-stakeholder approach towards climate risk management with few reported fatalities but significant financial impacts that are difficult to quantify and assign ownership to individual stakeholders (Dai, Wörner, & van Rijswick, 2017). This approach is exemplified by the July 2021 European floods where, unlike neighboring Germany and Belgium which reported 180 and 39 fatalities respectively, the Netherlands recorded zero casualties but an estimated €433 million in damages, with the ownership of the damages remaining challenging to attribute to either businesses, government institutions, or private citizens (Expertise Netwerk Waterveiligheid, 2021). The estimate is attributed to Deltares which is a knowledge institute that exemplifies the second key group of stakeholders in climate governance due to its focus on the development of decision-support tools, and the provision of data and climate services. Additionally, the role of this stakeholder group is involves facilitating action and mediate between the stakeholders in CGAs through knowledge-sharing and awareness-raising, although with significant challenges due to their lack of institutional mandate, short-term engagement without continuity between projects, difficulty in sustaining long-term engagement of stakeholders and conflicts in the needs and wants of other stakeholders (Dai, Wörner, & van Rijswick, 2017; Willems, van Popering-Verkerk, & van Eck, 2022).

In the Netherlands, Amsterdam is one of the flagship cities in implementing climate adaptation measures through its participative approach towards climate governance, exemplified in the Rainproof and Weatherproof initiatives (Dai, Wörner, & van Rijswick, 2017; Rekenkamer Amsterdam, 2023). Spearheaded by the municipal government under its Climate Adaptation Strategy (*Strategie Klimaatadaptatie*), Amsterdam aims to make itself "weatherproof" by 2050 through the implementation of climate adaptation measures to PCRs in collaboration with financial and advisory stakeholders in city. Within this structure, the municipal stakeholder group, which includes the diverse initiatives and organization clusters within the local government, seeks to use soft policy instruments, and regulatory and facilitatory strategies to motivate climate adaptation by the other stakeholder groups (Gemeente Amsterdam, 2020). Data is central to this strategy as 3D flood-risk and neighborhood vulnerability maps have been used to support stakeholder engagement. However, the data-driven approach faces the challenge of leveraging novel tools such as CRA in engaging stakeholders (Dai, Wörner, & van Rijswick, 2017; Willems, van Popering-Verkerk, & van Eck, 2022).

CRA is a promising decision-support tool for advancing the implementation of climate adaptation measures in cities. However, its utility is limited by its poorly defined role in CGAs both across the European Union and in cities such as Amsterdam. This lack of definition is compounded by insufficient understanding of the information needs of key stakeholder types in climate governance, which are the financial, advisory and municipal groups. Without deeper understanding of stakeholders and a clear definition of the role of CRA, its technical outputs may not be translated into actionable insights that align with the information needs of the stakeholders. This misalignment may hinder the implementation of climate adaptation measures rather than supporting it and contribute towards a decline in urban quality of life and economic wellbeing in face of climate change. To address this gap, this research aims to identify the needs and priorities of Amsterdam's stakeholders and define the role of CRA within local CGAs. By bridging this knowledge gap, the study seeks to contribute to the effective integration of CRA as a tool for data-driven decision-making in urban climate adaptation.

1.2 Research Aim and Questions

This research aims to contribute towards more effective and rapid implementation of urban climate adaptation measures in the Netherlands by identifying the role of climate risk assessment in the climate governance arena of Amsterdam as the case study. Based on the objective, the following general research question is answered: "**What is the role of climate risk assessment in the climate governance of Amsterdam?** "

To explore the main question, these sub-research questions (SRQ) are formulated:

1. How is Amsterdam's climate governance arenas structured in terms of actors, powers and interests?
2. What is the current state of climate risk assessment tools in the context of Amsterdam's climate governance arena?
3. How can climate risk assessment be improved further to address the information needs of stakeholders in Amsterdam's climate governance arena?

1.3 Research Scope

Climate governance is an extremely broad concept that stands at the crossroads of climate and political sciences. Identifying the exact role of CRA in broader climate governance at continental, national or even regional levels was not possible within the timeframe of this thesis and as such, only the case of CGAs in Amsterdam is considered. The City of Amsterdam as it falls within its municipal boundaries was chosen specifically due to the emphasis put on a multi-stakeholder approach in the municipal Climate Adaptation Plan (Figure 2). The entirety of the Metropolitan Region of Amsterdam was not considered as it includes multiple municipal governments which operate in separate governance arenas. Broadening the research area beyond the municipal boundaries of the City of Amsterdam was not possible within the timeframe constraints of the thesis. The area of Watergraafsmeer was chosen specifically for visualizations due to its historic reputation as a location with significant climate risks that was likely to be familiar to interview respondents.

However, not all stakeholders who are relevant in the case of Amsterdam operate solely within the municipal boundaries. For example, real estate investment firms often operate on national or international scales and excluding them from data collection and analysis based only on strict geographic boundaries would also lead to the exclusion of highly relevant insights that could affect the conclusion of the thesis.

Additionally, the concept of climate risk includes climate transition risks in addition to PCRs. The former is not considered in the thesis due to the difference in tools used for assessing risks emerging from social and policy changes versus those caused by physical phenomena such as floods because they are not spatially bound. Recommendations for researching the role of transition risk assessment in climate governance and other directions for research that were excluded in this thesis are given in Chapter 9.

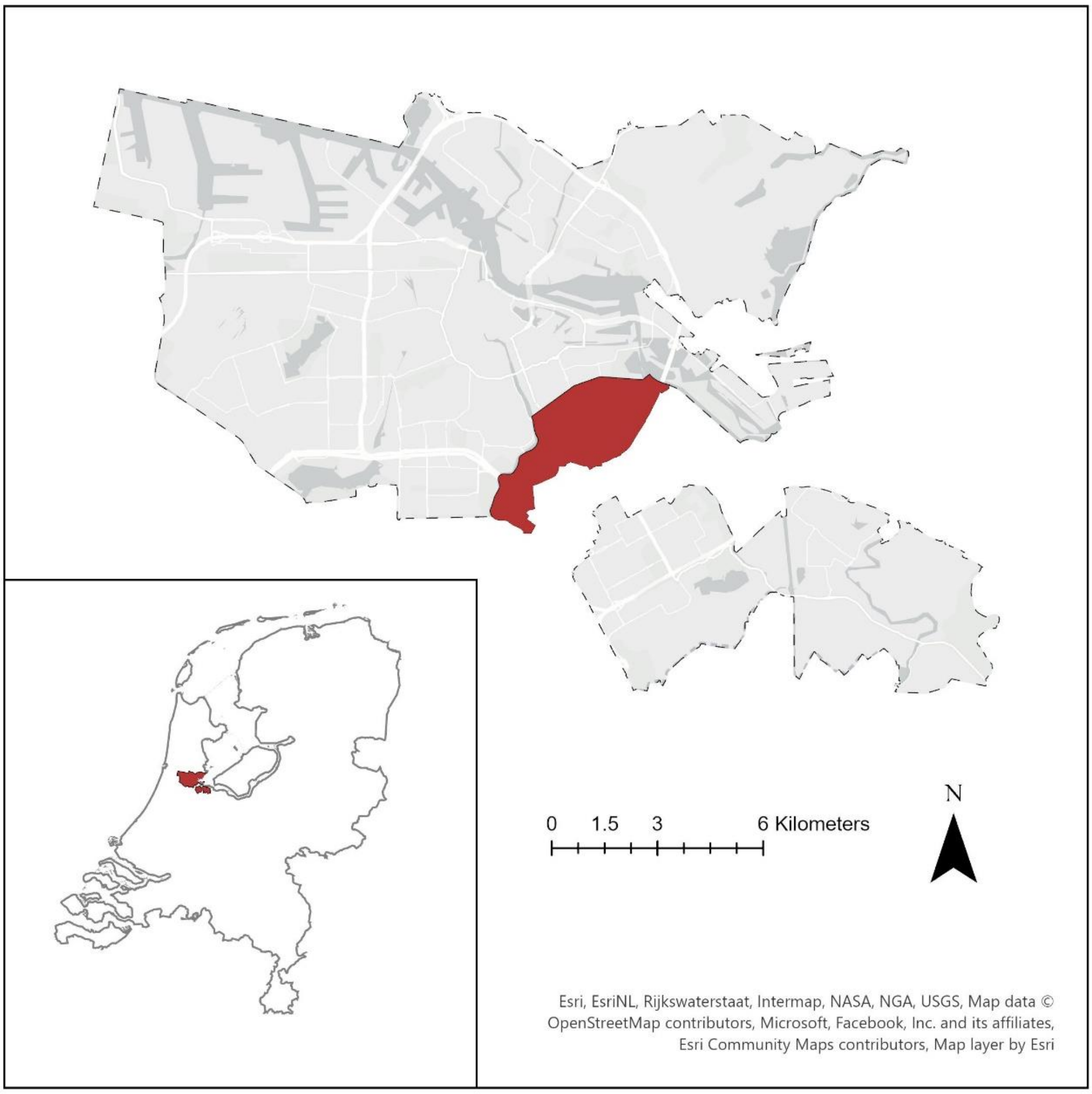

Figure 2. Map of the research area and the selected location of visualizations, Watergraafsmeer, with an inset of relative location in the Netherlands. Made by researcher.

2. Theoretical Framework

2.1 Introduction

The two main concepts of this thesis are climate governance arenas and climate risk assessment. The former primarily originated from the fields of environmental science and political science, while the latter is inherently interdisciplinary, drawing from climate science, geo-information science, risk management studies, and other related fields. Both concepts are embedded in several established theoretical frameworks, which provided a lens for the development of a conceptual framework in Chapter 2.4.

2.2 Decision-Makers in Climate Governance Arenas

Climate governance was first conceptually defined by Jagers and Stripple (2003, pp. 388) as "*all the purposeful mechanisms and measures aimed at steering social systems towards preventing, mitigating, or adapting to the risks posed by climate change*". From its origins, climate governance was inherently linked to the risks posed by climate change in addition to recognizing that "*governance can take on various forms*" (p. 386) and that it includes many sources of authority such as from the private sector, rather than solely the government.

The recognition of multiple sources of authority is further expanded in the idea of multi-level governance where five dimensions of governance are recognized by Heinen, Arlati, and Knieling (2021, p. 57): "*(1) the governance issue, (2) the types of decision-makers, (3) the types of interactions among decision-makers, (4) the rules-in-use, and (5) the formal degree of dependency among decision-makers*". The possible types of decision-makers are many and heavily dependent on the context of the case. In the Netherlands, the framework of Quadruple Helix is commonly used where four types of stakeholders which decision-making powers are recognized: financial, advisory, governmental and citizens (Carayannis & Campbell, 2009). Citizens are excluded from the scope of the research due to methodological limitations, but the first three groups are explicitly recognized in literature. For example, Jagers and Striple (2003, p. 389) already recognized that leading global insurers were concerned by the threat of bankruptcy as climate change exacerbates natural catastrophes and met in seminars with environmental NGOs and scientists to develop the *Statement of Environmental Commitment by the Insurance Industry*. Previously, Clapp (1998) recognized the existence of private climate regimes where the rules for interactions between decision-makers stem from private rather than public authority.

Unlike the multi-stakeholder perspective, risk assessment tools were not always integrated in the concept of governance as "*mechanisms and measures*" referred solely to the frameworks and actions used to exercise authority and their integration into climate governance came later (Jagers and Stripple, 2003, pp. 388). The integration of assessment tools originates in Integrated Climate Governance (ICG) which is defined by Tàbara (2011, p. 91; Figure 3) as "*a transition-oriented appraisal approach focused on the creation of assessment tools, policy instruments, and agent-based capacities aimed at dealing in an integrated way with multiple scales and domains related both with mitigation and adaptation*" with the objective of transforming agents to support sustainability in the EU. Furthermore, Tàbara (2011, p. 94) highlights "*that unless new processes, tools and methods are developed which are specifically addressed to tackle issues of power and agent transformation, there is little change of progress toward a transition to sustainability*".

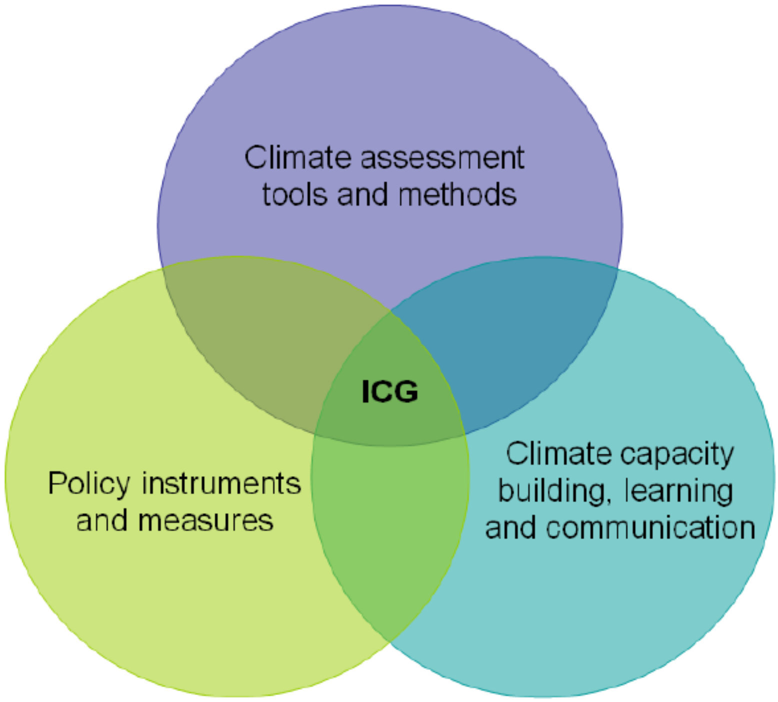

Figure 3. The components of integrated climate governance (ICG). Retrieved from Tàbara (2011).

When stakeholders and their assessment tools are brought together, a governance arena is formed. They are the physical, virtual and conceptual places where these diverse types of decision-makers interact according to set of rules and a degree of dependency to influence or implement policies related to climate. To inform their decisions, the decision-makers utilize decision-support tools such as CRA (Dore, Lebel, and Molle, 2012). The concept of climate governance arenas expands upon the original definition of Jagers and Stripple (2003) by focusing on the physical and abstract space in which different types of decision-makers with a degree of dependency interact according to a set of rules to make decisions about a climate governance issue.

The theory of climate governance arenas is applied as a framework by Dore, Lebel, and Molle (2012) to study transboundary water governance complexes. Smits and Middleton (2014) also apply it to study the effects of a decision-support tool, the Climate Finance Scheme, to support hydropower. This case sets further precedent for the use of the framework to study the role of CRA in governance as it was applied previously to other decision-support tools. In the context of the thesis, CRA is seen as a tool which brings scientific knowledge of climate risks into the decision-making processes of the municipality (Figure 4). They support existing or open new arenas which are physical and digital places where stakeholders are engaged and take decisions. Within these arenas, there are differences in the types of engaged actors, their power, and politics. Decisions refer to whether a process yields new policy, regulations, investments, or incentives. The impacts of these decisions are then the consequences of the decision which then again affect the context and the drivers in a circular process. The important development of this framework is the combination of actors, powers and politics as variables of climate governance arenas which are affected by technical tools (Dore, Lebel, and Molle, 2012).

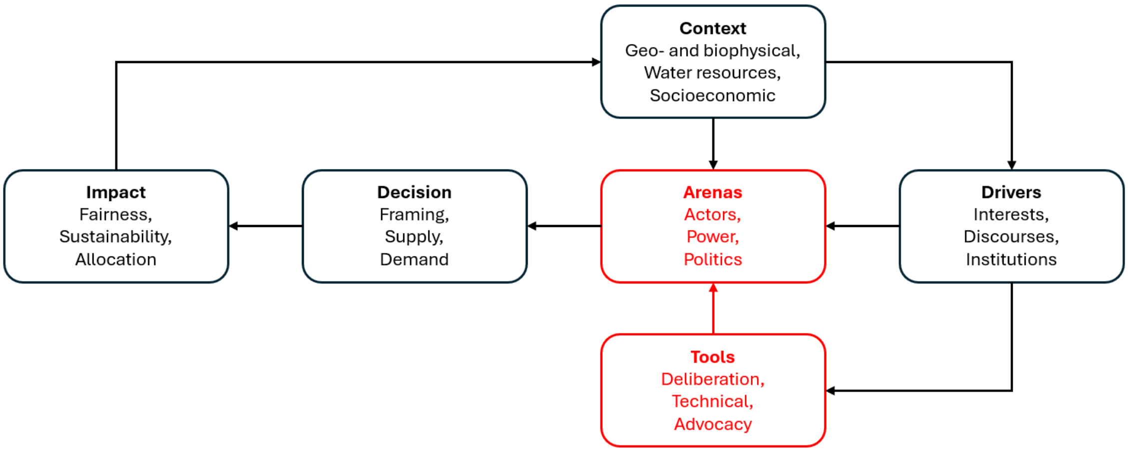

Figure 4. Framework for analyzing the role of CRA as a tool in climate governance arenas (highlighted in red). Adapted from Dore, Lebel, and Molle (2012).

2.3 Climate Risk Assessment as a Decision-Support Tool

At its simplest, risk is "*the potential for adverse consequences in human and ecological systems*" (Reisinger et al., 2020, p. 4). In the context of climate governance however, the meaning of risk is more complex as two types are commonly recognized, those being transition and physical risks (Cardona et al., 2012). The former is defined as risk related to the transition towards a more sustainable economy to mitigate climate change. The latter, which is the focus of this research, is the risk resulting from climate change driven by acute and long-term shifts in (TCFD, 2017). Physical climate risk consists of three determinants as defined by Cardona et al. (2012) which in turn draws on multiple other sources to define each factor: First, hazard is "*the possible, future occurrence of natural or human-induced physical events that may have adverse effects*" (p. 69). In the Netherlands, it is commonly categorized as either pluvial flooding, fluvial flooding, heat, or drought types of hazards. Second, exposure which is "*the inventory of elements in an area in which hazard events may occur*" (p. 69). Third, vulnerability is "*predisposition, susceptibilities, fragilities, weaknesses, deficiencies, or lack of capacities that favor adverse effects on the exposed elements"* (p. 70).

The assessment of climate risk Is defined as the application of techniques and instruments to qualitatively and quantitatively study uncertain factors which may jeopardize the process of achieving a certain goal (International Organization for Standardization, 2018). The most widely recognized definitions and guidelines for climate risk assessment are published by International Organization for Standardization (2021) with six variables in its implementation: (1) selected impact chains, (2) selected indicators per risk type, (3) availability and quality of data, (4) level of aggregation of indicators, (5) adaptive capacity of organization, (6) and the reporting of results. Impact chain refers to how the effects of hazards propagate through a system at risk while adaptive capacity is the ability of an organization to deal with the effects of the hazard. Indicator is a measurable variable of the hazard and aggregation refers to their combination into larger units. The reporting of results refers to whether the risk is expressed quantitatively or qualitatively for individual or aggregated risks. It can for example be presented as a map, diagram, graph, or a recommendation in text.

2.4 Conceptual Framework

Conceptualizing the full extent of the relationship between technical tools such as climate risk assessment (CRA) and climate governance arenas (CGA) is complex, but it can be visualized in a simplified form such as in Figure 5 where a set of independent variables of CRA influence the dependent variables of CGA. For the technical tool, the variables were selected from ISO (2021) based on their potential relevance for climate governance arenas. For example, the selected impact chains and adaptive capacity of organization are not included due to the complexity of assessing them within the limited timeframe of the research. The selected indicators per risk type are taken from Nationaal Kennis-en Innovatieprogramma Water en Klimaat – Klimaatbestendige Stad (2020) with direct and indirect damage to property as two indicators for the risk type of waterlogging. The level of aggregation is whether the indicators per each risk type are calculated and presented individually or combined into a single value for the risk type. Data availability is the quantity of data which can be used for the assessment in the research area. The scale of data visualization refers to the level of detail at which the results of assessment are visualized. In this case, administrative boundaries commonly used by Dutch local governments are used which are from largest to smallest (Figure 5): municipality (*gemeente*), neighborhood (*wijk*), sub-neighborhood (*buurt*), and building (*gebouw*).

The variables of climate governance arenas are the actors, power and interest which are further divided into sub-variables as described in Dore, Lebel, and Molle (2012). For actors, the type of stakeholder distinguishes between the four types in the quadruple helix model being private, public, civil and research categories. Power is an actor's ability to achieve their desired result in a decision-making process and it is determined by several sub-variables. Involvement in decision-making processes is how they engage with the arena and their strategic position such as them being an authority in climate change research or a policymaker for example. The resources are their financial and human capital in addition to knowledge and data. For interests, climate risk perceptions are prejudices and views of an actor with their perception of a climate risk as a practical example. Additionally, this is determined by their organizational objectives in terms of climate adaptation. Position is their strategic place in the arena such as them being an authority in climate change research or a policymaker for example.

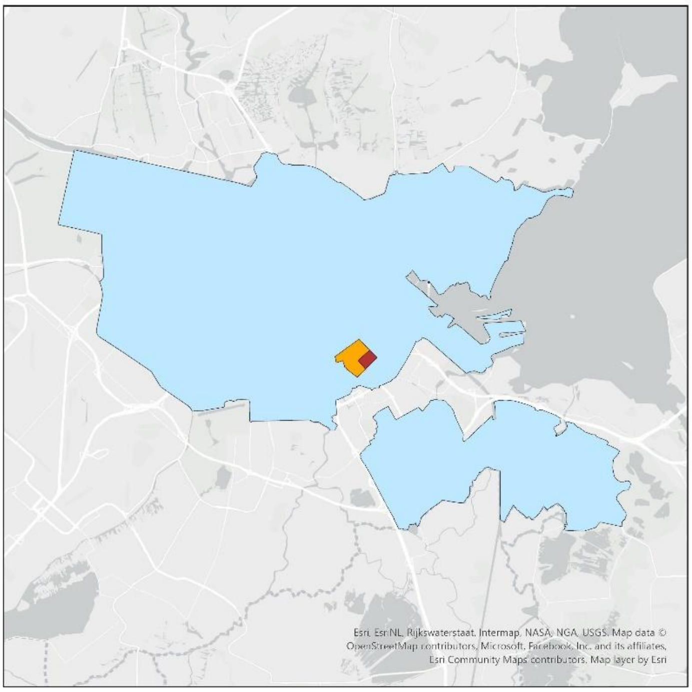

Figure 5. Size comparison of administrative scales: Municipality (light blue), neighborhood (orange), and sub-neighborhood (buurt). Made by researcher.

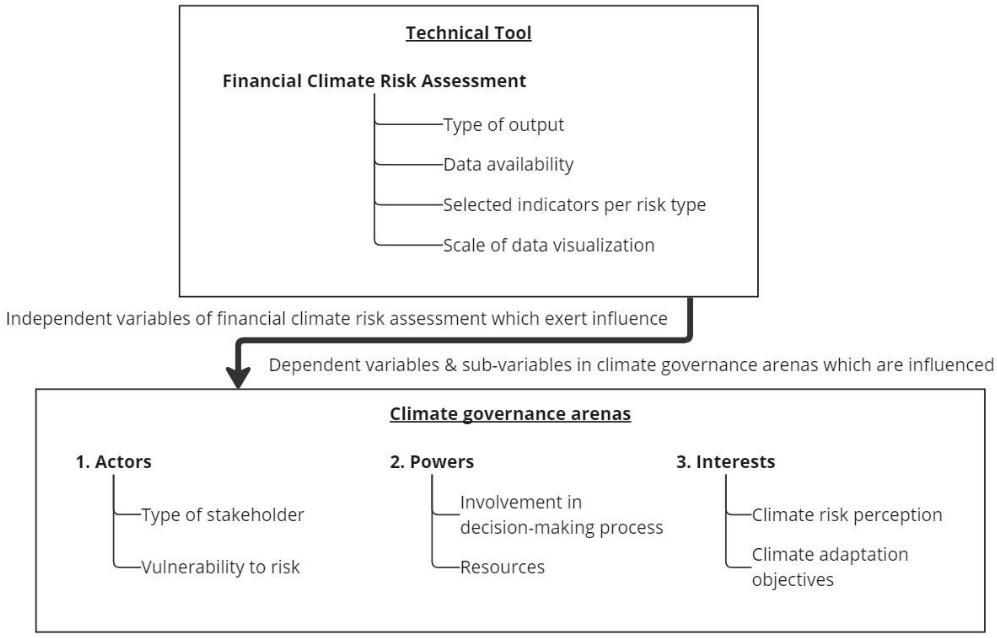

Figure 5. Conceptual framework of the independent variables of a technical tool and their relationship with the dependent variables and sub-variables of climate governance arenas. Made by researcher.

3. Methodology

3.1 Introduction

To answer the research question, a combination of GIS and qualitative research methods was used (Figure 7). Spatial data collection, analysis and visualization techniques commonly applied in GIS were utilized to create exemplary climate risk maps for the Watergraafsmeer area of Amsterdam. These maps were created because alternatives which express risk in a financial value did not exist for the research area. Localized maps were deemed as necessary because they would contribute significantly towards the qualitative research methods employed in the thesis. Their purpose in the interviews was to visually represent the outputs of novel CRA methods to the interviewees in order to identify the role of CRA in CGAs. Localized maps of Watergraafsmeer were utilized specifically because they contributed towards effective collection of data in interviews as respondents were familiar with the visualized area. The data collection process for both the GIS and qualitative research methods are described in Chapter 3.2 while the analysis process is explained in Chapters 3.3 and 3.4.

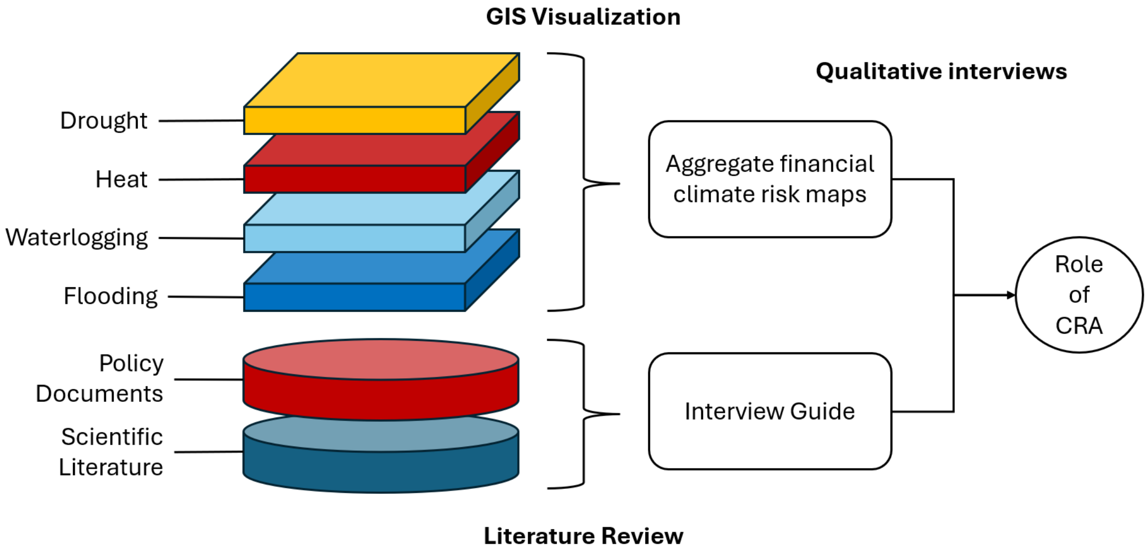

Figure 6. Overview of methods (in bold) and connections between them. Made by researcher.

3.2 Data Collection

Scientific and grey literature was the starting point of data collection and played a central role in the design of an interview guide used for further collection of qualitative data. Additionally, it was used to frame and discuss the findings from interviews in the broader context of climate governance and politics of risk assessment in Chapter 7.2. The approach towards collecting scientific literature was not to systematically review the entire body of research on the central concepts of the research, but instead for orientation in the research area and the wider scientific discourse around these ideas. However, selection was still made as literature which fell outside the scope of the research was excluded, even if it fell within the search terms. Similarly, any literature older than 2014 was not considered unless it was a primary source referenced in more recent papers. The Boolean search strings used on Web of Science were as follows:

- (*"climate risk"* AND (*"assessment"* OR *"analysis"*)) AND (*"governance"* OR *"policy"* OR *"planning"*) OR (*"real estate"* OR *"corporate"* OR *"insurance"* OR *"finance"*)
- (*"climate risk"* AND (*"assessment"* OR *"analysis"*)) AND (*"real estate"* OR *"corporate"* OR *"insurance"* OR *"finance"*)

- (*"technical tool"* OR *"map"* OR *"visualization"*) AND (*"stakeholder engagement"*)
- (*"climate risk"* OR *"climate governance"* OR *"climate adaptation"*) AND (*"Amsterdam"* OR *"Randstad"*)

Grey literature was collected from the website of the City of Amsterdam in addition to various initiatives and organizations directly involved in or influential in the city's governance arenas. These sources were identified based on findings from the review of scientific literature and the analysis of interview transcripts. In terms of selection, news articles were excluded in favor of primary sources such as reports, press releases and policy briefs produced directly by the relevant organization such as the European Central Bank, Amsterdam's Rainproof initiative and the Dutch Green Building Council.

Spatial data was collected from the data repository of the City of Amsterdam and PDOK. The datasets were selected based on their relevancy for the method of creating climate risk maps as described on *Klimaatschadeschatter* (NKWK-KBS, 2020). Datasets older than 2020 were excluded to ensure that the produced risk maps represented recent changes to the visualized area and so they were recognizable to the interviewees.

Semi-structured interviews were conducted to gain in-depth insights into the perspectives of the three stakeholder groups involved in Amsterdam's CGAs. Interviews were necessary as literature which discusses these perspectives of these groups on CRA were not identified. Additionally, the semi-structured approach was chosen to enable follow-up questions being asked to explore unexpected insights which may not be found in scientific literature.

Purposive and snowball sampling methods were employed to identify suitable interviewees. The purposive sampling relied on selecting interviewees who held decision-making positions directly within Amsterdam's governance arenas or were involved in organizations that did. For snowball sampling, an informal interview was conducted at the start of the research process for the purpose of orientation and the creation of an initial list of interviewees. Unlike the following interviews, the orientation interview was not recorded, and its findings were not included in this report. Afterwards, respondents to formal interviews were asked for referrals to relevant organizations if the potential interviewees did not respond to emails or phone calls.

Thirty-eight potential interviewees were contacted via email and phone, resulting in twelve positive responses, an acceptance rate of 32%. One interview was cancelled at the respondent's request, resulting in eleven formal interviews without including the informal interview (Table 1). Efforts were made to sample an equal number of respondents from the three identified stakeholder groups: municipal stakeholders, advisory stakeholders, and financial stakeholders. However, representation was asymmetrical, with six advisory stakeholders, three municipal stakeholders, and only two financial stakeholders participating. This imbalance was caused due to the use of snowball sampling as respondents from the advisory group were more willing to give referrals.

Upon agreeing to participate, each respondent was provided with an informed consent form (Annex A) and the example risk maps (Annex B). At the start of each interview, participants were asked for consent to record and transcribe the anonymized conversation. They were informed that participation was voluntary, that they could withdraw or refuse to answer any question, and that they could request portions of the recording to be removed. Participants were made aware that audio recordings would be deleted after the conclusion of the research, while the processed, anonymized transcripts would be securely stored and shared only upon request, as described in the consent form (Annex A). Consent was given both verbally and in writing, except in the case of Interviewee 5, who only gave clear verbal consent, which was noted on the form by the researcher after the interview. Interview 4 was conducted in English at the respondent's request, while the remaining interviews were conducted in Dutch. All interviews were transcribed, and Dutch transcripts were translated into English, with original Dutch versions retained except for Interview 4.

Three tailored versions of the interview guide were created, one for each stakeholder group (Annex C). The questions were adjusted to align with the background and expertise of each group. During the interviews, the interviewer deviated from the guide in all interviews to explore spontaneous and unexpected but relevant topics. These deviations are noted in the transcripts but are not included in the interview guide.

*Table 1. Overview of interviewees. Made by researcher. *Organizational cluster in case of the municipal stakeholder type.*

Number	Date	Stakeholder Type	Category of Organization*
#1	19 June 2024	Municipal	Digitalisation, Innovation and Information
#2	18 June 2024	Municipal	Public Space and Economy
#3	24 June 2024	Municipal	Public Space and Economy
#4	2 July 2024	Advisory	Public research university
#5	6 June 2024	Advisory	Public research university
#6	18 June 2024	Advisory	Consultancy – Public Infrastructure
#7	4 July 2024	Advisory	Consultancy – Data Provider
#8	29 May 2024	Advisory	Consultancy – Public Infrastructure
#9	26 June 2024	Financial	Pension Fund
#10	12 June 2024	Financial	Pension Fund
#11	5 June 2024	Advisory	Consultancy – Public Infrastructure

3.3 Spatial Data Visualization

The purpose of data visualization was to create example risk maps that can serve as basis of discussion in the semi-structured interviews. To create them, the collected spatial data in the JSON format was imported into ArcGIS Pro using the JSON to Feature function and reprojected to the RD New coordinate system as it was originally in the WSG 1984 projection. Each input dataset was clipped to the geographic boundaries of the Wategraafsmeer area within the municipality of Amsterdam. The geographic boundaries of Wategraafsmeer were obtained by selecting the following neighborhood geometries in the dataset without dissolving them. As a result, one dataset with multiple polygons, each being a neighborhood, was created. Additionally, the building dataset was first merged as it was downloaded in multiple separate tiles and then clipped to contain only Watergraafsmeer without using the dissolve function.

The calculation of the waterlogging, flooding, heat and drought risks followed the method used by *Klimaatschadeschatter*. As these calculations were not possible for all indicators of climate hazards due to data limitations or methods being unsuitable for application on a neighborhood scale, only a limited number of indicators was assessed and visualized:

The results of the calculations were visualized in three layouts: (1) waterlogging & flooding, (2) drought and heat, (3) and a map which sums the costs of all hazards (Annex B). The color scheme and overall style of the layouts was uniform across the three maps. Additionally, each layout included a disclaimer regarding the validity of the calculated risk and warned that the maps were created solely for the purpose of collecting qualitative data for research by the researcher and could not be applied in any other way.

3.4 Qualitative Data Analysis

The qualitative data gathered in interviews was first preprocessed by editing the raw transcripts for readability using the software Descript. The raw transcripts were first translated into English using the software, and repeated and filler words were removed. Furthermore, the transcripts were anonymized by removing any overt references to the identity of respondents, their professional affiliations, or any other identifiable information.

A hybrid coding approach was employed for the analysis of the edited transcripts. A basic coding frame was constructed using the deductive approach where a basic coding frame was constructed based on the operationalization outlined in Chapter 2.4. Subsequently, the frame was expanded following an inductive strategy incorporate emergent themes and unexpected patterns that surfaced during the analysis. This was done to ensure that all relevant insights were captured even if they were not grounded in the initial theoretical framework, The exact changes are discussed and reflected upon in Chapter 7.3.

The coding process was performed in two stages which first involved the basic coding framework. The edited transcripts were read line-by-line and assigned codes in Atlas.ti. As new patterns began to emerge, the coding frame was refined, and all transcripts were coded for a second time using the final version of the coding frame. To extract specific insights, supporting evidence and contradicting statements in the coded transcripts, co-occurrence analysis was done in Atlas.ti using its table option and a manual review of the coded fragments of the transcripts.

Using the hybrid coding approach, a significant number of insights was retrieved from the interview transcripts and various perspectives were collected regarding the potential role of the example climate-risk maps in Amsterdam's CGAs. The results of the analysis are listed in Chapters 4 to 6, while directions for further research are discussed in Chapter 7.4.

4. Amsterdam's Arena Under the Magnifying Glass

4.1 Introduction

To identify the role of climate risk assessment (CRA) in Amsterdam' climate governance arena (CGA), this chapter sets the first step by introducing examples of initiatives which exist within the CGA of the research area and analyzing the relevant actors. This chapter contains four sections where three representative examples of arenas are described, each led by a different type of stakeholder. In the fourth subchapter, the stakeholders are mapped in a power-interest matrix, and the conflicts and synergies between them are revealed. Two of these conflicts are highlighted with corresponding synergies which may counteract them. This sets the stage for Chapter 6 where the opposing and convergent interests of the stakeholders shape the future role of climate risk assessment.

4.2 The Municipal Climate Adaptation Program

Amsterdam's Climate Adaptation Program (*Klimaatadaptatieprogramma*) is an example of a government-led CGA where separate organizational branches of the City of Amsterdam meet with the overarching goal of making "*climate adaptation a standard mindset in the municipality*" (#3). It is a unique arena as it currently engages actors from a single stakeholder type with the explicit goal of influencing future policy and moreover, it is an evolution of initiatives which not only affected policymaking but also their implementation (#2).

The Climate Adaptation Program parallels the objectives of the Rainproof and Weatherproof initiatives but with a focus on solely the local government, and it can be seen as their effort to transform the municipal organization itself. As the Program influences the mindset of municipal officials, Rainproof and Weatherproof translate that mindset into change within the city. This is reflected in the difference in the composition of actors that Rainproof involved during its history versus the Climate Adaptation Program.

Starting in 2013, Rainproof was led by the municipality of Amsterdam and the local water company *Waternet* to make the city more resilient to extreme rainfall events by fostering collaboration with various urban stakeholders to "*provide a more fertile breeding ground for incorporating blue and green infrastructures in the city*" (Willems & Giezen, 2022, p. 11). This initiative evolved into Amsterdam Weatherproof which seeks to also address the climate hazards of drought and heat by for example "*employing a data-driven approach towards 'opportunities' rather than climate threats"* (Willems & Giezen, 2022, p. 7).

As of 2024, Weatherproof included around 110 partners around the city, but notably only seven of these are involved directly in real estate (Weerproof, 2024). The composition of actors involved in the overarching Climate Adaptation Program is even more limited as it includes only municipal clusters with the notable mentions of Data, City Development (*Grond en Ontwikkeling, G&O*), and Mobility and Public Space (*Verkeer en Openbare Ruimte, V&OR*) which are most influential in the management of the city's spaces (#1, #2 & #3). Additionally, the Municipal Real Estate (*Gemeentelijk Vastgoed, GV*), a branch of the municipality which manages its publicly owned buildings, is highly influential in the local government where it shares a similar interests and powers to financial stakeholders (#2).

The Climate Adaptation Program has made steady progress In entrenching climate adaptation as the standard mindset in municipal projects (#1 & #2). However, its success in addressing the relevant stakeholders from outside the local government is limited to the Weatherproof initiative where real estate actors are heavily underrepresented (#3; Weerproof, 2024). This concern is especially acute as the climate-adaptation mindset becomes increasingly entrenched within the municipality, but not in the financial actors with increasingly divergent interests between these stakeholder types.

Additionally, this is in conflict with the municipality's commitment to fostering collaboration with various urban stakeholders as a large and influential segment of them is excluded from this arena.

4.3 Red & Blue Consortium

The *Real Estate Development & Building in Low Urban Environments* (Red&Blue) program is an example of a climate governance arena which is led by the advisory stakeholder type, being the AMS Institute in Amsterdam. It is seen as relevant due to its unique position as a bridge between the municipality and actors involved in Amsterdam's real estate sector with the overarching aim of helping to address physical climate risks in the city. It is an arena as it involves multiple actors with the explicit objective of employing an interdisciplinary and data-driven approach to influence a future climate governance strategy in the Dutch delta region, which includes Amsterdam.

Launched in 2022, the consortium brings together governmental, advisory and financial types of stakeholders through living labs and workshops to attune the strategies of the public and private sectors (Figure 8; van Vliet & Mol, 2022). It targets climate resilience in the real estate specifically due to potential of physical climate risks to disrupt this sector with negative consequences for all involved parties ranging from tenants and homeowners to mortgage lenders, insurers and pension funds (Red&Blue, 2024).

Despite successfully bringing together the diverse actors involved in Amsterdam climate governance into discussion, Red&Blue faces the challenge of effectively bridging the gap between its municipal and real estate partners due to the "*politically charged and potentially conflictual*" nature of the sector (Red&Blue, 2024, p. 13). This echoes the sentiment expressed by other advisory actors which expressed that financial actors seek to address physical climate change hazards with different motivations and measures than the municipality of Amsterdam (#4). For example, a pension investment company targeting real estate is primarily motivated by the growth of its fund with fluvial and coastal flooding leading to potential damages to an asset, and thus a higher insurance premium with lower financial returns for the investor (#10). On the other hand, a municipal official seeks to minimize the risk of flooding to protect the wellbeing of the city's residents. The potential financial costs from damage to private property are viewed as the owner's personal risk (#2). Finally, the financial actors have only gained a vested interest in assessing and addressing physical climate risks only recently with the advent of European Central Bank's legislation in 2020 which sets expectation for investors to disclose climate risks of their portfolios (#4; European Central Bank, 2020).

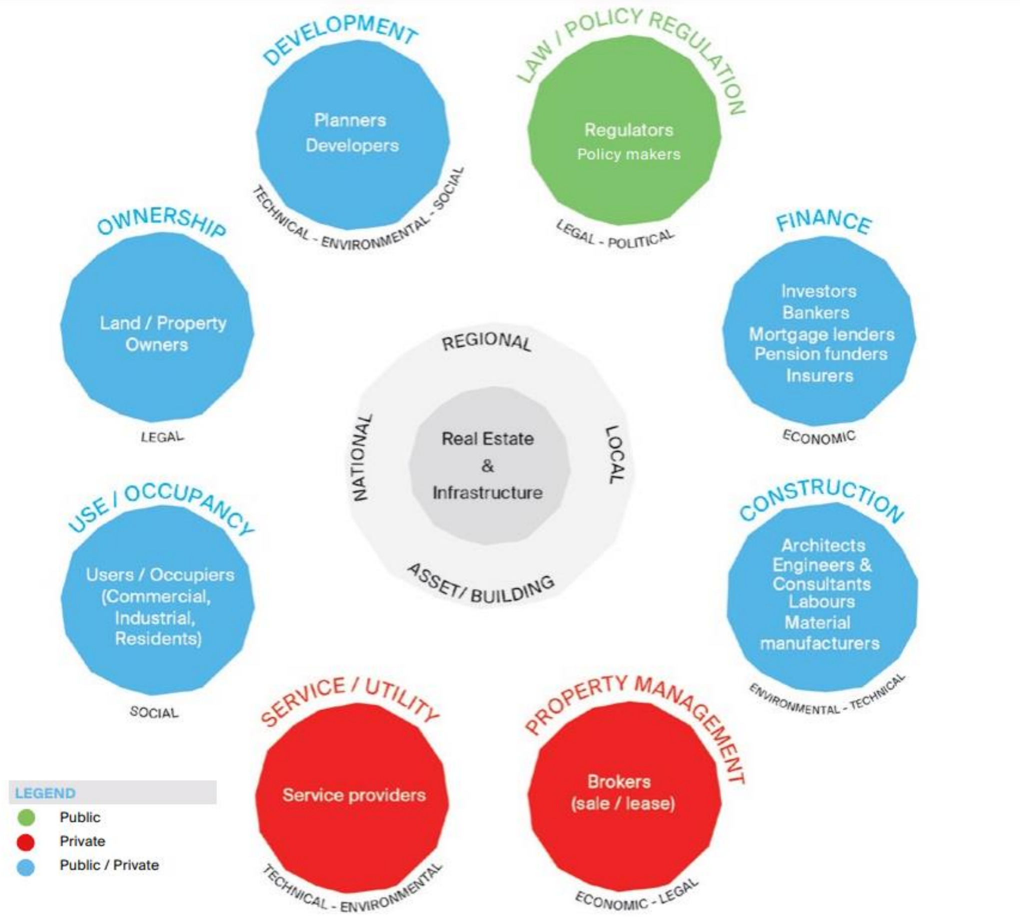

Figure 7. An overview of real estate, municipal and other actors seen for Red&Blue. Retrieved from Red & Blue (2024, p. 12)

4.4 Dutch Green Building Council

The Dutch Green Building Council, a foundation and network of organizations involved in the built environment of the Netherlands, exemplifies an arena where the financial institutions take the leading role in decision-making to influence policy. It seeks to establish sustainability as the leading value for the real estate sector at a national scale by bringing diverse actors together and supporting them in the conceptual development and implementation of sustainable building practices under the themes of CO2-neutrality, circularity, climate adaptation and health.

The foundation was launched in 2008 as part of the World Green Building Council with the bank ABN AMRO and other financial stakeholders such as Redevco, Dura Vermeer, SBR, and INBO as the founding partners in addition to the municipality of Amsterdam.

Despite the foundation's recent success in finalizing the Framework for Climate Adaptive Buildings, there are concerns regarding the data requirements of the framework which may limit its potential for wider implementation in the built environment as a standard or model for governmental regulations. Additionally, its involvement with local governments, such as the founding partner City of Amsterdam, appears to have decreased as the framework is not considered or integrated in the Climate Adaptation Program (#2).

4.5 Conflicts and Synergies Between Stakeholders

When viewed in isolation, the stakeholders within these arenas seem to work towards the same objective of contributing towards a climate-resilient and sustainable Amsterdam (Table 2). The Climate

Adaptation Program exists firmly in the network of Amsterdam's climate governance while Red&Blue aims to connect it with the real-estate actors' own network (Figure 9). However, there are several conflicts in their strategies and interest in the specific facets of climate resilience.

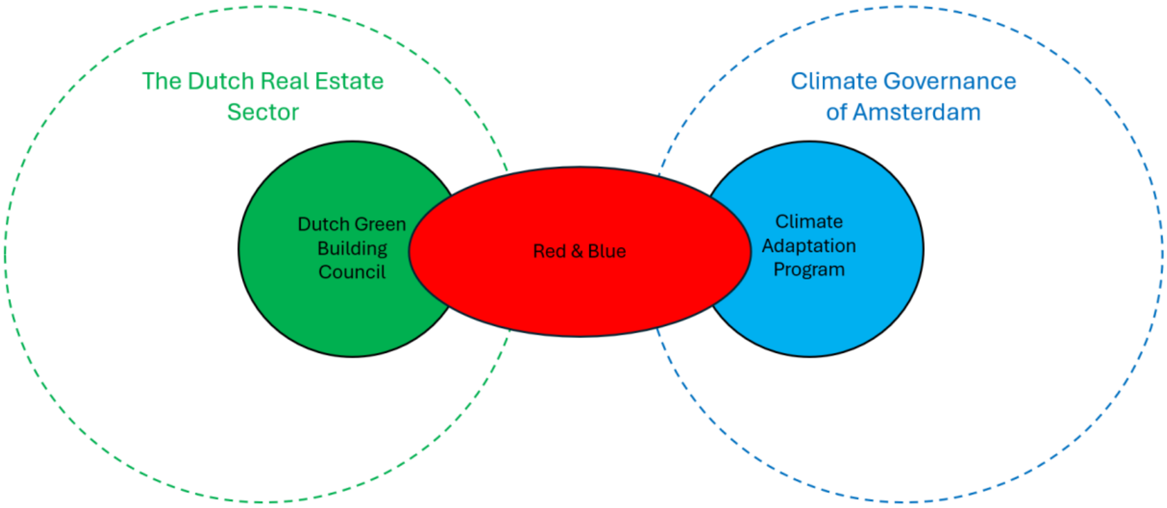

Figure 8. An idealized representation of how the three governance arenas connect with each other. Made by researcher.

For example, the municipal, advisory and financial stakeholders are interested in different physical scales for their analysis and measures. Local governments seek to improve the local environment and as such, do not pursue analysis on the global, national or even regional scales (#2). On the other hand, financial institutions such as real estate investors often operate on a global scale with portfolios spanning multiple continents with in-depth information about specific properties. As such, these organizations operate on the finest scale of analysis, the individual building, but expect global data coverage (#9 & #10). Meanwhile, the municipality operates only locally with an eye for scales greater than an individual building. They seek information that showcases the interdependency of characteristics in a public space such as a street or neighborhood (#3). This difference stems from the tendency of building-level characteristics to determine an asset's value to financial actors, while the characteristics of the surroundings affect the wellbeing of citizens. Additionally, financial actors cannot determine the composition of the public space while the municipality can (#2).

However, there are still overlaps to be found between the stakeholder types in terms of scale used for assessment of risk and the implementation of adaptation measures. Both the municipality and financial actors value the street and neighborhood scales, representing the public space, for different reasons. There are reasons for that such as G&O and V&O having the greatest influence over public space with only a limited ability to make private spaces more climate adaptive. As such, they are not interested in assessing climate risks at the scale of private buildings. To ensure the wellbeing of Amsterdam's residents, the municipality operates primarily on the scale of streets and sub-neighborhoods (*buurten*) to effectively design and implement their adaptation measures (#2 & #3). While financial organizations such as real estate investors may be primarily interested in the building scale, they still recognize that public space affects property values which makes the public space at street and neighborhood scales relevant. While they cannot effectively change it, financial stakeholders still see value in analysis beyond the building scale as urban greenery and attractive public spaces raise asset values (#10). Similarly, the municipality does not entirely devalue data about private terrain and buildings. For example, the Green Monitor utilizes remote sensing techniques to obtain data about private greenery as it improves the quality of their analysis at the neighborhood scale (#1). To conclude, while both municipal and financial stakeholders may claim that only a specific scale is relevant for their risk assessment, they may still use other scales if there is adequate argument for doing that.

Next to the conflict in preferences for the scale of risk assessment, there is disagreement in the overarching motivations between the municipal and financial stakeholders. The former is incentivized to analyze physical climate risks to climate-proof the city and thus ensure the wellbeing of its residents (#2). The latter pursues profit, the growth of their portfolio and better returns on investment which does not traditionally require the assessment of physical climate risks in the case of the Netherlands (#10).

Despite the pursuit of profits being the primary motivator for the financial stakeholders, there are different strategies and perspectives on this. In the case of pension fund investors, there is a distinction between bottom-up and top-down investment strategies which both value different outcomes but can still be combined into one optimized strategy (#10). At its simplest, the bottom-up strategy involves in-depth analysis of individual investments such as the exposure to climate hazards of a building. This is an attractive strategy for investors concerned with physical climate risks as it gives them insight into how their portfolio will be affected by hazards such as extreme rainfall or hail (#9). On the other hand, the top-down approach focuses on financial trends on the larger scale without analysis at the building-level of investment (#9). Large organizations with the greatest capacity for complex analysis can combine these approaches and analyze their investment in a building both at the finest and largest scales of environmental and financial trends (#10). Ultimately, this means that both financial and municipal stakeholders aim to create attractive environments that contribute towards a higher quality of housing and there is potential to align their goals further in the governance arenas.

Table 2. Summary of the three examples in the CGA of Amsterdam. Made by researcher.

ORGANIZATION	OBJECTIVES	STAKEHOLDERS	METHODS	CHALLENGES	FUTURE VISION
AMSTERDAM WEATHERPROOF	Enhance climate resilience by managing rainwater through collective action	City of Amsterdam, Waternet, community initiatives; excludes banks and real estate investors.	Uses simulations, maps, and stakeholder collaboration	Limited enforcement; difficulty engaging the real estate sector	Expand Weatherproof strategies within broader urban development
RED&BLUE PROJECT	Develop integrated strategies for climate-resilient real estate and infrastructure	Consortium of universities, cities, and private firms	Uses living labs, focuses on governance, law, and finance	Fragmented strategies, aligning public-private interests	Create models for climate-resilient real estate in urban areas
DUTCH GREEN BUILDING COUNCIL	Promote sustainable building practices via	350+ members from real estate, finance,	Administers BREEAM-NL, offers	Adapting to new market demands,	Support net-zero carbon goals by 2050, focus on

	BREEAM-NL certification	and public sectors	professional training DCGB assessment framework	competing certifications	circular construction

5. Current State of Climate Risk Assessment

5.1 Introduction

Contemporary climate risk assessment is the method used to estimate the exposure and vulnerability of objects and locations to climate hazards such as flooding, heat and droughts, expressed either as a score or financial estimate of costs. This chapter discusses the differences in the results produced by the different assessment methods, the intended scale of assessment, their data requirements, and selected indicators for each climate hazard. The different levels of aggregation used are introduced and reasons for using them are given. Afterwards, the selection of indicators is discussed with causes given for including or excluding specific ones. Furthermore, the availability of data per indicator types is discussed with an eye for differences in requirements per type of results. These differences are highlighted in the cases of *Klimaatschadeschatter* and the Climate Adaptive Buildings Framework (CABF) which different methods used in the Netherlands are recognized in the climate governance of Amsterdam.

5.2 Klimaatschadeschatter

Klimaatschadeschatter is a financial climate risk assessment tool produced through the collaboration of academic institutions and various consultancies which were involved in specific stages of its development from 2018 until its last update in 2020. Its first module, the *Wolkbreukschadeschatter,* started with solely the cost estimation of the pluvial flooding climate hazard at the street scale, which practically meant a group of building parcels along the road (#5 Public research university, #6 & #8 Consultancy – Public Infrastructure). It estimated the direct and indirect costs of pluvial flooding to these parcels in euros per year for the period of 2018 to 2050 because these numbers allowed for the identification of risk hotspots and represented the financial consequences of risk clearly (#8 Consultancy Public Infrastructure). It did not include highly specific information about each building, but rather differentiated between low-rise versus high-rise buildings, and residential versus commercial (#6 Consultancy Public Infrastructure). The method also produced a range of estimates with "*no climate change*" scenario as its minimum and "*high climate change*" as maximum based on the Koninklijk Nederlands Meteorologisch Instituut (KNMI) 2013 scenarios. The correctness of these cost estimations for specific buildings was not high, but when aggregated into larger clusters, the maps of costs still have insight into hotspots of risks in terms of costs (#5 Public research university).

As the *Wolkbreukschadeschatter* evolved into *Klimaatschadeschatter*, its selection of hazards and their indicators expanded beyond pluvial floods to include fluvial floods, drought and heat (#8 Consultancy Public Infrastructure). Moreover, pluvial flooding now also included costs of hail, damage to electricity boxes, traffic hinderance and resident infections as indicators, although with a strong disclaimer about the limitations of how these costs were estimated. The selection was expanded to give more complete insight into urban climate hazards generally as the interests of the targeted stakeholders went beyond just pluvial flooding (#6 Consultancy Public Infrastructure). Similarly, the aggregation changed and instead of showing individual buildings along a street, the costs were aggregated for the entirety of the municipality with comparison possible only between municipalities at the national scale. The most likely reason behind this significant change of scale was the reliability of the results at finer scale like individual buildings or street, although this caried significant implications for the usability of these results for various urban stakeholders (#7 Consultancy Data Provider).

As of its final update in 2020, *Klimaatschadeschatter* gives insight into the financial costs, in euros per year, between 2018 and 2050 for four climate hazards: drought, heat, fluvial flooding and pluvial flooding with separate indicators for each. The costs are calculated separately for indicators and then first aggregated per climate hazard type, and then per municipality. The reliability of the estimates differs per indicator and different formulas and input datasets are used for each. The purpose of the cost estimates it gives is to show the audience, primarily municipal officials involved in the management of the public space and the councils they serve, the costs of inactions in terms of implementing climate adaptation measures (#2 Public Space and Economy). Additionally, they can be of interest to higher levels of government such as the province, although this falls outside the scope of this research (#6 Consultancy Public Infrastructure). Their value to other stakeholders, however, is limited due to the choice of aggregating risk only at the municipal scale rather than neighborhood, sub-neighborhood or individual buildings. They are supposed to evoke the urgency of implementing measures by showing the expected costs of future floods and heat waves. In practice, visualization at only the municipal scale does not provide the municipal officials with enough information to affect their actions in regard to managing physical climate change risks (#2 Public Space and Economy).

5.3 Climate Adaptive Building Framework

The CABF was created by the Dutch Green Building Council (DGBC) differs from the *Klimaatschadeschatter* in terms of its outputs, intended scale of assessment, data requirements and the selection of climate hazards which it assesses. The overall objective of the method is to support financial stakeholders, such as real estate investors and property owners, who are involved in the Dutch built environment to meet the requirements of the EU Taxonomy and the Task Force on Climate-Related Financial Disclosures (TCFD; Kadijk et al., 2022). It achieves this objective by establishing two risk assessment methods and a framework which translates the resulting risk scores into actionable strategies for climate adaptation. The color-coded risk scores range from low risk to very high risk, zero impact to severe impacts requiring immediate adaptation respectively, which are combined into an overall score that can be used for prioritization of buildings and areas for adaptation, selection of suitable climate-adaptation measures, and the evaluation of adaptation progress (Bakker, Kadijk, Prijden, van de Velde, & Verbrugge, 2024).

Unlike the *Klimaatschadeschatter*, the CABF produces scores on two different scales (Table 3). First, the environmental score (*omgevingscore*), which assesses the surroundings of a property, and reflects the intensity and frequency of external hazards for a property. Effectively, it represents the exposure variable in risk. A score is calculated for each of the four types of hazards recognized by the DGBC which are heat stress drought, pluvial flooding and fluvial flooding. The highest of these four scores is selected as the environmental score. As it is not an average, the environmental score only reflects the risk of the most significant climate hazard in the location which can then be flagged as a priority for climate adaptation to guide further assessment of risk at the building level (Kadijk et al., 2022). Second, the building score (*gebouwscore*) which assesses the vulnerability variable of risk r a specific building to the climate hazards which were identified as impactful in the calculation of the environmental score. The score is not an average, but rather the highest score found for the individual hazards which are explicitly connected to building characteristics. For example, the score for heat stress is determined by the percentage of glass on a building's façade, the quality of insulation and ventilation and other data such as the function of the building and the density of occupants during extreme heat events. Finally, they are combined into an overall score using a maximum approach where high environmental risk takes precedence over the building score. For example, a building with high environmental risk but also low vulnerability will still be marked as overall high risk. A building with low environmental risk, but high vulnerability will be marked with overall high risk as well. This enables the relevant stakeholders to identify the actual risk of a property and whether it is caused by environmental factors or the inherent vulnerability of a building's design (Kadijk et al., 2023). The overall score enables the property's owners to prioritize which climate adaptation measures should be implemented most urgently and to meet the risk disclosure standards imposed by the TCFD (Bakker, Kadijk, Prijden, van de Velde, & Verbrugge, 2024).

The necessity of calculating both the environmental and building scores to obtain the overall risk score for a property complicated the data requirements of the CABF risk assessment method compared to *Klimaatschadeschatter.* The environmental score has the most comparable requirement which requires various types of climate and topographic data that is in many cases openly accessible on online databases such as PDOK or can be acquired from climate data and service providers. For example, elevation, flood depth, soil type and land surface temperature datasets may be used for the calculation of the score (Kadijk et al., 2022). On the other hand, the building score requires data which is rarely openly accessible such as structural, design and occupancy data for the specific building (Kadijk et al., 2023).

There is significant overlap in the selection of indicators for each climate hazard between CABF and *Klimaatschadeschatter*, although with some differences caused by the differences in the objectives of the tools. As the CABF focuses on the built environment and individual buildings, it does not include indicators such as the expected damage to public area greenery or agricultural losses for the drought hazard. Instead, it aims to primarily represent the risk of foundational damage due to water table changes (Bakker, Kadijk, Prijden, van de Velde, & Verbrugge, 2024). The differences are even clearer for the pluvial flooding hazard where costs to public infrastructure are not considered in favor of focusing solely on the effects which can be ascribed to a specific property (Kadijk et al., 2023). Such differences between *Klimaatschadeschatter* and CABF are explained by the differences in objectives between the tools as the former expresses a wider range of societal costs per municipality while the latter expresses the risk of a property for an intended audience of real estate investors, property owners and managers, and insurers (#7 Consultancy Data Provider).

Table 3. Overview of types of scores given in the Climate Adaptive Building Framework. Made by researcher.

SCORE TYPE	FOCUS	INPUT DATA SOURCES	DATA TYPES
ENVIRONMENTAL SCORE (EXPOSURE)	Climate hazards in the property's surroundings.	Open access: KNMI, AHN, PDOK, CAS	Climate data: - Regional hazard maps (e.g. flood depth maps) - KNMI'14 Climate Scenarios Geospatial and topographic data: - Elevation maps - Soil type maps - Location of local water bodies Groundwater level maps
BUILDING SCORE (VULNERABILITY)	Building-specific vulnerability to hazards.	Not open access: Architectural plans, inspections, maintenance logs	Structural data, design features, maintenance records

OVERALL SCORE (RISK)	Risk: Combined risk assessment of environmental and building vulnerabilities.	All of above	All of above

5.4 Challenges of Data

Four main categories of data used for climate risk assessment were identified during the research: Starting with (1) building data, this is usually the finest level of data which represents the building's characteristics that determine its vulnerability to physical climate hazards such as the type, number and orientation of windows in terms of the heat hazard. The (2) environmental data related to the surroundings of the building or various locations within an administrative boundary such as a neighborhood. For the pluvial flood risk, this would be the elevation in the form of a digital elevation model. Then there is the (3) socio-economic (4) and demographic data which may be used directly to estimate the risk of deaths in heat waves based on the number of the elderly living in a neighborhood or municipality (#7 Consultancy Data Provider). However, this data type may also be used differently. While data about the average income in a neighborhood is not used to assess flood or drought risk, it can offer novel insights when mapped in combination with physical climate hazards which are of interest to specific stakeholder groups which will be discussed at length in Chapter 6.1 (#5 Public research university).

Not all these types of data are suitable for assessment at every level of visualization. For example, socio-economic and demographic data can hardly be used for assessment of building-specific risk and rarely is this data even available for each specific household (#7 Consultancy Data Provider). Similarly, building-specific data may not seem suitable for assessment at neighborhood level but once aggregated it may prove suitable and offer valuable insights. In practice though, it is rarely open data and usually held privately by financial stakeholders such as asset managers and real estate investors who are hesitant to share it outside of their organizations (#9 & #10 Pension Fund Investor). Finally environmental data is generally suitable for assessment at all scales of visualization. The flood risk mapped for a neighborhood offers valuable insight into hotspots of risk for the entire area and indicates the risk for individual buildings (#11 Consultancy Public Infrastructure).

In practice, acquiring enough of suitable data is a greater challenge for the heat and drought hazards compared to pluvial and fluvial floods. As the methods for flood risk assessment are well established in the Netherlands, so is the data infrastructure to support them with a plethora of open data options. On the other hand, assessment methods of drought and heat are novel, and less open data is available (#5 Public research university).

Ultimately, it is the feasibility of assessment methods and the availability of data which determine whether a risk score, financial estimate of the costs or a label can be produced for a building or an administrative area. As seen in the examples of *Klimaatschadeschatter* and the Climate Adaptive Buildings Framework, a score and costs can be feasibly estimated, although there are concerns regarding the validity of these results from all stakeholder groups. Finally, no example of implementation was identified for a climate label in the Netherlands.

5.5 Current Challenges of CRA

The challenges of climate risk assessment start with the significant concerns regarding the correctness of their results and whether they can be feasibly performed, especially in the assessment of heat and drought hazards. In the example of *Klimaaschadeschatter*, even the pluvial flood hazard carries concerns due to its inclusion of hail as an indicator which does not have a well-developed method of assessment and translation into a risk score or cost estimate (#4 Public research university & #8 Consultancy Public infrastructure).

There is however much interest in the development of new methods for the assessment of specific indicators such as hail from the advisory and financial stakeholder groups. The advisory group for example seeks to develop a method of direct assessment of risk and its translation into costs using environmental data (#5 Public research university). On the other hand, the financial group seeks to first utilize data provided by insurers from past hail insurance claims to extrapolate future events in the form of costs (#10 Pension Fund Investor).

While there is much done to express climate risk as a financial estimate, there are few examples with significant coverage of the Netherlands besides the *Klimaatschadeschatter* which has not been updated since 2020 and does not integrate the newest KNMI Climate Change Scenarios of 2023 (#8 Consultancy Public Infrastructure). This still increases its relevancy and value as a financial climate risk assessment tool with the greatest coverage and history of implementation in the municipal climate governance within the Netherlands (#6 Consultancy Public Infrastructure). There is much interest in learning about the financial consequences of physical climate change hazards, but few openly available tools exist to fulfill this demand.

Despite the current lack of implementation for financial climate risk assessment, there is much opportunity in its future as indicated by the interest of all stakeholder groups in the further development of the method. This is further amplified by the dissatisfaction with methods that produce risk scores as results (#9 & #10 Pension Fund Investor), and the distrust towards the implementation of a climate risk label (#7 Consultancy Data Provider).

6. Information Needs and Climate Risk Assessment

6.1 Introduction

The purpose of the chapter is to showcase what each stakeholder group needs from climate risk assessment in terms of their preference for specific types of hazards to establish whether the tools in their current state address the information needs of the stakeholders. These preferences extend to the scale of assessment such as the building scale being strongly preferred by the financial stakeholders while the municipality deems it as less relevant than the neighborhood scale. Finally, these needs are placed in the context of Amsterdam's climate governance arena and the information needs of its stakeholders

6.2 The Relevance of Risks for Stakeholders

The choice of indicators is a key determinant for the role that climate risk assessment takes in a climate governance arena. There are significant differences between stakeholder types and their preferences for specific indicators as determined by their organizational objectives. The overarching objective of the advisory stakeholders is the provision of novel information regarding the consequences of climate change as part of their business model (#6 Consultancy Public Infrastructure & #7 Consultancy Data Provider). For the municipal stakeholders, resident wellbeing and the continued functioning of the city are central (#1 Digitalization, Innovation and Information; #2 & #3 Public Space and Economy). On the other hand, the financial group prioritizes profits and the continued growth of their portfolios in the case of the investors (#9 & #10 Pension Fund). This determines their preferences regarding the relevance of specific indicators of climate hazards for their organization.

The advisory group did not indicate a 'reference for a specific type of climate hazard, but rather indicators categorized under these climate hazards which are not well defined or a currently being developed such as in the case of hail or wind damage (#3 & #4 Public research university). Climate hazards such as pluvial and fluvial flooding and their indicators being direct and indirect damage to buildings in the case of *Klimaatschadeschatter* are more traditional research topics where novel insights can be given less easily and thus are less conductive towards the organizational objectives of actors within this stakeholder group.

The financial group has the highest preference for indicators which directly influence the value of assets with secondary importance given to the hazards in public space that may indirectly affect the asset (#9 Pension Fund). These are the pluvial and fluvial flooding hazard types with the indicators of indirect and direct damage to buildings being the primary ones. For the drought hazard, damage to foundations is most important due to its potentially substantial negative effect on values of assets. While investors recognize the negative social effects of heat stress, the physical effects are considered marginal for buildings (#10 Pension Fund). This is confirmed in the experience of data providers regarding requests for climate risk data about the pluvial flooding and drought risks being most in demand (#7 Data Provider). Additionally, the indicators of hazards which can be clearly given ownership to a specific stakeholder, such as waterlogging damages in a building, are preferred over hazards whose costs cannot be given ownership to such as loss of productivity due to heatwaves. However, this was not the case for the hail indicator, which does not have an assessment method that expresses its risk financially, due to its perceived high potential costs of reparation for asset owners despite its method of estimation still insufficiently developed (#9 Pension Fund).

The municipal group prioritizes the indicators which affect societal well-being and safety with secondary importance given to the quality of the public space (#1 Digitalization, Innovation and Information & #3 Public Space and Economy). Practically, this means that preference is given to indicators for the heat climate hazard such as additional hospital visits and deaths due to heat stroke.

They are especially interesting due to their highly localized nature as the heat island effect can be particularly severe in specific locations of the city, but not others. Using these indicators can enable municipal officials to identify areas of highest priority within their area of work. Fluvial and pluvial flooding are still considered relevant, but mainly regarding its effects on the public space rather than private property which is seen as personal responsibility of the owner and thus not in the purvey of municipal officials (#2 Public Space and Economy). However, tools which offer insight into the risk of pluvial floods on private spaces have been developed and used by this group as found in interviews with representatives of advisory stakeholders. This is because the municipality still assigns a high value to assessing risk in public spaces where adaptation measures can be more easily implemented by this group compared to private residences (#5 Public Research university, #6 & #8 Consultancy Public Infrastructure). This means that despite the pluvial and fluvial flood hazards being indicated as less interesting by representatives of the municipal stakeholder group, their indicators are still clearly relevant. Additionally, concern was expressed over indicators which can have significant effects on asset values such as in the case of foundation damage for the drought hazard type. The respondent was concerned whether a municipality should publish information which may significantly affect asset prices throughout the city, especially if the method of its estimation is highly uncertain (#2 Public Space and Economy).

The main difference between the financial and municipal stakeholder groups is the former prioritizing flood risk while the latter expressed more interest in the heat hazard type (Table 4). As indicated by the financial stakeholders, the indicators of fluvial and pluvial flood risk can be better quantified into their effects on the prices of specific assets and as such, they correspond more to the organizational objectives of this group. On the other hand, the municipal stakeholders find heat more interesting due to it being highly determined by the arrangement of public space and highly localized nature which means that the municipality has more potential to change it. The advisory group has no preference for a specific hazard type, but they rather seek to develop novel methods of estimation for indicators such as hail. Unlike the municipal stakeholders, the financial group expressed clear interest in the further development of assessment methods for hail.

Table 4. Overview of relevant climate hazards per stakeholder type. Made by researcher.

CLIMATE HAZARD	MUNICIPAL STAKEHOLDERS	FINANCIAL STAKEHOLDERS	ADVISORY STAKEHOLDERS
PLUVIAL/FLUVIAL FLOODING	Indirect and direct damage to public spaces and infrastructure (neighborhood scale)	Direct and indirect damage to buildings; high demand for financial cost estimates	Limited interest in traditional flooding indicators; prefer novel methods
DROUGHT	Limited interest due to focus on public spaces	Foundation damage indicator; high priority due to asset value impacts	Interest in developing innovative methods for drought assessment
HEAT	High interest in assessing heat stress impacts on public spaces	Marginal interest; physical effects on buildings considered minimal	Moderate interest in novel heat stress assessment methods

HAIL & WIND	Low interest due to limited impact on public spaces	High interest due to potential costly repairs; preference for insurance-based estimates	High interest in developing new methods to assess hail damage using environmental data

6.3 Choice of Scale and Visualization

The choice between municipal, neighborhood, and building scales for assessment and visualization is another important determinant for the role that climate risk assessment takes in a climate governance arena as the stakeholder types do not deem all of them as relevant for their objectives. This is additionally complicated by conflicting interests in how costs are expressed as a score or a specific monetary value. Finally, there are differences in preferences even for the inclusion of multiple scenarios of risk and whether the information is presented in combination with other data in user interfaces.

The advisory stakeholder group shows preference for higher levels of scale such as the municipal and neighborhood levels due to the lower level of uncertainty when estimation is at a higher level of aggregation. While the methods of estimation may fail to correctly estimate risk at the level of an individual building, once aggregated at the level of neighborhood, these results become less uncertain and more representative of reality (#5 Public Research University & #8 Consultancy Public Infrastructure). The concern of publishing highly uncertain results also leads to the preference for giving a range of values in different scenarios as is currently done for the tool *Klimaatschadeschatter*. Instead of an average of the estimated costs, a minimum and maximum values should be given with different scenarios of climate change, such as KNMI'23, reflected in these estimates. Additionally, advisory stakeholders hold a preference for presenting climate risk data in combination with other datasets such as various socio-economic data to offer more novel insights in their publications.

The financial stakeholders show very different preferences with the building scale as the most preferred, despite being aware of the uncertainty of estimation at this level, with the sub-neighborhood and municipal scales as viable alternatives (#9 Pension Fund). The neighborhood scale, however, was seen as a purely administrative boundary which includes a less uniform environment than the sub-neighborhood scale and does not offer insight into risk for specific assets. The municipal scale was seen as relevant for real estate investors because it allows for a convenient comparison between municipalities when making investment decisions (#10 Pension Fund). An important concern for this is the coverage, though, as having the costs estimated for the extent of a single Dutch municipality or province will not affect the decision-making process of organizations which operate at the national and international levels (#9 & #10 Pension Fund). Similarly to the advisory stakeholders, no opposition or concern was identified during the interviews for showcasing different climate change scenarios or a range of values when performing the estimation of risk. However, it was noted that when a range of values is created, the average of this range will likely still be used in the decision-making process, at least in the case of real estate investors. Notably, interest was expressed in the combination of climate risk information with other types of data even if it does not directly affect the value of assets. For example, the location of vital infrastructure and buildings such as hospitals was deemed valuable information by interviewees of the financial stakeholder group (#10 Pension Fund). Interestingly, representatives of the advisory group stated that financial stakeholders are predominantly not interested in this type of information unless they manage or want to invest in the building (#4 Public Research University & #7 Consultancy Data Provider).

A very different type of preference for scale was again shown with the municipal stakeholders who indicated that the building and municipal scales are the least relevant for their objectives. The former is too fine of a scale because the municipality has less influence over private terrain which is usually the predominant focus of the building scale except in the case of property owned by the local government (#1 Digitalization, Innovation and Information). The municipal scale on the other hand is too large and allows only comparison with other municipalities, but it cannot influence decision-making or the implementation of climate adaptation measures locally (#2 & #3 Public Space and Economy). The neighborhood and sub-neighborhood scales are most preferred as they are universally useful for comparison and identification of hotspots of risk within the city (#2 Public Space and Economy). In terms of using different climate change scenarios or ranges of estimates, conflicting responses were identified during the interviews. On one hand, presenting climate risk estimates with different scenarios is done commonly and officials with a background in climate management will not find it challenging to interpret these results (#2 & #3 Public Space and Economy; #7 Consultancy Data Provider). On the other hand, officials without a suitable background may prefer the clarity of a single scenario with an average value chosen for the estimate of the costs (#1 Digitalization, Innovation and Information). When it comes to combining climate risk estimates with other types of information, clear interest was expressed in socio-economic data to gain insight into environmental injustice within the city. Additionally, making a distinction in the function of buildings was also deemed as very relevant for the objectives of municipal stakeholders, although risk estimates for specifically these buildings were not seen as extremely useful (#2 Public Space and Economy).

6.4 Understanding the Information Needs of Stakeholders

The information needs of each stakeholder type regarding climate risk assessment differ significantly, although there are some remarkable overlaps. To identify the future role of climate risk assessment, these information needs are summarized for each stakeholder according to their desired scale, output, data needs, and selected indicators. By doing this, the overlaps and conflicting needs become clearer and make it possible to identify the compromise solution to how climate risk assessment should look in the future.

Municipal stakeholders prioritize climate risk assessment at broader spatial scales, such as neighborhoods and public spaces, rather than individual buildings, due to limited regulatory influence over private properties and concerns about privacy and data sharing. The building scale is not relevant for their objectives unless it pertains to critical infrastructure such as transport hubs and hospitals. This is because their ability to implement climate adaptation measures for individual buildings is limited and relies on regulations. On the other hand, local governments have significant influence over the public space and scales which shed information on it, such as the sub-neighborhood and neighborhood, are considered valuable. Financial estimates were seen as very valuable to their potential use to quicken the implementation of new climate adaptation measures. Unlike an estimate in euros, risk scores cannot be effectively used to highlight the costs of inaction and thus do not contribute towards the faster implementation of measures. For data availability, it is extremely important that the data used for risk assessment is publicly shareable without the danger of privacy infringement for individual residents. As such, estimating foundational risk on building scale is simply undesirable for the municipality as it labels individual households as risky. Hazards such as heat and flooding are applicable for public spaces and as such are universally interesting for the local government, especially as they may directly affect the safety and wellbeing of residents.

The financial stakeholders Indicated that Individual buildings are their most preferred scale of analysis as it sheds light on the profitability of their investments. Higher scales do not give such precise insights, although the sub-neighborhood scale was given as a close-second if assessment of individual buildings is not possible. This still allows for conclusions to be drawn about the climate risk involved in the property and its immediate surroundings. Regarding output, producing cost estimates in euros rather than scores was the definite preference. Financial estimates are simply more suitable to inform decisions regarding investments. When it comes to data availability, this stakeholder group did not indicate a strong preference for open data. In fact, building-specific data is often not publicly available, and investors currently have no incentive to publish it openly. Finally, their preference regarding the selection of indicators is dependent on their perceived costs. As such, the climate hazard of drought with the foundational damage indicator is extremely relevant for financial stakeholders. The high costs involved in the renovation of rotting foundations determines the profitability of property investment in cities such as Amsterdam where it is a significant issue. Otherwise, indirect and direct damages from pluvial flooding are relevant, and there is increasing interest in estimating the costs of extreme hail and wind.

The advisory stakeholders did not express a clear preference for a specific scale of assessment, except in terms of novelty. Flood risk assessment at the scale of buildings is novel and thus interesting but estimating the costs of hail for neighborhoods is novel as well. This preference for novelty is not unique for only the scale of assessment, but also the output of the method. Estimating risk in euros is interesting to this stakeholder type because it is a new trend in risk assessment. Similarly, hail and wind were given as examples of the most interesting indicators because the methods for the estimation of their costs have not been established. This need for the development of new assessment methods puts the advisory stakeholders in a unique position compared to the previous two types and allows for unique synergies between these groups in establishing the future role of risk assessment.

7. Discussion

7.1 Introduction

The information needs of each stakeholder have been identified and the role of climate risk assessment in governance arenas is increasingly clear. However, before conclusions can be drawn and the main research question is answered, these findings need to be placed in the broader context of the scientific discourse. This is done in the following subchapter while Chapters 7.3 and 7.4 discuss the limitations and future research directions respectively.

7.2 Reflection on the Politics of Climate Risk Assessment

The findings of the research reflect the wider context of politics of risk assessment found in literature. This preference expressed by the interviewees from a finance background is logical and follows the recently implemented guidelines of the ECB and TCFD on the quantitative disclosure of climate risk. Notably, this indicates that the political context of climate governance affects the form of climate risk assessment rather than the decision-support tool affecting the interactions between stakeholders in a CGA. Such findings suggest that the main research question may be inverted to instead ask: "*What is the role of climate governance in determining the form of climate risk assessment?*"

The form and role that decision-support tools take in climate governance is recognized as being dependent on the stakeholders that aim to use them. As found by Constable, French, Karoblyte, and Viner (2022), there is no one-size-fits-all tool as stakeholder information needs and dynamics are not always synergistic, but often conflicting. To balance their power dynamics and interests, it is recommended to involve the stakeholders in the development process of these tools while still striving for technical effectiveness and legitimacy of the methods used. This carries several challenges, however, as decision-support tools rarely represent the complexity of climate risks while accounting for stakeholder information needs. Translating the information needs of stakeholders into effective decision-support tools which lead to actionable climate adaptation policy proves even more challenging due the complex nature of these steps (Mackie, Connon, Workman, Gilbert, & Shuckburgh, 2022).

In Amsterdam, a complex system of discourse and politics exists around climate risk assessment which influences the form and role of the decision-support tool. The recent example of this trend is the call to develop a standardized form of risk assessment which can produce a "*climate label*" for all residential buildings in the country. This label would reflect the exposure and vulnerability of the building to climate hazards in a scale of A to G, similarly to the existing energy label (Bani et al., 2024). However, following the arguments of Constable, French, Karoblyte, and Viner (2022), the stakeholders and researchers who approach this subject should be aware that a standardized, one-size-fits-all label may not be a suitable solution for addressing climate risks in cities.

Overall, the findings of this research invite reflection on the relationship between decision-support tools such as climate risk assessment and the climate governance arenas. It is not linear as formulated in Chapter 2, but rather a complex bidirectional relationship where the development of decision-support tools affects the politics of stakeholders within governance arenas and vice versa. On one hand, designing such a climate risk assessment tool, the selection of assessment scale, output, and climate hazard indicators determines whether the tool answers the information needs of stakeholders. On the other hand, the politics and powers of stakeholders determine how such a tool is designed as each has its intended audience. This idea is reinforced by the identified differences between the Climate Adaptive Buildings Framework and the *Klimaatschadeschatter*, which both exist in the same CGAs, but cater to the information needs of different audiences. This invites even further discussion of whether the information needs of stakeholders determine the perceived reality of climate risk as they affect the design of tools which are used to estimate it and could offer a new direction of research.

7.3 Concerns of Validity and Reliability

The implications and conclusion of the research must be prefaced with a discussion of limitations that are grouped under the concerns of validity and reliability. Starting with internal validity which is affected by the reliance on semi-structured interviews. While the interview guide is designed with clear, unbiased and open-ended questions in mind, leading questions were asked at times when respondents give unexpected answers that require a follow-up. Still, the researcher checked their interpretation of these responses by stating it directly during the interview and asking the interviewees to confirm if it is correct. Additionally, some of the respondents were contacted before the finalization of the report to confirm whether direct quotations are used correctly per their request. Additionally, concerns regarding credibility are also partially addressed through triangulation where scientific and grey literature is compared with the responses when possible. The interview transcription is also done verbatim with minimal editing for clarity to minimize the chance of misinterpretation by the researcher. These measures contribute towards interpretative validity as well and it is further enhanced by the continuous development of the conceptual and theoretical frameworks during data analysis.

External validity was the second concern. The research bases its findings on only eleven interviews with select representatives of three stakeholder types identified for Amsterdam's climate governance arenas. This means that the findings are representative only for the scope of the research area and precautions should be taken when generalizing them to the rest of the Netherlands. Even within Amsterdam itself, the transferability of the findings can be questioned. The sampling strategy for the interviews attempted to collect responses from all stakeholder groups involved in its climate governance, but it fails to include the average residents. Additionally, within the financial stakeholder type, only respondents from pension fund investment firms are interviewed while for example insurers are also an important member of this group. Despite attempts at arranging interviews with them, it was not possible to conduct such interviews due to time constraints of the data collection phase of the research. As such, the sample size is small and potentially unrepresentative of climate governance arenas within and outside of the study area. However, the interview was in depth with respondents who carry significant experience and knowledge in their fields of expertise. Despite the limited sample size, a significant number of insights was obtained which are echoed in scientific literature.

Continuing with reliability, the reproducibility of the results depends strongly on the time in which this research is performed and who is sampled for the interviews. Climate risk assessment is a quickly developing topic and the opinions around are changing rapidly as well. The interviewees are part of this developing discussion and as such, their responses could change in the future even if they were asked the same question. This risk is elevated by the reliance on semi-structured interviews which inherently are more flexible than structured interviews. Still, the methodology of the research is described in a transparent and comprehensive manner to ensure that the findings are as reproducible as possible with the data management plan included in the supplementary materials. The concern of reliability is inherent to research which relies on interviews and a significant number of precautions were taken to maximize the reproducibility of the findings.

7.4 Implications and Future Research

With consideration for the concerns of validity and reliability, this research still has significant implications for the future of climate risk assessment and Amsterdam's climate governance arenas. By identifying the current shortcomings of climate risk assessment and what the stakeholders need from it in the future, these findings can be used to inform the further development of climate risk assessment and lead towards its continued use to inform decision-making in climate governance arenas. The greater use of risk assessment may lead towards more climate adaptation measures being implemented at locations which urgently need them.

However, more research is needed before that objective can be realized. The concerns regarding the transferability of the research findings make it difficult to apply the lessons learned from this research outside of Amsterdam, which is needed if risk assessment is supposed to be applied more broadly and effectively. However, the methodology used in this research can be replicated in other case areas. Future studies should thus sample interviewees from other locations in the Netherlands such as the province of Limburg where flooding is a significant and widely recognized issue. Additionally, more stakeholder types such as city residents should be included in data collection as ultimately, they are most severely affected by individual extreme weather events compared to international organizations such as cooperative pension investors.

Next to methodological improvements, future research should also implement a narrower scope to study the relevance of specific climate risk indicators for the stakeholder types. For example, risk assessment methods for hail are currently only being developed by researchers and private businesses, but their approaches vary significantly. The former relies primarily on environmental data to model the potential costs of hail while the latter uses data from insurers to estimate costs based on the severity of individual events. Researching which of these approaches addresses the needs of various stakeholders best and why is a very relevant direction for further study.

Finally, a finer distinction should be made within the stakeholder types as, for example, large municipalities like Amsterdam approach their climate governance differently from small local governments such as in Bronkhorst. By making the distinction between various sizes of local governments, future research could give more directed recommendations for these stakeholders and ensure that their findings are applicable throughout the Netherlands. Similarly, internationally active pension investors analyze the profitability of real estate differently from investors who only operate on the national scale. The needs of pension investors are also different from those of insurers who are grouped under the same type of stakeholder in this research. With a finer distinction between stakeholders, better insights could be obtained regarding their needs for climate risk assessment.

8. Conclusion

This chapter first summarizes the findings of the research and answers the main research question by identifying the role of climate risk assessment in the climate governance of Amsterdam. Subsequently, a recommendation is given to Amsterdam's three stakeholder groups suggesting how they should compromise between their information needs and jointly support a climate-risk-assessment tool that will most effectively support the quicker implementation of climate adaptation measures in Amsterdam's governance arena.

8.1 The Role of Climate Risk Assessment

This thesis aimed to explore the role of climate risk assessment in Amsterdam's climate governance arena and how it can contribute towards more effective and rapid implementation of climate adaptation measures in cities. Using a combination of research methods, which included the creation of example climate risk maps and their use in semi-structured interviews with representatives of the main stakeholder groups in Amsterdam's climate governance, several insights were discovered. The structure of Amsterdam's climate governance arena was characterized by its decentralized, multi-stakeholder structure where three key types of stakeholders emerged, each with distinct powers and interests:

- The municipal stakeholders, who included the organizational clusters of the municipality of Amsterdam, prioritize the general wellbeing of the city's residents, with significant influence over its public spaces but limited power in the management of private ones.
- The financial stakeholders, which referred to pension funds and other organizations that invest in or manage real estate. While being primarily profit-driven due to their organizational objectives, this group also sought to adhere to recent regulations of the ECB, which mandate the disclosure of climate risks in their investments. Unlike the municipal stakeholders, this group cannot change public spaces but has significant power over the implementation of climate adaptation measures in the private spaces of the city.
- The advisory stakeholders, who consisted of consultancies, climate data and service providers, and researchers that aimed to develop novel methods of risk assessment and provide decision-support tools to the other two groups in Amsterdam's climate governance arena. Rather than influence the public and private spaces in the city, their power is to advise the municipal and financial stakeholders.

The current state of climate risk assessment in the context of Amsterdam's climate governance was found in the examples of *Klimaatschadeschatter* and the Climate Adaptive Building Framework, which differ significantly in their method of assessment, but both present some limitations:

- The currently available tools did not match the information needs of Amsterdam's stakeholders regarding the scale and output of the assessment. For example, *Klimaatschadeschatter* expresses risk as a financial value, which addresses the needs of financial stakeholders, but only at the municipal scale, which had no utility for this group.
- In terms of data requirements, methods such as the Climate Adaptive Building Framework needed building-specific data, which is rarely openly available and in certain cases, may not exist in formats suitable for risk assessment.

Based on the characterization of Amsterdam's stakeholders and the limitations in the current state of climate risk assessment, several points for its improvement were identified as the interview respondents indicated that climate risk assessment tools should be tailored to the information needs of the stakeholder groups:

- In the case of municipal stakeholders, a neighborhood-scale method of assessment should be used, which relies on open data without the risk of privacy infringement.
- For financial stakeholders, interest was expressed in tools that estimate risk in financial values for individual buildings or at the sub-neighborhood scale of assessment for hazards that have significant effects on the value of real estate assets, such as the foundational rot indicator of the drought hazard.
- The advisory stakeholders did not indicate a clear preference for a specific scale of assessment but rather the development of novel methods for underrepresented hazards such as hail and wind.

If these points for improvement are addressed, climate risk assessment may become a decision-support tool that better matches the information needs of stakeholders in Amsterdam's climate governance arena. This may lead to climate risk assessment contributing towards the more effective and rapid implementation of urban climate adaptation measures, with a city that is more resilient to physical climate risks as the result.

8.2 Recommendations for Amsterdam's Stakeholders

For climate risk assessment to become an effective driver in the implementation of adaptation measures, Amsterdam's stakeholders should seek compromise in their information needs and support the development of a risk assessment tool that addresses the needs of all three stakeholder types, rather than only one of these groups.

The improved risk assessment tool should be applicable on the scale of sub-neighborhoods (*buurten)* because it would fulfill the needs of municipal stakeholders for data on a coarser scale that sheds insight into the risk within public spaces that they operate in. Additionally, it is suitable for addressing the needs of the financial stakeholders who require data that can shed insight into risk at the level of buildings. Due to the relative uniformity of sub-neighborhoods in Dutch cities, information can be derived from visualization on that scale about specific buildings that fall within their geographic boundaries.

In terms of output, all stakeholder groups indicated that expressing risk in financial values such as Euros answers their need for information regarding the financial impacts of physical climate risks. The municipal stakeholders can utilize it clearly quantify the cost of not implementing climate adaptation measures and express the potential benefits of climate adaptation measures in values that are immediately understandable to all other stakeholders. For the financial group, expressing risk in Euros rather than abstract scores enables them to integrate these outputs more effectively in their decision-making processes. The advisory group indicated readiness to accommodate both of these stakeholder types.

In terms of data availability and the transparency of methods, all stakeholders expressed interest in the use of open data and methods rather than paywalled, private datasets and black-box models. For the municipal stakeholders, all data should be preferably suitable to be openly published without potential to infringe upon the privacy of individual residents. Additionally, the use of transparent and understandable assessment methods corresponds to their organizational objectives. For the financial group, the use of open data may contribute towards achieving greater coverage of climate risk assessment and correspond towards the more national and international scale of operations that these actors operate on.

Finally, a clear compromise could not be found in terms of preference for specific physical climate hazards or their indicators. The organizational objectives and interests of these stakeholder groups differ too much to identify a small subset of all possible indicators that could fulfill all their information needs. Therefore, a broad approach should be taken to assess as many hazards as possible given the limitations of available data and methods. This answers the information needs of the municipal stakeholders for insights into heat and drought hazards without ignoring floods when they affect public spaces. For financial stakeholders, the other indicators are relevant which are the direct and indirect effects of pluvial floods in addition to foundational damages which are categorized under the drought hazard. Finally, the advisory group indicated interest in the development of more novel methods for assessment of indicators of climate hazards such as hail which are currently in development and not available to the Amsterdam's stakeholders

As such, support should be given towards the development and continuation of CRA tools and methods which correspond to these characteristics. *Klimaatschadeschatter* which expresses risk in financial values on a neighborhood scale with national coverage for as many indicators as possible, is one of such tools, although its last update was in 2020. Additionally, support for such development should come from all three stakeholder groups with clear initiative taken by each to ensure that the information needs of each are considered during the development. However, care should be taken during the development of the tool to not approach it with a one-size-fits-all approach as scientific literature suggests that such tools are not effective at supporting the further implementation of climate adaptation measures in cities.

If these compromises are made with a critical and measured approach, climate risk assessment can become an integrated part of urban climate governance arenas in the role of a decision-support tool which sheds direct insight into the financial consequences of physical climate hazards, but also indirect insights into the social and environmental effects. It will enable the municipal stakeholders to more effectively implement climate adaptation measures in a quicker fashion as the costs of not implementing them can be clearly quantified. For financial stakeholders, it will contribute towards more effective disclosure of climate risks and motivate further reduction in the vulnerability of private buildings for climate hazards. By answering the information needs of stakeholders within climate governance arenas, risk assessment can effectively be designed to lead towards the implementation of more climate adaptation measures and contribute towards resilient cities that are better prepared for the challenges of the future.

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Annex A: Informed Consent Form

RESEARCH INFORMATION SHEET

Project Title *(working title)*: *Money Talks, Policy Walks: The Role of Financial Climate Risk Assessment in Amsterdam's Climate Governance Arenas*

Researcher: *Kuba Kowalski*

This consent form describes the research study to help you decide if you want to participate. This form provides important information about what you will be asked to do during the study, about the risks and benefits of the study, and about your rights as a research subject.

If you have any questions about or do not understand something in this form, you should ask Kuba Kowalski (kuba.kowalski@wur.nl) for more information.

What is the purpose of this study?

This is a research study. I invite you to participate in this research study because you have relevant knowledge.

The purpose of this research study is to identify the role of financial climate risk assessment in climate governance by analyzing the potential effects of climate risk maps on the powers and interests of stakeholders in climate governance arenas based on the case of Amsterdam. This information is sought due to the recent call by stakeholders in municipal climate governance for more information about the financial implications of climate change hazards.

What will happen during this study?

During the interview, the participant will be presented with three climate risk maps: (1) waterlogging & flooding, (2) drought & heat, (3) and an aggregate map of the 4 types of hazards. The researcher will ask questions about how the information presented in these maps may affect which stakeholders are included or excluded in climate governance arenas, and how their powers and interests may change. Participants may end the interview or refuse to answer specific questions at any time and for any reason.

The interview will take between 45 and 60 minutes at a location chosen by the participant or at the AMS Institute in Amsterdam. If an in-person interview is not possible within the timeframe of the research, an online interview will be conducted instead over Microsoft Teams.

The audio of the interview will be recorded on the researcher's phone with paper notes taken throughout the meeting. The recording will be used to create an anonymized transcript of the interview where references to the participant's identity have been manually removed. The transcript of the interview will be delivered to the participant for review. The participant may request for any part of the transcript to be redacted and not used for this study.

During the timeframe of the research, (1) the audio recording, (2) the digitized notes, (3) the reviewed interview transcript, (4) and the signed consent form will be saved by the researcher on the OneDrive of their Wageningen University & Research account with a backup copy made on a physical hard drive. These four items will not be shared with anyone except the two thesis supervisors of the researcher. After the conclusion of the research which is the thesis defense expected in September 2024, the main and backup files of the audio recording and the digitized notes will be permanently deleted. The reviewed interview transcript and the signed consent form will be delivered to the

Environmental Policy chair group of Wageningen University for secure archival purposes over a period of ten years.

What are the risks of this study?

No physical or reputational risks are foreseen for the research subjects as the recordings will not be made public in any form. Additionally, the participants will not be referred to by name in the results of the research. Instead, they will be referenced in an anonymized form as Interviewee 1, Interviewee 2 and so forth.

What are the benefits of this study?

The expected benefits of this study are two-fold: First, the participants will be presented with novel products of financial climate risk assessment in the form of climate risk maps. These maps give insight into the financial implications of physical climate change hazards in an area of Amsterdam which the participants will gain knowledge of. However, the information presented in these maps is for research purposes only and may not accurately represent reality. The participants are advised to verify this information by using reliable sources before making any decision based on the maps.

Second, the study will contribute towards the further development of financial climate risk assessment as a field. In the future, more information will be made available about the financial implications of physical climate change hazards which may prove useful by supporting decision-making in climate adaptation for the participant or their organization.

What will happen with the information I provide?

The information provided by the participant will be used in an anonymized form in the researcher's thesis report and thesis presentations. No identifying information of the participants will be given such as names, professional titles, work and educational history, names of their current employers and contact information. The participants will be referred to as Interviewer 1, Interviewer 2 and so forth in the thesis report and thesis presentations. Additionally, when quoting the participant, only the reviewed interview transcripts will be used by the researcher. The participant may request for any portion of the interview transcript to be redacted before the end of the research. The original and reviewed interview transcripts will not be included in the thesis report or the thesis presentations.

As previously mentioned, (1) the audio recording, (2) the digitized notes, (3) the reviewed interview transcript, (4) and the signed consent form will be saved by the researcher on the OneDrive of their Wageningen University & Research account with a backup copy made on a physical hard drive during the research. These four items will not be shared with anyone except the two thesis supervisors of the researcher. These supervisors are: Mattijs Smits of the Environmental Policy group at Wageningen University, and Maged Elsamny of the Management in the Built Environment department at TU Delft. Only the researcher will have access to the information about the name, age, gender, and organizational details of the participant unless one of the supervisors was involved in arranging the interview. After the conclusion of the research which is the thesis defense expected in September 2024, the main and backup files of the audio recording and the digitized notes will be permanently deleted.

The reviewed interview transcript and the signed consent form will be delivered to the Environmental Policy chair group of Wageningen University for secure archival purposes over a period of ten years. The data will be stored on a secure folder at Wageningen University and are kept separate from interview data files. All data will be archived after the study is finished in a password locked folder and will only be accessible for purposes of inspection of research integrity.

Is being in this study voluntary?

Taking part in this research study is completely voluntary. The participant may choose not to take part at all. If you decide to be in this study, you may stop participating at any time and for any reason. If the participant decides not to be part of this study, or if they stop participating at any time, they will not be penalized in any form or prevented from future participation in the research.

What am I signing?

This Prior Informed Consent Document is not a contract. It is a written explanation of what will happen during the study if you, the participant, decide to participate. You are not waiving any legal rights by signing this Prior Informed Consent Document. Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive physical and digital copies of this form.

PRIOR INFORMED CONSENT

Researcher copy

Please tick boxes

1. I confirm that I have read and understand the information sheet dated 30 May 2024 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐
3. I understand that any information given by me may be used in the master's thesis report of the researcher. ☐ ☐
4. I give you permission to make audio recordings of me during this study. ☐
5. I understand that my name or identifying information will not appear in any reports, articles or presentations. ☐
6. I agree to take part in the above study.

___________________________	_________________	_________________
Name of Participant	Date	Signature
___________________________	_________________	_________________
Researcher	Date	Signature

When completed, please return in the envelope provided (if applicable). One copy will be given to the participant and the original to be kept in a secure file of the Environmental Policy Group, Wageningen University.

If you have further questions, please contact Kuba Kowalski (kuba.kowalski@wur.nl)

PRIOR INFORMED CONSENT

Participant copy

Please tick boxes

1. I confirm that I have read and understand the information sheet dated 30 May 2024 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐
3. I understand that any information given by me may be used in future reports, articles or presentations by researcher. ☐
4. I give you permission to make audio recordings of me during this study. ☐
5. I understand that my name will not appear in any reports, articles or presentations. ☐
6. I agree to take part in the above study. ☐

__________________________ __________________ __________________

Name of Participant Date Signature

__________________________ __________________ __________________

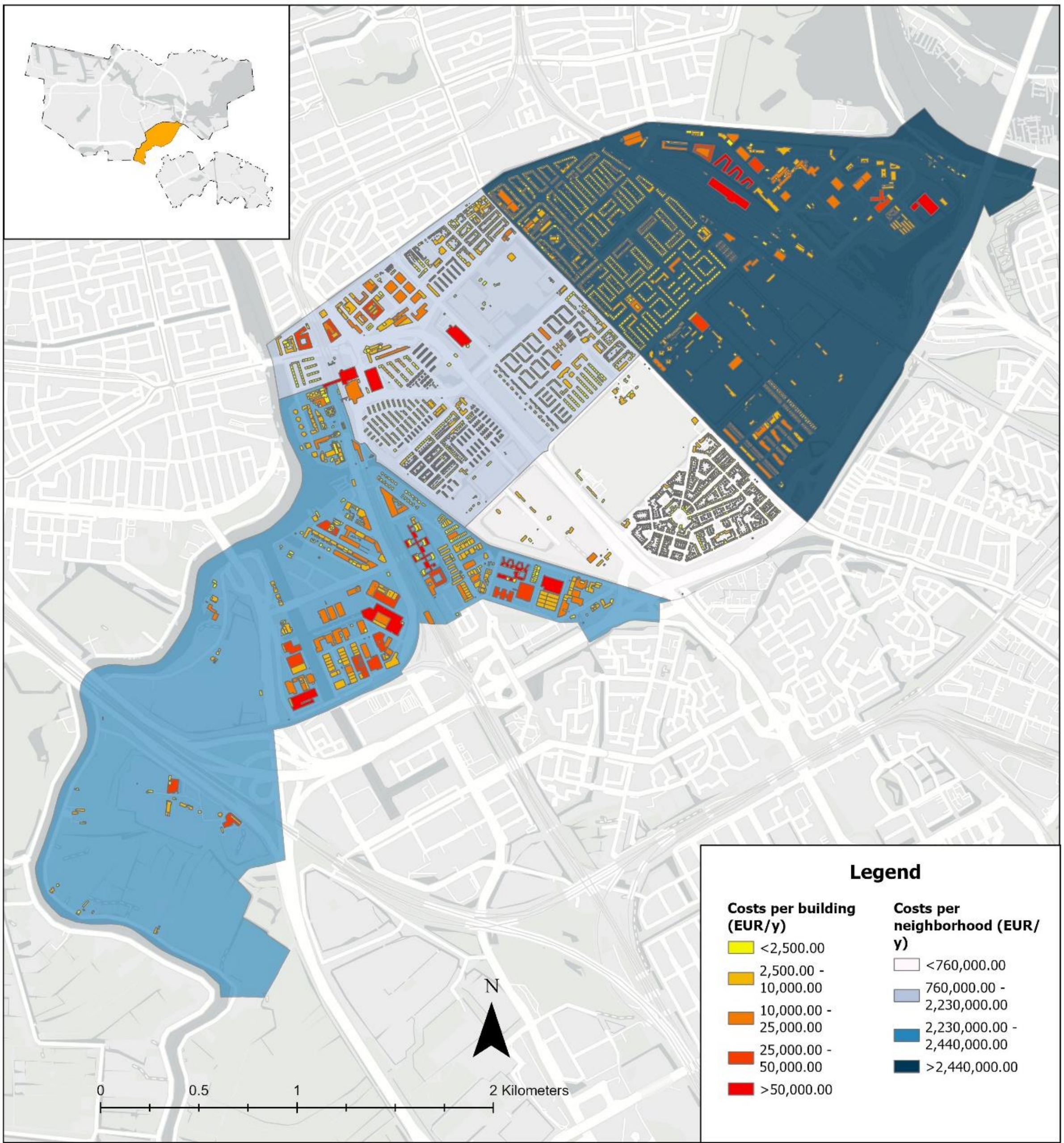
Researcher Date Signature

When completed, please return in the envelope provided (if applicable). One copy will be given to the participant and the original to be kept in a secure file at the Environmental Policy Group, Wageningen University.

If you have further questions, please contact Kuba Kowalski (kuba.kowalski@wur.nl).

Annex B: Climate Risk Maps of Watergraafsmeer

Map data © OpenStreetMap contributors, Microsoft, Facebook, Inc. and its affiliates, Esri Community Maps contributors, Map layer by Esri



Watergraafsmeer - Waterlogging & Flooding Risk per Year for 2018-2050

For interactive version, visit: https://arcg.is/K9L0q0

Watergraafsmeer - Amsterdam, Netherlands

Climate hazards & variables shown:
- Flooding: Damage caused by flooding
- Waterlogging:
  - Direct water damage to properties
  - Indirect water damage to properties

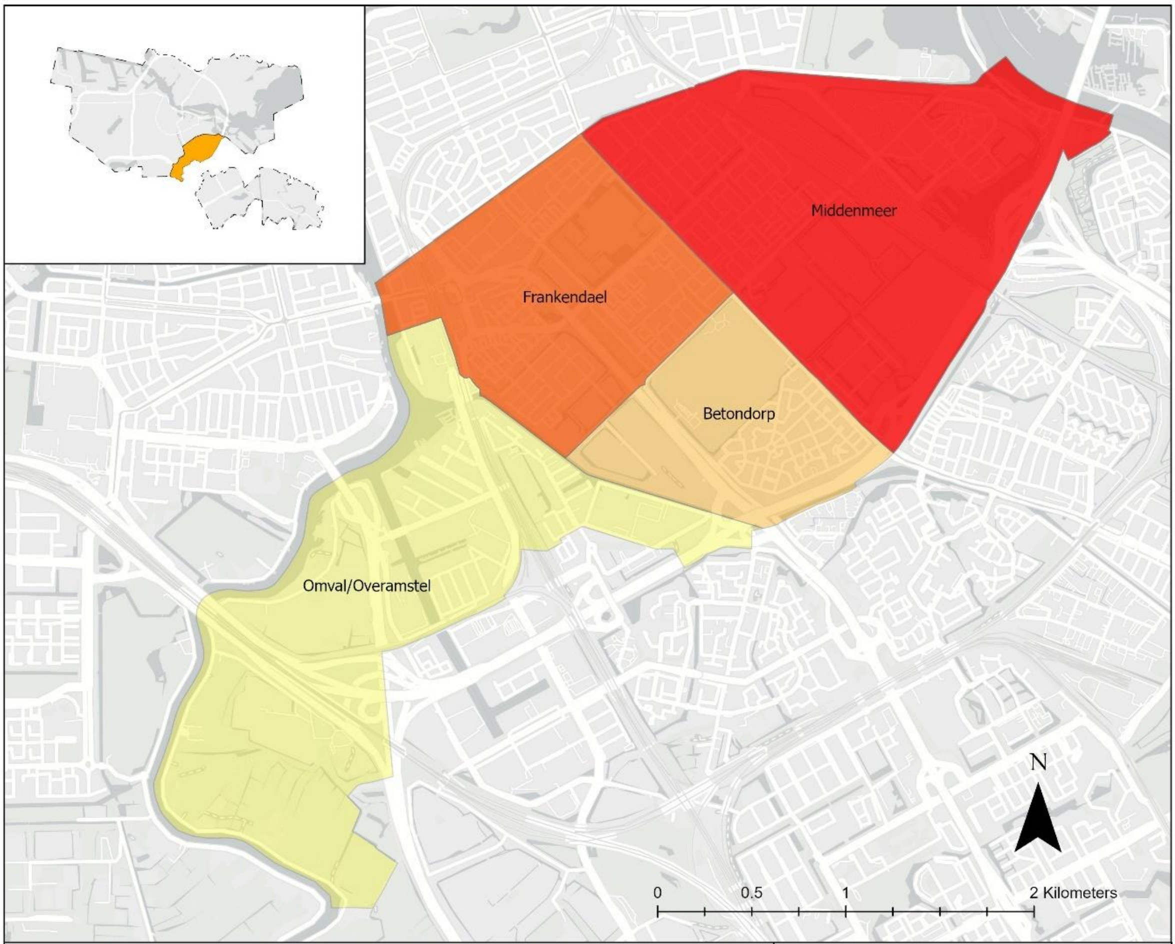
Created using Klimaatschadeschatter.nl and following datasets:
- Hoogtestatiestiek Gebouwen 2020: https://3d.kadaster.nl/basisvoorziening-3d/
- Amsterdam Indeling Wijk: https://maps.amsterdam.nl/open_geodata/?k=200

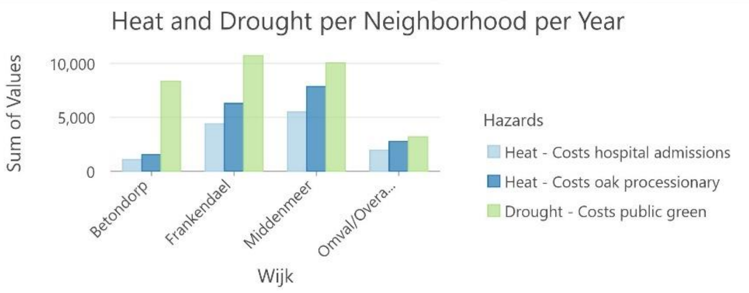
Made by Kuba Kowalski on 19/05/2024

MSc Thesis "Money Talks, Policy Walks: The Role of Financial Climate Risk Assessment in Climate Governance".

Disclaimer: The data presented in this map is for research purposes only and may not accurately represent reality. Viewers are advised to verify this information by using reliable sources before making any decision based on this map.

Map data © OpenStreetMap contributors, Microsoft, Facebook, Inc. and its affiliates, Esri Community Maps contributors, Map layer by Esri





Legend

Costs per Neighborhood (EUR/y)

- <8,000.00
- 8,000.00 - 11,000.00
- 11,000.00 - 21,000.00
- >21,000.00

Watergraafsmeer - Drought & Heat Risk 2018-2050

Watergraafsmeer - Amsterdam, Netherlands

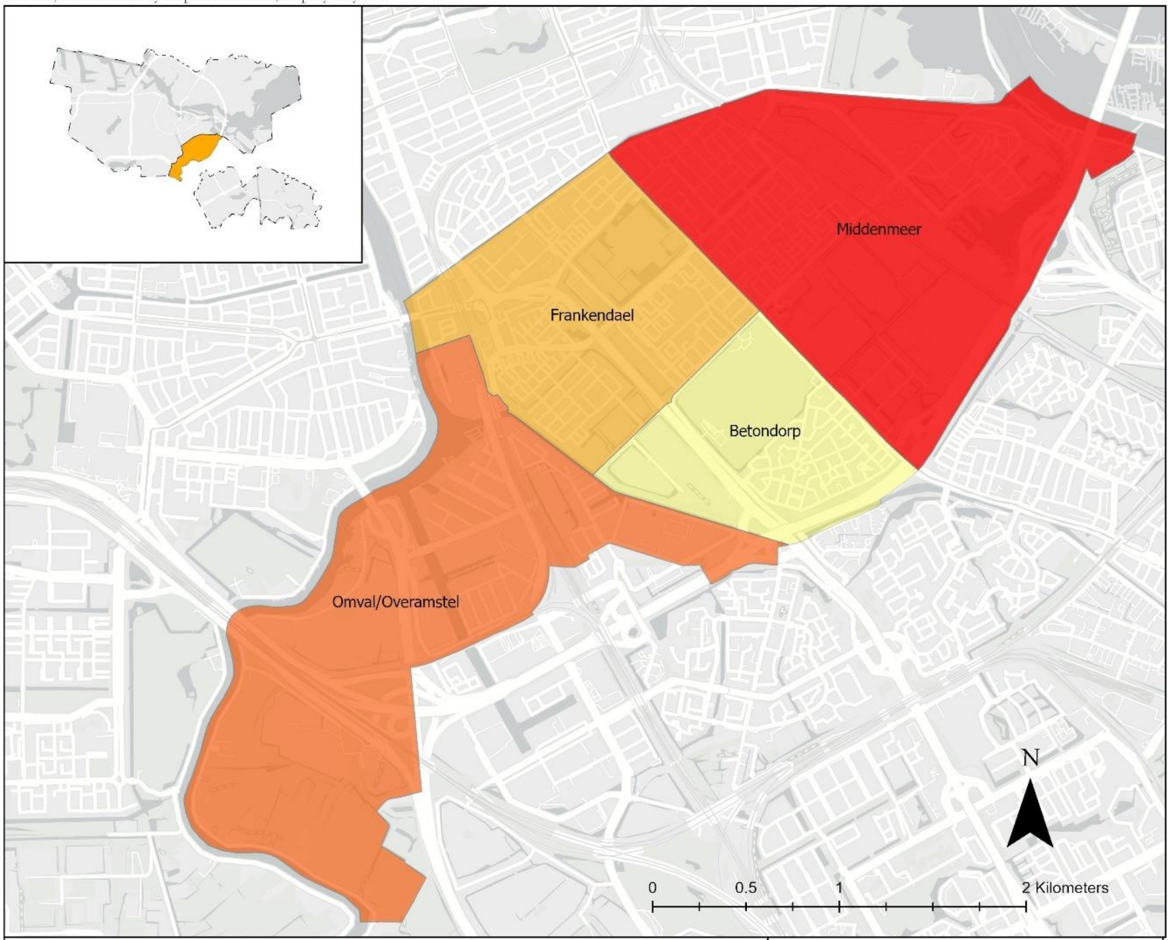
Climate hazards & variables shown:
- Drought : Damage to public green
- Heat:
  - Hospital admissions due to heat stress
  - Oak processionary control costs

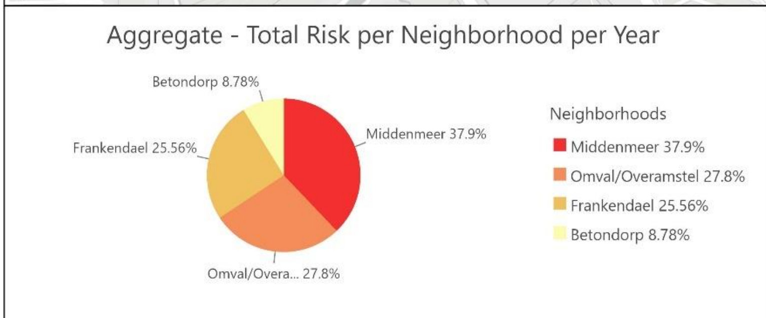
Created using Klimaatschadeschatter.nl and the following datasets:
- Amsterdam Indeling Wijk: https://maps.amsterdam.nl/open_geodata/?k=200
- Kerncijfers Wijken en Buurten 2021 CBS: https://opendata.cbs.nl/#/CBS/nl/dataset/85039NED

Made by Kuba Kowalski on 19/05/2024

Disclaimer: The data presented in this map is for research purposes only and may not accurately represent reality. Viewers are advised to verify this information by using reliable sources before making any decision based on this map.

Map data © OpenStreetMap contributors, Microsoft, Facebook, Inc. and its affiliates, Esri Community Maps contributors, Map layer by Esri





Legend

Total Costs per Neighborhood (EUR/y)

- <800,000.00
- 800,000.00 - 2,250,000.00
- 2,250,000.00 - 2,450,000.00
- >2,450,000.00

Watergraafsmeer - Total Climate Risk 2018-2050

Watergraafsmeer - Amsterdam, Netherlands

Climate hazards & variables shown:

- Flooding: Damage caused by flooding
- Drought : Damage to public green
- Waterlogging:
  - Direct water damage to properties
  - Indirect water damage to properties
- Heat:
  - Hospital admissions due to heat
  - Oak processionary control costs

Created using Klimaatschadeschatter.nl and the following datasets:

- Hoogtestatiestiek Gebouwen 2020: https://3d.kadaster.nl/basisvoorziening-3d/
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- Kerncijfers Wijken en Buurten 2021 CBS: https://opendata.cbs.nl/#/CBS/nl/dataset/85039NED

Made by Kuba Kowalski on 19/05/2024

Disclaimer: The data presented in this map is for research purposes only and may not accurately represent reality. Viewers are advised to verify this information by using reliable sources before making any decision based on this map.

Annex C: Interview Guide

Interview Procedure

Before the interview, the following documents are sent to the interviewees: risk maps and their disclaimer, consent form, list of questions. They are requested to review the maps and read through the consent form.

At the start of the interview, its objective and the data which is expected to be collected is explained to the interviewee. Afterwards, they are presented with a printed consent form which is either signed or not by the interviewee. If the form is not signed, the interview is not continued. Additionally, it is made clear that the interview is semi-structured.

During the interview, the audio is recorded on a phone. The initial questions are meant to establish the background of the interviewee and put them at ease. This also includes exploratory questions which cannot be easily connected with specific variables and indicators of the conceptual framework. Then, the interview proceeds to the 4 key questions which measure the effect of the dependent variables on the independent ones. Each question is clearly connected with both of the concepts and a set of variables, and it is open ended. If the relationship between some of the variables is not given in the initial answer to the question, follow-up questions are asked as well.

After the interview, the recorded data is saved on a separate device, and the paper notes are digitized. The interviewee is contacted after the thesis defense and the results of the research are shared with them.

Interview Questions- Version 1 “Municipality”: Interviews 1, 2 and 3

Introduction

1. Who are you and what is your background?
    a. Are climate risks and climate adaptation major themes in your work?
    b. Which other parties do you interact with in your work?
2. What are examples of important decisions you make in your work?
3. To what extent do you use information about climate risks in your work?
    a. Is this information mainly presented in the form of maps?
    b. Do you also encounter data for specific buildings?
4. Are you familiar with the climate risk maps for Amsterdam or the Climate Damage Estimator tool?
    a. In your opinion, what is the added value of expressing climate risk in monetary terms instead of a score?

Main Questions

5. For which stakeholder groups in urban climate management are climate risk maps relevant, and which information from these maps is particularly important for these groups?
    a. Are the maps more useful or more problematic for certain stakeholders than for others?
        i. What are the implications of this information for homeowners (or resident organizations such as neighborhood or district councils)?
        ii. How about stakeholders in real estate (investors and asset managers)?
        iii. What about the municipality? Is there any information or data that you would choose not to publish?
    b. How do political objectives factor in? Could the maps influence how certain areas of the city are prioritized for climate adaptation?

            i. Could this information increase socioeconomic inequality between city districts?
6. How can the Climate Damage Estimator (KSS) maps be used by stakeholder groups in discussions about municipal climate adaptation?
    a. Does visualizing the risk at the neighborhood or building scale have an impact on these discussions?
    b. What if the maps were combined with datasets on the socioeconomic conditions within an area?
7. In your opinion, have the KSS maps changed stakeholders' risk perception in urban climate management? If not, why?
    a. Again, would using a smaller scale, such as building level instead of municipal level, change this?
        i. Would you interpret the maps differently if a range of values was provided instead of a single figure?
        ii. Would your interpretation change if multiple climate scenarios were represented?
8. What is the future of climate risk analysis as a concept, and what should the next step be?
    a. What are the obstacles?

Conclusion

9. Can you recommend other people or publications that could help me with my research?

Interview Questions – Version 2 "Advisory": Interviews 4, 5, 6, 7, 8, and 11

Introduction

1. Who are you and what is your background? How did you become involved in the work on climate risk and adaptation?
    - What parties and stakeholders are involved in risk-based decision making?
        i. Have you also come across stakeholders from real estate such as investors, asset managers, insurers or developers?
    - How is uncertainty recognized and dealt with in risk-based decision making?
2. What are some important developments in flood risk assessment that are occurring right now, and you are involved with?
    - Have these developments changed how stakeholders engage with risk-based decision making?
    - Are you familiar with Klimaatschadeschatter and have you seen it make any wider impact?
    - Could you give other examples?
3. In your experience, what is the added value of expressing climate risk in money rather than a score?
4. Has financial climate risk assessment been used by decision-makers in municipal climate governance? If not, do you know why?

Main Questions

5. For which stakeholder groups in urban climate governance are my maps relevant and which information from the maps is particularly important for these groups?
    - Are the maps more useful or problematic to some stakeholders than others?

        i. What are the implications of this information for homeowners (or resident organizations like buurt/wijkbestuur)?
        ii. What about stakeholders in real estate (i.e. investors and asset managers)?
        iii. What about the municipality?
    - What about political objectives? Can the maps influence how certain areas of the city are prioritized for achieving the municipal climate adaptation goals?
        i. Could this information worsen socio-economic inequality between city areas?
    - Should the maps be combined with other datasets such as socio-economic or demographic ones for added context?
6. How could the maps be used by the stakeholder groups in discussions around municipal climate adaptation?
    - [Reference own maps] Does visualizing the risk at the scale of a neighborhood or building affect this?
7. In your opinion, can they change the perception of risk among stakeholders in urban climate governance? If not, what prevented them from affecting the perception?
    - [Reference own maps] Again, would using a smaller scale like building-level instead of municipality change this?
8. What is the future of climate risk assessment and what should be the next step?
    - What are the problems for developing the concept of financial climate risk assessment further?
    - What role should the municipality take in this?

Closing

9. Can you recommend any other people or publications that could help me with my research?

Interview Questions – Version 3 “Financial”: Interviews 10 and 11

Introduction

1. Who are you and what is your background? How did you become involved in real estate investment?
    a. Which other parties do you interact with in your work?
    b. Could you briefly explain the differences between top-down and bottom-up strategies? Which approach do you personally apply?
2. To what extent is the concept of sustainability included in top-down strategies? Does it also fall under the concept of social returns?
    a. Does sustainability focus only on energy and materials, or does it also include risks from climate hazards in real estate?
    b. Does investing in real estate with lower (climate) risks lead to better social returns?
3. To what extent do you use information about climate resilience and climate risks in decision-making?
    a. Is this information also presented in the form of maps?
    b. Have you encountered situations where climate risks are expressed in monetary terms?
    c. What is the added value of this for an institutional investor?
    d. If risks are expressed in monetary terms, does it only change your view on social returns or also on financial returns?

Main Questions

4. Which groups within the real estate sector have a strong interest in information about climate risks? Is this different for institutional investors?
    a. Is this information always useful for you, or can it be problematic?
        i. Does this depend on how the information is presented (e.g., maps)?
            1. When using maps, is a local scale (building or street) always more useful than neighborhood, municipal, or provincial levels?
            2. Why would an institutional investor be interested in municipal-level information rather than building-level information?
        ii. Can these maps influence your decision-making on their own? If available, would you choose the less risky option? What if this negatively impacts financial returns?
            1. When are climate risks acceptable?
            2. Does this vary by type of climate risk (e.g., heat vs. flooding)?
        iii. To what extent is uncertainty in these maps acceptable?
            1. Would you interpret the maps differently if a range of values was provided instead of a single figure?
            2. Would your interpretation change if multiple climate scenarios were represented?
5. If such maps exist at a scale most useful for you, should they be publicly available or used internally?
    a. To what extent can these maps be used in discussions with other stakeholders you often engage with?
6. The data needed to develop such maps is not always available. What would convince organizations to make this data accessible?
7. What are your expectations from local governments regarding information provision and climate adaptation?
8. What is the future of climate risk analysis as a concept in your work? What should be the next step in its development?
    a. What are the obstacles to further development?

Conclusion

9. Can you recommend other people or publications that could help me with my research?