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	Gijs ten Bosch
Student number	5081653

Studio		
Name / Theme	Metropolitan Ecologies of Place	
Main mentor	Luca Iuorio	Flood design protection / Infrastructure / Environmental technology and design
Second mentor	Daniele Cannatella	Landscape Design / Vulnerability Risk / Resilience / Urban Data Science
Argumentation of choice of the studio	This master's has enticed me to critically think about the way the future will shape the urban environments we live in today. I am interested in exploring ways of dealing with climate threats, especially water-related ones, which can be seen as one of the biggest contemporary transitions in habitats and environments on the planet. I chose the studio Metropolitan Ecologies of Place because of its core principles and how they would interact in this thesis. Water threats, urban vulnerability, and the state & design of infrastructural systems create a significant complexity in the socio-economic and ecological context of the United States. In my view, this combination requires an open-minded approach where landscape architecture, environmental technology, and urbanism intersect to create an interdisciplinary design perspective, which stands central in the studio. I want my project to contribute to the exploration of the potential of urban landscape design and strategy in the context of complex, vulnerable areas that are dependent on critical infrastructural systems. This exploration requires a multi-scalar research and design approach where complex systems intersect with each other through the scales.	

Graduation project	
Title of the graduation project	Uninsurable futures Designing Infrastructural Landscape Strategies for Flood Resilience in Vulnerable Urban Areas in Boston
Goal	
Location:	Boston, Massachusetts, USA.

	Analytical scale: Boston Metropolitan Area Design scale: Zoom-in – city & neighborhood scale
The posed problem	Worldwide, society faces severe consequences from climate change, which places urban environments under immense pressure. Increased flood risks due to extreme precipitation, heightened river runoff, and rising sea levels threaten the Metropolitan Area of Boston. Although projections of sea level rise depend on global carbon emissions, the IPCC (2019) indicates that the American East Coast is experiencing one of the highest rises. Additionally, Boston ranks 8th globally in terms of average annual economic loss caused by coastal floods (Hallegatte et al., 2013), and the city faces 100% flood exposure if sea levels rise by 1.80 meters (6 feet) (Berger et al., 2020). These are merely coastal flood risks, not to mention the hazards that arise from inland flooding (pluvial & fluvial). Furthermore, Boston is particularly vulnerable to floods due to the land making history of the city, which correlates to land subsidence along the coast and areas developed throughout the city's history. The flood risk management system in the United States differs from that of the Netherlands. Dutch water management relies on physical flood defenses, while in the United States, insurance (and evacuation strategies) are more important (Hooimeijer et al., 2022). Between 1988 and 2017, Davenport et al. (2021) estimate that flood damage accounted for just over 200 billion dollars. The requirement of purchasing insurance to mitigate flood risk, combined with significant inequalities in the United States, creates an unfairness in protection. Increasing flood risks are not only threatening the Metropolitan Area of Boston, but the infrastructural systems that support the urban environment are also nearing the end of their lifecycles. This issue of longevity places pressure on the system's functionality, as the urban environment depends on these infrastructures. Furthermore, systems like the sewage network are operating beyond capacity and are likely to fail, with combined sewer overflows occurring regularly. Additionally, centralizing large engineered infrastructures, such as wastewater treatment plants and dams, creates a false sense of security. The reliance on an external energy supply, combined with the centralization of the wastewater plant, places the system at significant risk of collapse. The construction of dams in the area has led to increased development. However, these outdated dams also have limited lifespans and pose heightened hazards in the event of dam failure. The condition of the infrastructure is not the only issue. Simply the presence of infrastructural systems disrupts vital natural landscapes and core habitats in the area, obstructing ecologies and rare species. This is demonstrated by the disastrous effects that

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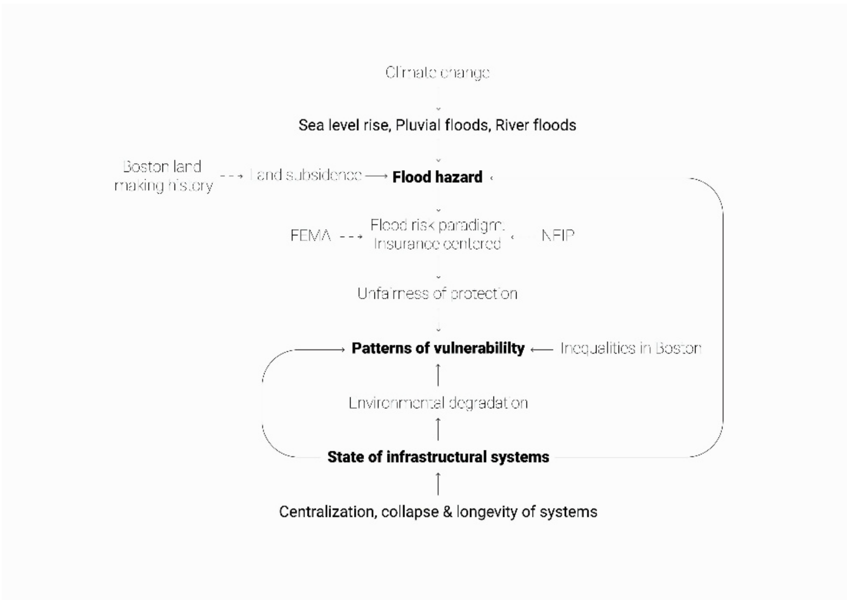
dams have on fish migration and how they diminish fish spawning areas.

The combination of flood hazards and the current state and effects of existing infrastructural systems shape vulnerable people, animals, and areas. Environmental degradation, historical land making-induced land subsidence, and socio-economic inequalities contribute to unfair levels of protection and disparities in the accessibility of essential resources and infrastructures, particularly in the context of the insurance paradigm in the United States.

Problem Statement
Flood hazards, in combination with the insurance paradigm of the United States, together with the current state and effects of existing infrastructural systems shape vulnerable people, animals, and areas. Environmental degradation, historical land making-induced land subsidence, and socio-economic inequalities contribute to unfair levels of protection and disparities in the accessibility of essential resources and infrastructures.



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Main Question
How can integrated infrastructural landscape-based flood design strategies increase the adaptive capacity of vulnerable areas in the urban fabric of the Metropolitan Area of Boston?

Sub-questions
1. What is the current state of water and landscape infrastructural systems in Boston?

2. How will extreme water scenarios develop in Boston and what are the implications?

3. How do complex patterns of vulnerability work in Boston?
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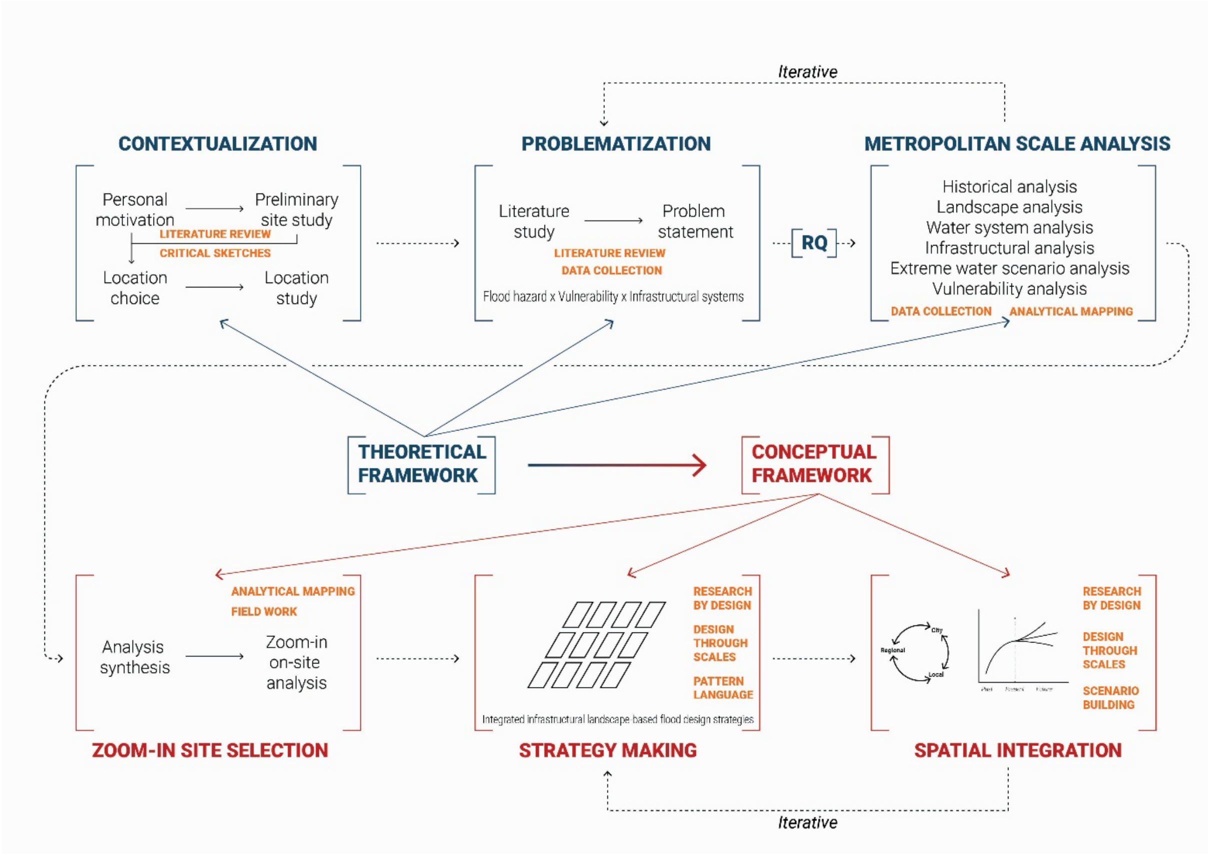
	4. What are suitable integrated infrastructural landscape-based flood design strategies? 5. How to integrate infrastructural landscape-based flood design strategies?
design assignment in which these result.	**Design aims** 1. To build a foundation by analyzing the historical developments and current state of landscape, water, and infrastructural systems, how they interact with each other, and the identification of critical problems in relation to these systems. 2. To gain a contextual understanding of the extreme water scenarios caused by climate change and their implications for the urban fabric. 3. To understand and decompose the different layers that collectively create the complex patterns of vulnerability in Boston in order to design for the people who are most vulnerable. 4. To explore, design, and collect suitable integrated infrastructural landscape-based flood design strategies to create a collection of potential strategies that utilize landscape as infrastructure. 5. To use all insights from previous sub-questions and spatially integrate certain flood design strategies in zoom-in area(s) to increase the adaptive capacity of flood-prone, vulnerable areas by combining landscape and infrastructure in the urban fabric of Boston. **Design outcomes** 1-3: The first three sub-questions lead to an atlas that lays out water, landscape, and infrastructural systems and the problems that are related to these systems; flood maps; socio-economic vulnerability maps; and finally, a synthesis where all information is combined to frame the problems and build a foundation for the design phase of the thesis. 4: A pattern language where various landscape as infrastructure design interventions are collected, designed, and combined to create building blocks for infrastructural landscape design strategies for flood resilience. 5: A spatial integration that shifts between city and neighborhood scales, where the identified strategies from sub-question 4 are applied to the urban fabric in the zoom-in location(s) that were derived from the first three sub-questions.

Process

Method description



The methodology of this thesis is composed of six sections. The theoretical framework serves as a foundation for the first three analysis-oriented sections, whereas the conceptual framework serves for the last three design-oriented sections. After the contextualization of the project, an iterative process occurs between the metropolitan scale analysis and the problematization section. The metropolitan scale analysis generates important information that serves as input to build the problematization section, which gives direction to the analysis. The metropolitan analysis section mostly consists of analytical mapping, in combination with the search and collection of data to start answering the first three questions. Below, the methods per section will be explained:

Contextualization

Literature review: Introducing the problems regarding floods, infrastructural systems, and vulnerabilities

Critical sketches: Preliminary analysis and site comparison for project location

Problematization

Literature review: Understanding the complexities and different layers of the problem framework

Data collection: Find data to support findings

Metropolitan scale analysis

Data collection: Finding statistics, historical data, and geospatial data to support analytical mapping

Analytical mapping: critical mapping exercise to understand spatialize landscape, water, infrastructural systems, flood threats, and patterns of vulnerability to identify problems and threats

Zoom-in site selection
Analytical mapping: to understand the context in the smaller scale and get familiar with the design context

Field work: To observe and document the local conditions and knowledge. Engage in conversations with residents and possibly local universities to explore local opportunities and limitations in the integration of infrastructural landscape-based flood design strategies.

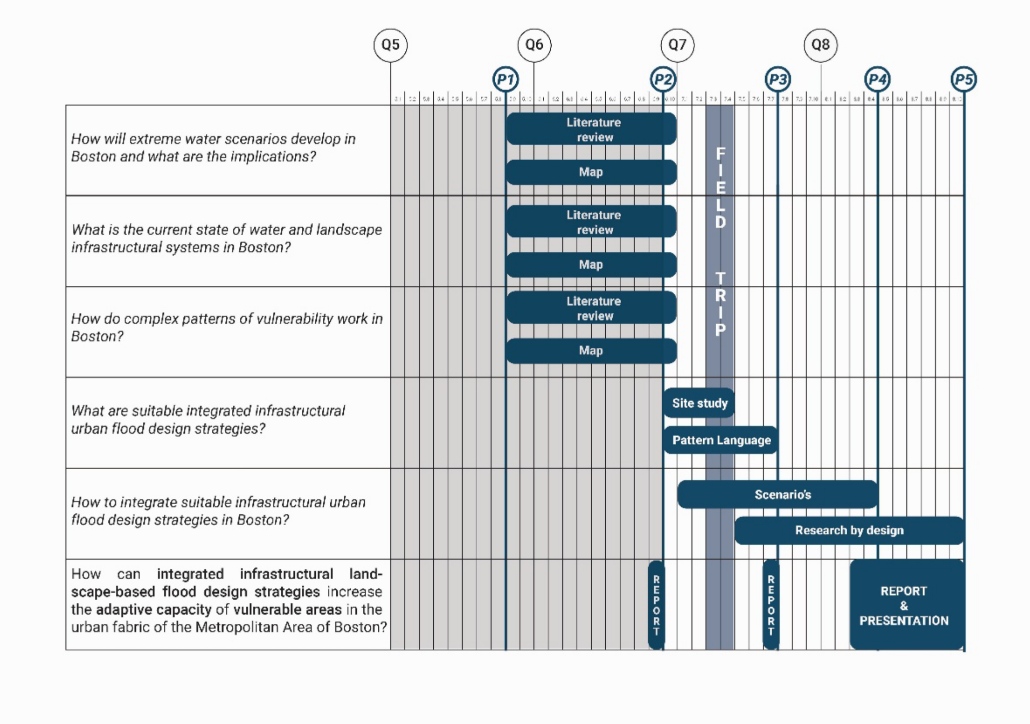
Strategy making & Spatial integration:
Research by design: This iterative method applies design as a method where the goal is to understand and research the identification and creation of landscape-based infrastructural flood design strategies and their integration in the urban fabric

Design through scales: The strategy-making and spatial integration exercises adopt an open-minded stance where the interaction between different design scales is shown, and how they relate to one another.

Pattern Language: Constructing a 'vocabulary' of landscape-based infrastructural flood design strategies by categorization, collection, and design of them in patterns. The pattern language is an exploration of strategies that are applied in the Spatial integration section of the thesis.

Scenario building: A speculative method where the exploration of possible futures stands central by projection different 'what-if' scenarios that relate to the fundamental research from the analysis phase of the thesis. The design of future uncertainties is integrated into the urban fabric of the zoom-in location(s).

Project timeline



Literature and general practical references

The theoretical underpinning supports the analytical component of the project's problematization. By creating a subdivision of theories and concepts, the various aspects of the problematization will be examined to create a stronger connection between this project and the existing body of knowledge. If possible, the relationship between theoretical concepts will be highlighted in this section. Finally, the theoretical framework provides an overview of how the key literature can be applied to this project. Three distinct groups of theoretical concepts are identified and examined: landscape infrastructure design, flood resilience design, and vulnerability and adaptive capacity.

Landscape infrastructure design
Currently, especially in the American context, urban environments are heavily dependent on large, ultra-engineered infrastructural systems. These systems are built to last for a certain period. However, times are changing, and due to climate change, these infrastructures might not be able to cope with the added pressure of intensifying flood threats. Landscape infrastructure design is based on the concept of utilizing landscape and water properties by integrating ecological systems into the urban fabric. The uncertainties over time make landscape infrastructure design a strategy with the potential to adapt to future water conditions.

Landscape is a dynamic system that displays the connection to culture and how it has been altered by nature and humans over time. It is a multi-layered plane that shifts through different physical properties where humans settled and depleted it. The landscape is subject to dynamic processes that span over centuries. Since the twenty-first century, landscape has risen to the light due to deindustrialization and increased environmental awareness. Before, the practice of landscape (architecture) was not connected to architectural or urbanism practices. According to Corner (2006), landscape gained recognition in planning theory and was seen as a tool for urban and architectural planning. This led to the creation of 'Landscape Urbanism'. The city is a fast-paced, dynamic system that constantly evolves. As a consequence of this rapid urbanization process, negative byproducts like pollution are present. Landscape systems allow citizens to escape from the overwhelming dynamics of the city. On top of that, these systems play a significant role in ecological and environmental conservation in the urban environment. The Back Bay Fens, as part of the Emerald Necklace structure in Boston, is not merely a park, but also a hydrological and stormwater management system.

Ian McHarg was responsible for the integration of ecological principles into urban planning and design processes. First, this was only related to the natural and landscape components in this planning process. Later, the fluid dynamics of the landscape and ecology were connected to urban systems. "The designation terra firma (firm, not changing; fixed and definite) gives way in favor of the shifting processes coursing through and across the urban field: terra fluxus." (Corner, 2006).
This notion is relevant to the intervention of landscape (urbanism) into urban infrastructure.

Infrastructures support urban flows most critically; thus, they are indispensable in the urban system. In fact, they play the main role in the urban system. Not all infrastructural systems are prominently visible. Many pipes and cables are laid underground, and large structures are usually positioned outside of busy urban centers. However, failures – caused by floods, for example - in the infrastructural systems that support urban environments remind us that they are not indestructible. Industrialization led to the centralization of large infrastructural systems. According to Bélanger (2010), the privatization of public services, due to a doubling in the U.S. population and a stagnating economy, has resulted in deteriorated urban infrastructures. Bélanger states that the privatization of infrastructure has led to underinvestment and overdue maintenance. This “will require an investment of $2.2 trillion over the next five years” (Bélanger, 2010).

Bélanger (2017) critiques the overreliance on civil engineering and pledges to integrate multiple disciplines into the design of infrastructural systems. With this in mind, he questions the equation that defines infrastructure as equal to economy and proposes a new equation where economy equals ecology, making ecology synonymous with infrastructure. He also addresses the increasing failures of ultra-engineered gray infrastructural systems, such as pipes, dams, and highways. These structures are layered across the landscape. Instead, Bélanger argues for the integration of these infrastructures within the landscape, as the landscape itself also supports urban life. The centralized infrastructures are nearing the end of their lifespan. Sooner or later, they will collapse, revealing the false sense of security in urban areas that relied on these structures.

These developments, which lead to the alarming state of infrastructural systems in the United States, raise the question of how to move forward. Essentially, how can infrastructural systems support urban life in the future? According to Bélanger (2010), ecological and environmental concerns are inseparable from the state of infrastructural systems in today’s context. The system flows are interconnected with their environmental consequences, bridging ecology and economy. The concept of infrastructure as landscape demands an interdisciplinary and flexible approach in the construction and management of infrastructural systems, as well as the (re)integration of the landscape.

Nijhuis & Jauslin (2015) deduce from the definitions of infrastructure and landscape that infrastructure modifies the natural environment, thus inevitably affecting the landscape. They indicate that combining both systems allows for optimization and integration, creating landscape as infrastructure systems that serve both purposes. The multidisciplinary nature of this combination highlights the importance of collaborative design. In this design process, they emphasize the significance of the multi-scalar dimension and ‘longue durée,’ reflecting dynamics over an extended period. Nijhuis & Jauslin also note that the design process of urban landscape infrastructures would benefit from a research-by-design approach.

The landscape as infrastructure approach does not oppose the existence of infrastructure. In fact, urban areas cannot function without it (e.g., transport, electricity, water, sewer, communication systems). However, the organization of infrastructural systems established during the industrial era requires reassessment. Alehashemi et al. (2017) have analyzed methods for adapting these infrastructures in the post-industrial era. They state that a “multi-dimensional and holistic approach” is necessary, where the social, ecological, and economic domains of the urban fabric intersect with the landscape as infrastructure approach to achieve more flexible systems.

Flood resilience design

The theoretical framework of flood resilience design focuses on water management methods that differ from traditional land protection approaches. These older methods involve large, physical barriers, while newer designs embrace water through more open interventions, promoting flexibility and adaptability. Flood design regards not only sea level rise and storm surges but also pluvial and fluvial floods.

Currently, flood risk management is predominantly focusing on the primary defense line and reducing the likelihood of flood events. However, Iuorio & Bortolotti (2021) assert that this engineering-focused risk reduction approach may not always result in a design that aligns coherently with the landscape. This challenge can be addressed by integrating design into flood management, involving the (urban) area, and reintegrating ecological systems behind the primary defense line, a concept referred to as 'integrated (urban) flood design.' According to Hooimeijer et al. (2022), this idea "is still underdeveloped."

Moreover, it is crucial to frame the concept of flood resilience. Laidlaw & Percival (2023) have identified a shift in the flood risk management approach. Initially, flood management focused on risk, but it is now transitioning toward resilience-based approaches. However, they note that there is no coherent, overarching definition of flood resilience. The concept of resilience originates from engineering, describing the capacity of a system to return to a normal, balanced state after a disruption. Davoudi et al. (2012) proposed a conceptual framework based on three dimensions of resilience: engineering, ecological, and evolutionary. The ecological resilience perspective emphasizes a system's ability to withstand and absorb external shocks (Holling, 1996).

Nonetheless, the notion of shock absorption and returning to a previous state, central to ecological and engineering resilience, has been challenged by the emergence of the socio-ecological approach known as evolutionary resilience (Davoudi et al., 2012). This perspective acknowledges the differences between human and natural systems, contesting the idea of an unchanging, balanced state over time (Davoudi et al., 2012). Evolutionary resilience focuses on shock absorption, followed by adaptation, transformation, and evolution into a new, improved state. A comparison between flood resistance and flood resilience illustrates that while flood resistance aims to prevent water intrusion, flood resilience prepares the system to adapt to flooded conditions and ensures that the system functions as quickly as possible (Davoudi et al., 2012).

The concepts of integrated (urban) flood design and evolutionary resilience are interconnected. Liao (2012) advocates for a resilience-based management approach for river cities instead of a risk-based one. Relying solely on physical structures like levees and dams does not account for uncertainties over time. In light of extreme, intensified water scenarios brought on by climate change, this approach has become outdated. Liao's urban resilience theory regarding floods asserts that urban areas should be designed to accommodate floods, with the percentage of floodable area serving as a key performance indicator. In this context, the degree of flood control is replaced by the degree of flood adaptation to reduce flood hazards.

Jha et al. (2012) categorize flood management measures into structural and non-structural types. Structural measures focus on controlling water flow, while non-structural measures target flood risk reduction through urban planning and management. Examples of non-structural measures include emergency planning, risk awareness, and flood risk avoidance via land use strategies. Effective non-structural measures require a comprehensive stakeholder engagement plan. The principles and goals of integrated urban flood design, evolutionary resilience, and landscape infrastructure design overlap and synergize with one another. While it may appear that similar principles can be applied universally, Jha et al. (2012) emphasize that each location and flood type necessitates a tailored, context-specific flood management plan.

Vulnerability & adaptive capacity

The complexity of urban environments, coupled with flood hazards, places pressure on vulnerable groups, particularly. Understanding vulnerability and adaptive capacity is crucial to assessing risk distribution in urban settings. By integrating the concepts of vulnerability and adaptive capacity, this thesis aims to propose design interventions that benefit everyone, including the most vulnerable groups.

Flood hazards driven by climate change are impacting urban environments worldwide. However, certain groups—even within the same area—face greater risks. According to Thomas et al. (2018), vulnerability often arises from social and economic factors. The extent of vulnerability at the local level is heavily influenced by the availability of essential resources for at-risk populations. These findings indicate that both local and larger governance scales significantly affect vulnerability patterns. As previously mentioned, vulnerability is directly linked to the differences in exposure to flood threats across communities and their respective adaptive capacities (Smit & Wandel, 2006). Research suggests that adaptive capacity is typically associated with the community scale, whereas the reason to increase the adaptive capacity arises from issues at the city, regional, or even global levels. This leads to complex adaptation strategies. Mortreux & Barnett (2017) emphasize that the challenges of implementing adaptation are tied to research that builds on "a one-size-fits-all assets-based theory" equating adaptation with capital. Mortreux & Barnett (2017) identified several influential drivers of adaptation actions: "risk attitudes, personal experience, trust and expectations of authorities, place attachment, and competing concerns." The integration of urban flood design with the landscape as infrastructure concept presents an opportunity to bridge the gap created by the multi-scalar complexity between adaptive capacity and adaptation. Furthermore, the social and governance aspects of flood hazard management play a vital role in ensuring local-scale integration within larger systems.

This theoretical framework brings together landscape infrastructure design, flood resilience, and vulnerability to support a comprehensive approach to urban water challenges. Landscape infrastructure offers an adaptive alternative to rigid, centralized systems, aligning with flood resilience strategies that embrace uncertainty and change. Integrating vulnerability and adaptive capacity adds a critical social dimension, highlighting the unequal impacts of flooding and the need for inclusive, locally informed responses.

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Important datasets

American Community Survey (2019) – socioeconomic vulnerability analysis

Commonwealth of Massachusetts (varies) – statewide vector data

Decennial Census (2020) – disadvantaged communities

Trust for Public Land (2023) – community vulnerability scorecards: Metropolitan Area of Boston

Woods Hole Group (2023) – Massachusetts Coast Flood Risk Model

Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

To me, this project is an exploration of climate adaptation in the context of intensifying flood threats. However, it is more than just climate adaptation; it is about the interplay between complex infrastructural systems that support urban life and the vulnerabilities in the urban environment, and how these factors affect each other in both directions. The combination of these urban domains in the context of flood threats aligns with the Metropolitan Ecologies of Place studio, which examines the socio-economic and ecological transitions in today's urban environments in response to climate threats, such as floods. The project identifies itself as a crossover landscape architecture, environmental technology, and urbanism, by exploring and utilizing the concepts of landscape urbanism and landscape as infrastructure to research strategies by design.

The project focuses on the integration of landscape-based infrastructural flood design strategies in the urban fabric of Boston. The multi-scalar aspect of the project, where regional analyses serve as a foundation for city and neighborhood scale adaptation strategies, aligns with the master track of Urbanism. The project's methodology alternates between research by/and design. The integration of research in the design of socio-economic, environmental, sustainable, and resilient urban environments where complex systems intersect to support urban life aligns with the core of urbanism. On top of that, the project's focus on resilience planning and cross-disciplinary nature to create sustainable urban development in the future reflects the master's programme. I see that this project has the potential to serve as a foundation for the other tracks in the programme to join in, from flood resilient landscape & building design to the management and stakeholder engagement towards flood-resilient urban planning.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

The social relevance of the project lies in the importance of increasing the adaptive capacity and addressing the uneven spatial distribution of flood vulnerability. In Boston, certain areas are more vulnerable to flood threats, caused by an unfairness in protection. By engaging with landscape as a spatial system that can absorb, delay, and distribute water, it simultaneously serves its basic infrastructural purposes. This thesis proposes a way to reimagine adaptation as both an ecological and a social project. It argues for resilience strategies that are not only functional but also just and inclusive.

Professionally, this thesis contributes to the response to challenges in the field of urbanism and landscape architecture, regarding climate change, aging infrastructure, and socio-economic systems. By integrating research, design, hydrology, infrastructure design, and spatial vulnerability, the work explores alternative urban futures that challenge traditional 'hard' infrastructure and explores potentials through the lens of landscape as infrastructure design. The scenarios and design strategies developed can inform both planning agencies and design practitioners working on climate adaptation, resilience, infrastructure design, and vulnerability in urban areas.

Scientifically, the thesis fills a gap between theories on adaptive capacity, vulnerability, and infrastructural resilience and the integration of these concepts in spatial planning and design. It builds on and extends landscape-as-infrastructure theory by applying it to the urban fabric

of Boston, which is prone to inequalities, aging infrastructural systems, and urban inequalities. By spatializing adaptive capacity and proposing flood design strategies that work across scales and systems, the thesis offers a model for integrating landscape urbanism with climate resilience, with regard to infrastructural systems and vulnerable urban areas.