Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Milou Mulder
Student number	4833813

Studio		
Name / Theme	Planning of Complex Cities	
Main mentor	Juliana Goncalves	Spatial Planning and Strategy
Second mentor	Marjolein van Esch	Environmental Technology and Design
Argumentation of choice of the studio	In my research, I want to create a first step towards a holistic understanding of urban heat vulnerability. Therefore, triangulated research needs to be conducted where the comparison of social and spatial variables is completed with literature results and personal experiences of individuals. Additionally, governance analysis plays a crucial role since many spatial and social variables are often the result of governmental decision-making, though in The Netherlands, they are also shaped by market forces influenced by government policies. The research-based scope of the studio Planning Complex Cities gives me valuable insights into these diverse methods.	

Graduation project	
Title of the graduation project	The Multidimensionality of Climate Vulnerability: A Holistic Approach to Tailored Urban Heat Strategies in The Hague
Goal	
Location:	The Hague, NL
The posed problem,	Urban areas are increasingly vulnerable to the impacts of climate change, particularly extreme heat events. This phenomenon, intensified by the urban heat island effect (Ahmed et al., 2023; Kleerekoper et al., 2012; Tapia et al., 2017), disproportionately affects certain groups based on socioeconomic, demographic, and spatial factors (IPCC, 2022g). Despite global recognition of urban heat as a critical issue, current resilience strategies often adopt a one-size-fits-all approach, failing to address the complex and multidimensional nature of climate

	vulnerability (Hulscher et al., 2023; IPCC, 2022c; Samen Klimaatbestendig, 2023). The complexity of climate vulnerability is often overlooked by narrowly focusing on socioeconomic status (IPCC, 2022c; Samen Klimaatbestendig, 2023). Climate vulnerability is not just a socioeconomic issue; it is a multidimensional phenomenon that impacts entire systems, including individual, social, and spatial domains (Ahmed et al., 2023; Eklund et al., 2023; Gamble et al., 2016; IPCC, 2022c; United Nations, 2022). For instance, during the 1995 Chicago heatwave, income levels or socioeconomic status could not fully explain neighbourhood mortality rates. Instead, research showed that strong social networks – an element of adaptive capacity – played a crucial role in survival, enabling residents to respond more effectively to heat stress (Klinenberg, 2018). The city of The Hague is no exception; Rising temperatures, dense urbanization, and ageing infrastructure contribute to urgent heat-related issues. Vulnerability to urban heat is influenced by a range of factors, including age, income, housing conditions, access to green spaces and urban morphology (Ahmed et al., 2023; Tapia et al., 2017; van der Hoeven & Wandl, 2018). Current strategies often emphasize physical solutions such as cooling infrastructure but fail to address the broader interactions between exposure, sensitivity, and adaptive capacity, leading to maladaptive policies that unintentionally widen inequalities (cf. Diekmann et al., 2023; Hulscher et al., 2023; IPCC, 2022c; Samen Klimaatbestendig, 2023). This research applies the concepts of exposure, sensitivity, and adaptive capacity to explore the multidimensional nature of urban heat vulnerability through different scales and domains. By identifying key variables and patterns and bridging gaps in current policies, the study seeks to develop tailored strategies that address both social and physical dimensions, fostering more equitable and effective resilience.
research questions and	Research Question *How can a multidimensional approach to climate vulnerability in the context of urban heat improve tailored resilience strategies?* Sub Research Questions: *1) What factors contribute to individuals' exposure and sensitivity to urban heat?*

	2) What spatial and social patterns emerge when analyzing heat vulnerability in The Hague? *3) How can The Hague's existing heat-mitigation strategies be improved?*
design assignment in which these result.	Along the process of this research, multiple results are created. As a starting point, the literature review is used to design **the conceptual framework**. Furthermore, this theoretical background will result in a **vulnerability matrix**, where the several variables that contribute to a person's vulnerability mentioned in the literature are noted (SRQ 1). The variables highlighted in the matrix are used for a Principal Component Analysis, which will show patterns of heat vulnerability in The Hague (SRQ 2). Based on these results, aligned with a governance analysis, an **adaptation toolkit** will be designed (SRQ 3). This toolkit can help municipal decision-making to become more tailored, as well as it gives citizens valuable insight on how to increase their adaptive capacity to become more resilient during hot days.

Process

Method description

This research will conduct multiple methods to answer the research questions. Figure 1 shows that a single method is used for multiple results. This triangulation strengthens the results by adding different perspectives of quantitative and qualitative insights.

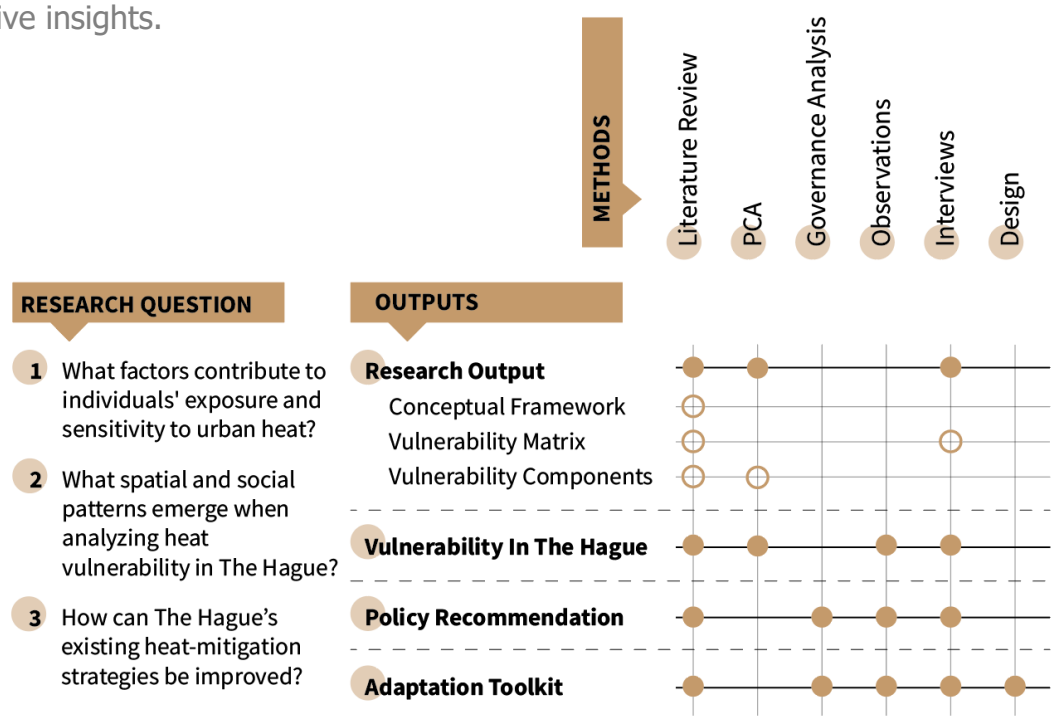

Figure 1: Methodological framework

Literature Review
The literature review forms a valuable backbone of this master thesis. It is not only used to understand bigger theories and phenomena, such as climate resilience and justice and urban heat, but it also gives input for possible variables that increase a person's vulnerability to heat. This information is gathered in a matrix, where correlations are noted according to the literature. These variables were later used to conduct quantitative analysis and were also used during fieldwork.

Quantitative analysis
A quantitative analysis will be conducted to analyse vulnerability patterns of a certain location. It is attempted to use the Principal Component Analysis (PCA), an often used method to visualize complex vulnerability problems.

In contrast to the literature review, which was not location specific, the PCA and the below explained methods are done in the context of the case study of The Hague, The Netherlands.

The PCA analyses quantitative information regarding social and spatial aspects on different scales. The data is retrieved from open-source websites, such as CBS, Den Haag Cijfers and Klimaateffectatlas. After collecting and preparing the data (filtering N/A data and standardizing it), the software SPSS will be used to execute the analysis. This will result in components containing several variables that are often seen together in different locations, increasing the exposure and sensitivity of the citizens to heat. A hypothetical example is a component consisting of the variable's *low income*, *migration background*, *social housing* and *poor access to green*.

It is to be expected that certain neighbourhoods that are known for their (social) problems will be highlighted by the PCA. However, through the components, this analysis will give a more in-depth explanation about why, how and where heat vulnerability happens. This multidimensional perspective is of high importance to be able to solve this problem in a holistic way.

Additionally, by adding spatial elements to the variables, I hope to visualize that the urgent of heat mitigation is not only for the 'poor', but that there are many faces of heat vulnerability based on the composition of multiple social and spatial variables.

Governance Analysis
The governance analysis is used to get information about the current strategies of The Hague, as well as governmental policies on heat mitigation. Together with the results of the PCA, it can be examined whether these policies are sufficient and tailored enough or where there are shortages.

Furthermore, a stakeholder analysis will give information about who could use the adaptation toolkit, as well as identifying stakeholders that can benefit from it.

Observations
Observations will be done in locations highlighted as 'high presence of vulnerability' according to the PCA. During these observations, the emphasis lays on the spatial elements. In-depth local information about the social aspects will be collected from interviews.

Interviews
During observations, small randomized street interviews will be conducted to talk with residents about their experiences during heat waves.
Additionally, expert interviews will be done to gather more information about how vulnerable citizens deal with heat. The plan is to talk with the following professionals:

- *Municipality employee* – to talk about the general heat strategies of The Hague
- *Employee of an elderly facility* – What measurements do they, as a facility, take during heatwaves? Is this enough and what would they need additionally? How do the elderly experience heat?
- *Employee of a community centre* – What changes do they see in the community during heat events? Do they think the municipality is doing enough, or what would they need additionally?

Design
The results of the previously explained methods are gathered to create a toolkit that provides information about what the different stakeholders, identified in the governance analysis, can do to reduce the burdens of heat on the short term (acute urban heat during heatwaves) as well as on the long run, by minimizing stressors that contribute to urban heat islands.

The toolkit will mainly be used by the municipality or citizen initiatives that want additional information about what to do. However, the toolkit will also contain a factsheet where residents can find multiple small interventions they can do. If enough time, this factsheet will be specified for different housing typologies (terraced house, porch flat, apartment building) to ensure the residents who receive it can better identify themselves with the suggested solutions.

Quality of Methods
A triangulation of the methods is applied to increase the quality of the results. For example, the results of the quantitative analysis will be cross-verified and amplified by the quantitative analysis. This will ensure to cover eventual gaps caused by the abstract quantitative analysis by talking to experts and residents about their experiences.

Literature and general practical references

Climate & Heat

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Data

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Reflection

Reflection

This project's scope resulted from a personal interest in understanding social problems in urban areas (inequalities and vulnerability) and enhancing social resilience with an eye on climate change.

Heat vulnerability in urban regions is an urgent problem; temperatures are rising, urban areas are densifying and at the same time, inequalities are increasing. By analysing the social and spatial contribution of heat vulnerability in The Hague, my project fits perfectly within the studio of Planning of Complex Cities (PCC). Furthermore, the research-focused perspective of the studio aligns with the goals I want to achieve with this degree: I believe that being an urbanist does not only mean that one is able to design something; it is also about fully understanding the complexity and the core of the problems one is designing for.

Scientific Relevance

This research contributes to a deeper understanding of the multidimensional nature of climate vulnerability by exploring the interplay between social and spatial factors across various scales. By applying the IPCC framework of exposure, sensitivity, and adaptive capacity, it highlights how these dimensions shape residents' vulnerability to urban heat. Despite the importance of such a comprehensive perspective for effective and targeted adaptation strategies, this approach remains underdeveloped in current research.

Furthermore, this study also provides a transferable framework that can guide future investigations into climate vulnerability in other urban contexts. By emphasizing the connections between social and spatial domains, the research supports the development of more tailored and equitable solutions for urban heat resilience.

Societal Relevance

As urban areas face rising temperatures and more frequent heatwaves, the societal impacts of urban heat vulnerability are becoming increasingly evident. Vulnerable populations, such as the elderly, low-income households, and residents in poorly insulated housing, are disproportionately affected, leading to heightened health risks and social inequities. Current adaptation strategies often fall short of addressing these disparities due to their one-dimensional focus.

This research aims to bridge this gap by identifying the social and spatial factors that contribute to heat vulnerability, emphasizing the importance of tailored, multidimensional solutions. By focusing on The Hague, the findings will provide actionable insights for policymakers and urban planners to design equitable and effective heat adaptation strategies. These strategies can reduce health risks, improve quality of life for vulnerable populations, and foster community resilience.

Moreover, the proposed framework has the potential to inform similar efforts in other cities, ensuring that climate adaptation measures not only address environmental challenges but also promote social justice and inclusivity in the face of a warming world.