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Assessment of flood risk management strategies in three case study cities around the globe

Analysis of urban flood resilience strategies of Boston, Rotterdam and Melbourne

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Bachelor Thesis - Spatial Planning & Design
June 11th, 2021

Colophon

Title: Assessment of flood risk management strategies in three case study cities around the globe

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Version: Final version

Date: June 11th, 2021

Supervisor: prof. dr. J. (Johan) Woltjer

Cover page: City of Boston

Abstract

This research evaluates the flood resilience of three case study cities. Due to climate change, the risk of floods is increasing in frequency. This development has inspired a paradigm shift in Flood Risk Management, moving from a traditional to a flood resilience approach. Therefore, this paper provides clarity on the concept of resilience based on indicators from a literature review to provide an evaluation of the flood management strategies of the three cities. A theoretical framework serves as the construct on which the strategic policy documents of Boston, Melbourne and Rotterdam are assessed. While all cities have strategic plans in place which pass beyond the traditional flood management style, each has a distinct focus on one of the three pillars of resilience. The cities have different maturity levels regarding the integration and implementation of the strategies. While Boston and Rotterdam emphasise strong urban planning and development, Melbourne's focal point is situated in the risk communication and education to initiate private endeavours.

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1.Introduction

Cities are facing challenges of climate change-related consequences. Flooding in cities is becoming more common, owing to climate change-related phenomena. The risk of flooding due to heavy precipitation from extreme weather conditions and sea level rise presents a significant challenge to cities. At the same time, urban densification and land-use changes increase the vulnerability of cities to urban flooding (Sörensen, 2016).
Coastal cities, in particular, are especially exposed to flooding. Globally, 1.2 billion people (23% of the world's population) live within a 100 km radius of the coast. Around 15% of the world population are directly threatened by a rising sea level (Sörensen, 2016). This population is exposed to natural hazards in the form of coastal flooding, tsunamis and hurricanes (Adger, 2005). Despite coats being historically densely populated strips of land and trillions of dollars of assets located in coastal flood-prone areas, the effort in shielding communities has often been inadequate. Developments to foster resilience and increase climate adaptation were postponed for short-term economic reasons (Aerts, 2014).
Therefore, it is of crucial importance to develop strategies and plans to combat, mitigate and adapt to the challenges.

Over the last few decades, flood management has changed. It moved away from large-scale structural flood protection and towards an integrated flood risk management strategy. The new flood risk management approach recognises that the natural force of flooding cannot be stopped from happening at certain places. Therefore, it deems necessary to focus its emphasis on how to reduce flood consequences and limit the hardship for flood-prone communities (Schelfaut, 2011). The shift was formally embedded into the agenda of the European Union Flood Risk Management Directive (2007/EC/60). Since then, it presents a helpful framework for resilient flood management. The directive recognises that implemented measures should lower flood sensitivity and practical steps that can reduce flood sensitivity and generate effective risk governance (European Commission, 2007).
However, the approach towards resilience flood management is confronted by various challenges. Oftentimes, the conceptual definitions of resilience are lacking in consistency and do

not appear to fit for its operational use. The methods to enhance it are insufficiently known by flood managers and stakeholders. Furthermore, resilience is challenging to put into quantitative measurements and may vary from the source of disturbance and area-based local features (Schelfaut, 2011).

This paper elaborates on the challenges and demonstrates opportunities and obstructions to translate the abstract concept of resilience into practical strategies in the field. The discussion is based on the assessment of the flood risk management strategies in three case study cities around the globe. The three cases are selected to grant for a generalisation of the efforts to manage urban flood resilience in a range of cities worldwide. The purpose of this case study is to show the many possibilities and issues that a city may face when implementing Resilient Flood Management. The paper goes into detail about flood resilience engineering and land use measures and how to incorporate flood resilience into decision-making processes.

2.Research problem

The aim of this research is to critically evaluate strategies on their effort to build flood resilience and combat the lack of preparedness in view of flood events to secure the urban environment and to draw lessons and recommendations for other cities around the world. The concept of resilience introduces the idea of a more flexible and adaptive approach to flood management, opposed to the traditional, static interpretation. This research intends to establish a framework within which city resilience initiatives may be evaluated in terms of how the theoretical idea of resilience may be used in practice.

This research adopts the following research question:

To what extent have the flood management strategies addressed the urban flood resilience of Boston, Rotterdam and Melbourne and which general lessons can be drawn for the resilience planning of other cities around the globe?

Consequently, the questions that follow from the main research question and the specific case of Boston, Rotterdam and Melbourne:

- *What is the concept of flood resilience?*
- *How can strategies for cities address urban flood resilience in general?*
- *How is urban flood resilience addressed in strategies for Boston, Rotterdam and Melbourne?*
- *What are the lessons learned? How can they serve as recommendations for other cities?*

Structure

This thesis is made up of six distinct chapters. Starting with the introduction and followed by the research questions, which are tried to be answered. The Core theory of resilience will be further defined in chapter three. Chapter four elaborates on the different research methods and the specific case being studied. The fifth chapter presents the content analysis of the three case studies for the strategic plans. Chapter six will concludingly answer the main research question and provide recommendations.

3.Theoretical framework

3.1 Defining Resilience

What is the concept of flood resilience?

The paper aims to elaborate on how far the concept of resilience has been included in flood management of various cities. The paradigm shift in water management approaches moved away from traditional flood control to risk management, focused on minimizing flood consequences. This has been clearly expressed in the maxim of resilience rather than resistance. Vis et al. (2003) define resilience as a system's ability to persist if disturbed and to recover after the response. As a result, resilience is the polar opposite of resistance: the ability of a system to continue in the face of adversity without showing any signs of distress.

According to Vis et al. (2003), the flood resilience paradigm responds to the reduction of the flood consequences and recovery. Therefore, it is detrimental to take the scenario of potential flooding into account. The aim is to minimize the damage potential, for example, by land-use adaptations. The Resiliency approach to flood management relies on risk mitigation instead of a resistance focused approach of hazard control (Vis, 2003).

However, other scholars including Davoudi et al. (2012) consider resistance and resilience not as opposites as they are presented by previous scholars. In their definition of resilient flood management, one attribute of resilience is persistence or robustness. Davoudi's evolutionary resilience emphasizes the dynamic interplay between the components' persistence, adaptability and transformability. Furthermore, the idea of evolutionary resilience has been introduced which underlines the importance of preparedness and that systems are eternally changing and need to be able to adapt to change. In this paper, Davoudi et al. (2012) definition of resilience has been applied to flood resilience planning.

Resilience flood management demands are built upon those three essential pillars: persistence, adaptability and transformability. The concept of resilience has to combine these, on first look, contradicting elements (Davoudi, 2012). However, the importance of one element is case dependent. One situation requires different priorities regarding its implementation. Therefore, resilience-building can shift its focus to one of the three pillars (Restemeyer, 2015).

The ability of a resilient system and community to recover quickly and effectively from the consequences of a hazard is highlighted by Jahr et al. (2013).
Schelfaut et al. (2011) emphasize the belief that knowledgeable and well-prepared communities are a means to counteract harm and limit the actual flood impact. Conceptual model- key factors in strengthening resilience are mitigation, preparedness, response and recovery.

Although the numerous definitions of resilience focus on certain aspects of the board concept, there are some unifying features and common notions of resilience. Gallopin et al. (2006) summarized the notions of concordance into three main attributes. Developing resilience is thought to be a sound method for dealing with uncertainty and surprise. Complex and dynamic systems have a trait called resilience. Resilient systems are capable of coping with recovering from disruptions.

The concept of resilience has gained significance under the Hyogo framework for action conference in 2005. However, the implementation into practice presents a challenge due to its complexity (Schelfaut, 2011). Thus, the necessity appears to assess different strategies in what way they have overcome the challenges and at which points they still struggle. The result will allow for the formulation of recommendations addressing each reviewed case as well as a framework for the assessment of flood resilience in cities in general.

3.2 Resilience as the three pillars

How can strategies for cities address urban flood resilience in general?

Robustness or Persistence aligns along with the attributes of traditional flood management. It aims to control changes and forces them into presumably stable systems.
A persistent city has to rely on technical measures to be persistent and to withstand a flood event. Fundamental measures are for example dikes, sluices and storm surge barriers. However, the recent history of flood events has shown that only relying on a robust flood system is not

sufficient. Especially under the aspect of a changing climate, there will always be flood events that overtop the first line of protection (Restemeyer, 2015).

Therefore the second pillar of Adaptability is necessary. Adaptability as a part of resilience building implies that the city adjusts to the likelihood of flooding so flood consequences can be held to a limit. In regard, it is necessary to adapt to the physical environment and the social dimension of flood management (McClymont, 2020).
Measures to adapt to the physical environment may include Land use plans to prohibit developments in flood-prone areas, Evacuation plans, Insurance policies and guidelines for flood-proof houses. However, the approach of adaptability in flood management requires a social dimension. When drastic decisions regarding the urban fabric and the physical environment are being made, the city's inhabitants' lives are directly affected. In this case, flood risk management becomes a societal task and needs to respond in cross-disciplinary collaborations. Water management spatial planning and disaster management have to work in synergy to successfully prepare flood adaptation strategies. In this process, active citizen participation is aligning with a decentralised, bottom-up, flexible management structure (Zevenbergen, 2008).

Transformability addresses the change of people's sets in connection with a responsive physical environment. The transformation takes place on a socio-ecological dimension. It enables a shift in capacity from the interpretation of ‘water as a threat’ to the position of ‘living with the water’ and ‘water as an asset to the city’. Pahl et al. (2006) illustrate the shift as an attribute and strength of an integrated adaptive regime that holds the position of predict and control understanding. Therefore, the capacity to transform presume change based on new insights and a circle of continuous drive for appropriate flood management.
Davoudi et al. (2013) discuss the capacity of transformability as a distinguishing factor of evolutionary resilience to engineering and ecological resilience.
Transformability considers disturbances to systems as an opportunity to escape the equilibrium and to expand the threshold. The phase of creative destruction and transformation has been called the omega phase by Davoudi et al. (2013). The adaptive cycle is framed as a window of opportunity with the potential to transform socio-ecological processes towards radically different and more desirable paths.

3.3 Implications of a resilience-based strategy for decision-making

The three pillars of Persistence, Adaptability and Transformability are established as the prerequisites for resilient flood management. However, each condition has different implications for technical measures, collaboration, organisation and stakeholders (Restemeyer, 2015).

Persistence is a key notion for a resilient city and requires technical measures such as dikes and dams to make a place to withstand flooding. Adaptability as a component of resilience demands strong cooperation between departments as spatial planners and risk management. Furthermore, it is the shared responsibility of private and public stakeholders. Finally, transformability envisions the social responsibility of the public as a means to create innovative solutions and adhere to potential opportunities which appear from disturbance. A bottom-up governance approach and the localization of knowledge capacity and public support are necessary (Bertilsson, 2019).

Therefore, establishing the concept in a real-life situation apart from the theoretical concept approach to be highly complex and challenging.

Hutter et al. (2006) proposed the addition of three perspectives that support the analysis of the multidimensional strategy of resilience. Therefore, the parameters of content, process and context were introduced.

3.4 A strategy-based framework for assessing the flood resilience of cities

The incorporation of the multidimensional parameters is serving the building of comprehension towards the evaluation of flood resilience. Each of the parameters can be applied to the three pillars of resilience which were described in the sections above.

3.4.1 Content

Accordingly, the parameter regarding the dimension of the content focuses on measures and policy instruments necessary to foster resilience. In regard to reducing the risk of flooding, the applied measures are influenced by the more traditional approach to flood management and therefore more technical such as dams, dikes and sluices (McClymont, 2020).

In order to prepare the city for floods, adaptive spatial measures are becoming more relevant such as zoning plans to avoid flood-prone areas. Transformability aims to induce societal change. Private responsibility can be a leading force to reducing flood vulnerability by initiatives to flood-proof houses. The transformation of the city by inhabitants rely on awareness building and empowerment of local stakeholders and inhabitants. This way changes in the physical environment can be induced. Self-organisation and involvement in decision making stimulate private development (Schelfaut, 2011).

3.4.2 Process

The process dimension interprets the organisational structure of flood management and the capacities of the public and private stakeholders involved. flood risk management can take different approaches depending on its individual case of which are favourable for robustness, adaptability and transformability. The governance approaches and structuring of responsibilities are indicators of where the focus has been laid (McClymont, 2020).

3.4.3 Context

The context dimension draws a picture of how external conditions have led to the current way flood management has been dealt with. Which strategies were implemented because of the identity of the place and its relationship with water?

The contextual factors present a certain path dependency and initiate how past decision making led to current situations. Therefore, the resilience program at the place also draws back on the institutional structure and legislation as internal conditions (Restemeyer, 2015).

3.5 Conceptual model

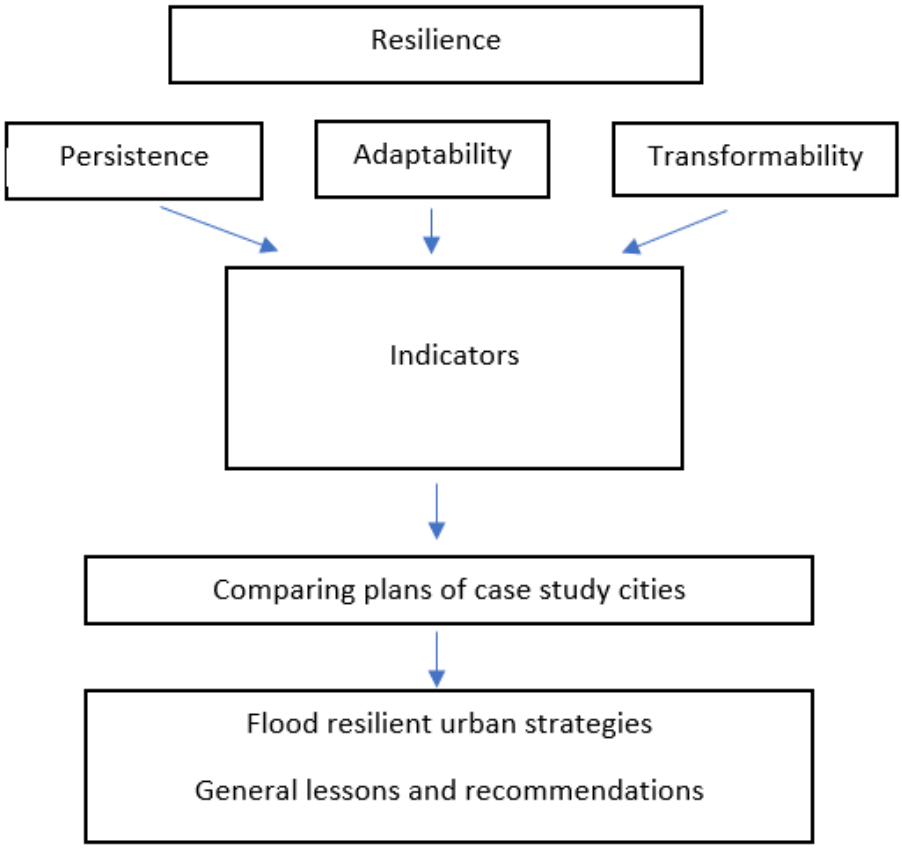


Fig. 1: Conceptual model

The conceptual model visualizes concepts and components of the process in assessing the flood resilience of cities. Moreover, it can be utilized as a way to indicate the various stages in which the research will be conducted.

3.5 Hypothesis

Due to the fact that the chosen cities for the case study do have an existing blueprint on flood management measures and constructions, the policy strategies will be most likely advanced too. To draw up expectations for the latter report, the case study cities will have extensive and complete policy strategies in regard to flood management. However, it is to be examined to what extent they apply as flood resilient measures.

4.Methodology

4.1 Case study method

The research method of a case study is applied. A case study aids the comprehension of complex issues. This approach provides the opportunity to acquire in-depth and comprehensive knowledge about a single object or process in practice (Clifford, 2016).

4.2 Case selection

For the case study, the cities of Boston, Melbourne and Rotterdam have been chosen. This is due to their location of close proximity to the coast. All of them are vulnerable to coastal flooding and have to protect millions of people and billions of dollars in assets from hazards. Each city has already existing flood management strategies at hand.
However, the city's geographical situation differs in the sense that it can represent various coastal cities all over the world (Britannica, 2020).

4.3 Data collection

The data collected for the research will partly rely on secondary and primary data sources. The policy reports are presented as the main data source. The use of a literature review of qualitative data helps to present current knowledge on the topic of resilience planning and introduces theoretical and methodological contributions by various scholars from that field of expertise.
For the data analysis, comparative analysis in form of a case study on three cities is conducted. Its goal is to analyse how the cities differ from one another by conducting a comparative analysis. The case study lays emphasis on comparing the cities on what measures have been taken and what have they planned in the future.
The Case Study of three cities in regard to their urban flood resilience strategies can serve to formulate general lessons based on them. This will allow the conclusion of recommendations in view of what other cities can learn from the cases presented.

4.4 Data analysis

The research aims to assess different policy strategies in their effort towards building resilience because of flooding risks. The to be analysed strategy plans are 'Imagine Boston 2030', Rotterdams 'Climate change adaptation Strategy' and Melbourne's 'Flood management strategy for Port Phillip and Westernport'.

The variables are based on literature and aim to connect the various approaches, concepts and strategies of resiliency. In order to identify the primary focuses and priorities of different policy approaches, the framework above presents factors and variables under which resilience building can be evaluated. The framework includes measures, institutional and organisational structure towards a sustainable flood management system.

Variables	**Persistence** Reduce flood probability	**Adaptability** Reduce flood consequences	**Transformability** Encourage change in society
Policies and strategies- **Content**	Engineering measures Maintenance	Land use plan, avoid flood-prone areas Evacuation Insurance Flood proof houses	Risk communication Water retention Education and information (citizens)
Collaborative process- **Process** Who is involved Capacities of actors	Top down Engineering and planning Strong water sector Strong cooperation between water and spatial managers	Hybrid Vulnerability reduction and adaptability) Importance of disaster management Shared responsibilities public private	Bottom up, local actors Social acceptance Awareness and empowerment of local citizens
Contextual factors- **Context**	Water threat	Synergies	Water as a tool for shaping places and people's identities Innovative networks

Fig. 2: theoretical framework of flood resilience assessment.

The theoretical framework serves the assessment of different urban flood resilience strategies. It aims to serve the objective of evaluating policy documents and the identification of resilient flood management measures. The indicators, represented in the framework, are seleccted according to the following literature. The three components of resilience-building are based on Davoudis et al. (2013) approach on evolutionary resilience. The dimension under which each

resilience component can be analysed is based on Restemeyers et al. (2015) strategy on assessing the flood resilience of cities.

The presented framework will be applied to the cases of Boston, Melbourne and Rotterdam.

The conceptual model as depicted in Figure 3 is used for identifying potentially relevant code groups.

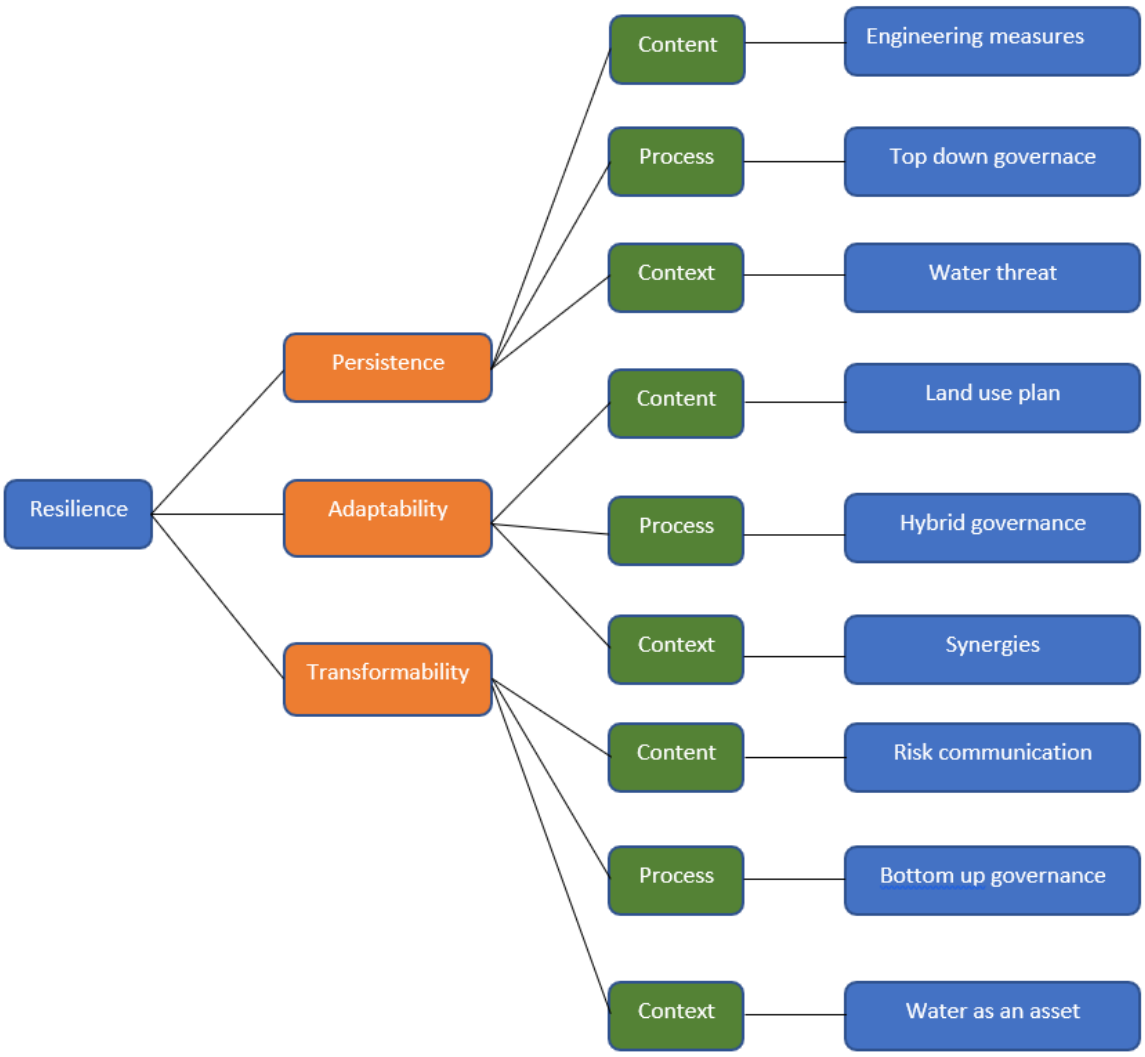


Fig. 3: Deductive coding tree

To understand the complicated idea of resilience in the numerous strategic plans, the tool Atlas.ti is utilized for data analysis. The program provides tools to create coding groups which serve the evaluation and recognition of their significance.

4.5 Assessment of the current situation

The assessment table in the Appendix I is used to evaluate the various strategy documents. By assigning a quantitative value to each evaluation factor, the flood risk management maturity level for each of the three cases can be determined.

4.6 Ethical consideration

When conducting research, it is important to be aware of ethical considerations.

During this research, the ethical considerations however are rather limited. Due to the use of strategic plans as a primary data source, interaction to respondents and businesses is little to nonexistent. However, some considerations are yet relevant in this research framework. The process of writing the thesis is conducted under the umbrella of integrity, including the avoidance of committing fraud. References are presented in text and in the reference list in the Harvard citation style.

Furthermore, the analysis and assessment of the various policy documents is conducted without bias or under any political influence.

5. Results

How is urban flood resilience addressed in strategies for Boston, Melbourne and Rotterdam?

5.1 Case study: Boston

The consequences of a changing climate pose a significant risk to the city. Increasing temperature, continuous extreme weather events and rising sea level will impact Boston's highly urbanized coastal residential and industrial environment. In recent years the scenarios of flooding, storms, and extreme heat are frequently occurring.

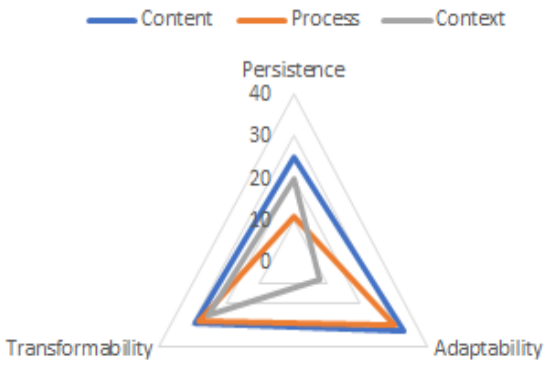
Scientists predict that major flooding will occur as early as 2070. A total of $80 billion in property worth will be exposed (Stefon, 2021).

Due to Boston's geographical location and the environmental conditions, coastal and riverine flooding have the most significant climate hazard consequences for the city.

5.1.2 imagine Boston 2030

In order to evaluate the flood resilient strategies of Boston, the strategic plan 'imagine Boston 2030' has been analysed based on the set factors described previously. Imagine Boston 2030 is Boston's first citywide plan in 50 years (Boston government, 2021).

The applied coding scheme in a qualitative analysis program gives an overview of where the main focus of imagine Boston 2030 in terms of flood resilience is located. It presents a relatively balanced approach between the three pillars.



5.1.2.1 Content

Imagine Boston 2030 incorporates a wide range of measures by making use of various action approaches. Boston's engineering measures for a robust flood management network sees Flood protection infrastructure that provides additional benefits like open spaces for the public.

In order to Strengthen the shoreline and protect vulnerable neighbourhoods, the plan foresees the

implementation of flood protection mechanisms as can be seen in Figure 5.

Next to the traditional flood management measures, Boston has developed plans to prepare the city in case of flooding. The city has adopted climate-ready zoning regulations. Furthermore, building standards and regulations were set in places to upgrade local buildings to become flood resistant. Boston council has ordered the conduction of a study on flood mechanism and flood risk areas in order to proceed with a proactive approach to flood mitigation.

Fig.5: Water management measures in South Boston

As part of the embracement of the new water culture and basis for a transformative and evolutionary approach to flood resilience, Boston's city council started multiple initiatives to increase the awareness and empowerment of local citizens. Web Surveys for residents were set up to present the city's inhabitants, so they could express their ideas on Boston's waterfront. The strategic action plan 'Imagine Boston 2030' is partly influenced by the outcome of the contribution of 15.000 residents. The enhancement of the Support for educated, connected communities aims to foster operational preparedness, adaptation planning and emergency response. The transformative and unique waterfront lies at the heart of the flood management measures (Boston Government, 2017).

5.1.2.2 Process

In order to implement the measures above, imagine Boston 2030 envisions close collaboration between the public and the private sector, especially in the case of adaptive and transformative approaches. The involved stakeholder of the municipality, risk management and spatial planning has a particular focus on protecting Boston's most vulnerable populations. Public investments are aimed at District-wide flood resilience. Local governmental emphasis has been put on flood protection and open space creation.

Planning at a district scale has been initiated as the more cost-effective solution. The new zoning and building regulations are applied to secure the effective support of priority spaces.

However, the governance approach in Boston's flood management strategy foresees the involvement of public participation as a crucial asset. Residents actively develop local climate resilience plans to prepare existing high-risk neighbourhoods. To Feature resilient communities, citizen engagement in the organizational process underlines the intention of bottom-up resilience management at a local district scale (Boston Government, 2017).

5.1.2.3 Context

The vulnerability of Boston can be expressed in the prediction of the 100-year flood. The consequences of such an event are illustrated in Figure 6. This common expression more accurately is described as the high-level flood which has a 1 percent chance. Over a 30-year period, there is almost a 1 in 3 chance that a 1 percent annual chance flood will occur at least once. The average monthly high tide is the area expected to be flooded about once a month even without a storm.

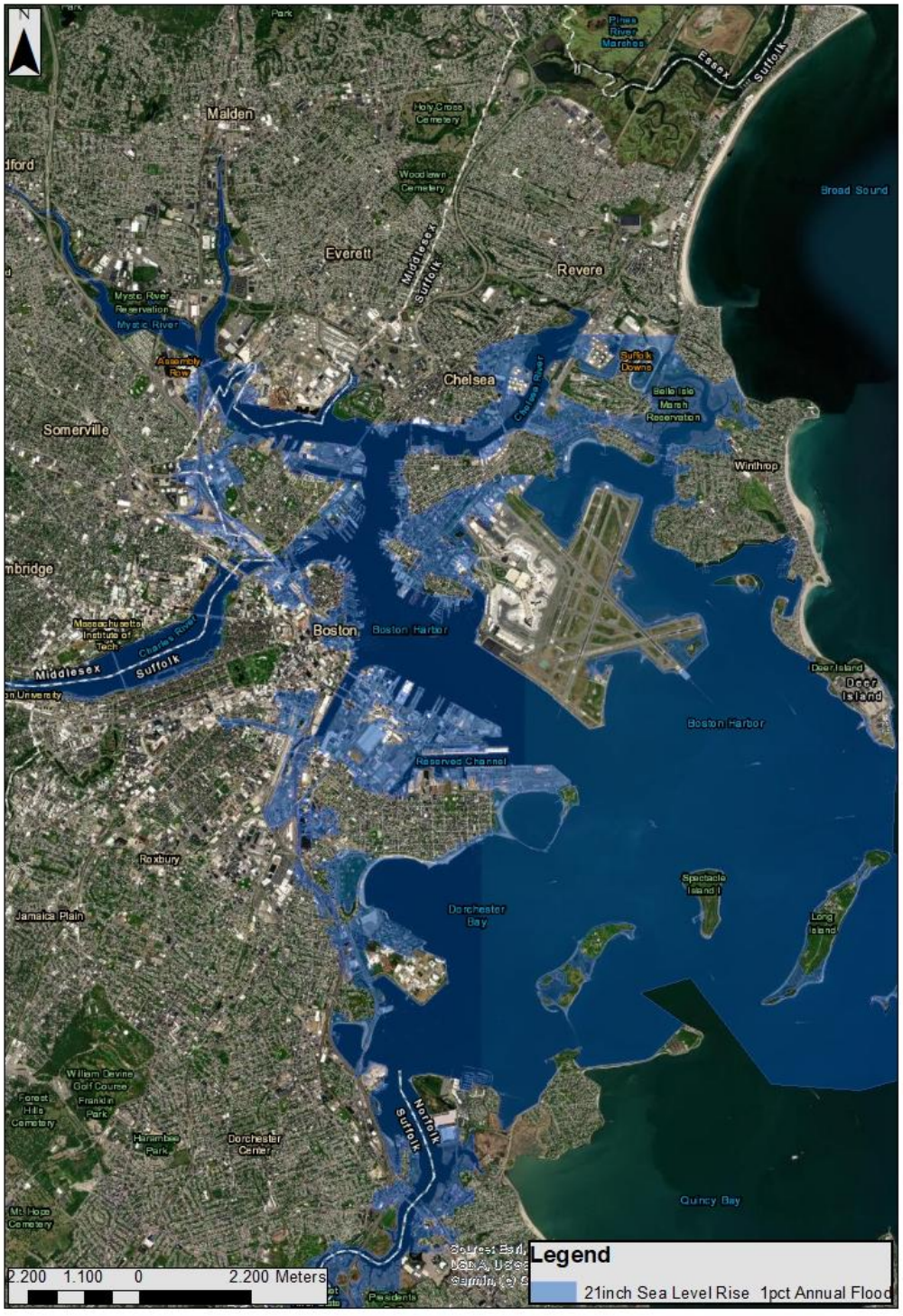


Fig. 6: Flood Map Boston (Holzer, 2021)

The city has found its way to incorporate the medium of Water as an addition to the place.

This development can be seen in the multi-layered flood protection system to prepare the economy, people and places.

The city of Boston has set its own agenda to become the Leader for 21th century waterfront cities by establishing a coastal environment

for future generations (Boston Government, 2017).

5.2 Case study: Melbourne

Melbourne is the capital of the Australian state of Victoria. It is located at the head of Port Phillip Bay, on the southeastern coast. The Port Phillip and Westernport region houses approximately 4 million people, and the population is expected to almost double in size by 2050 (Melbourne Water, 2015).

Metropolitan Melbourne is situated at the northern end of Port Phillip Bay which connects to the Bass Strait by the bay's narrow entrance. Most of the flat terrain is less than 120 metres above sea level (Prescot, 2020).

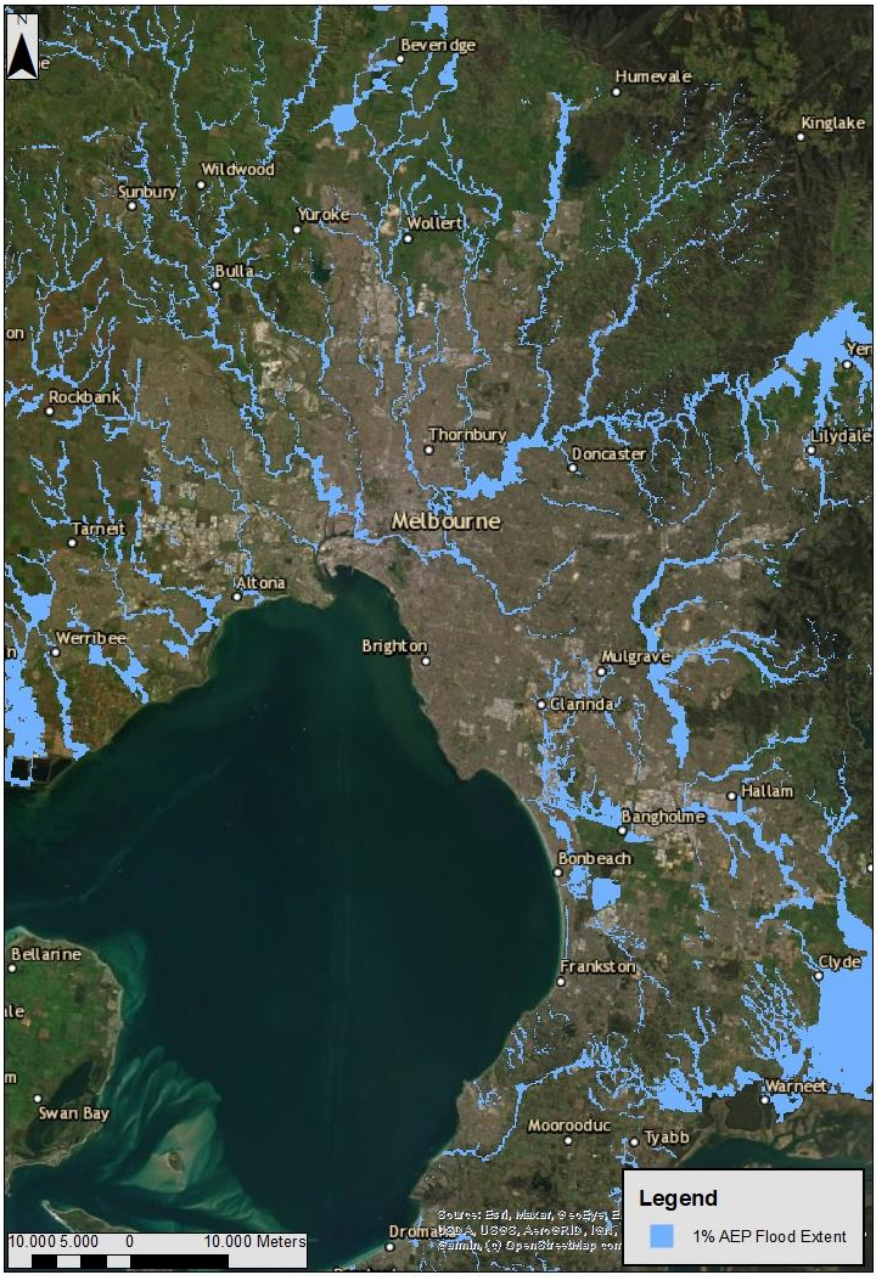


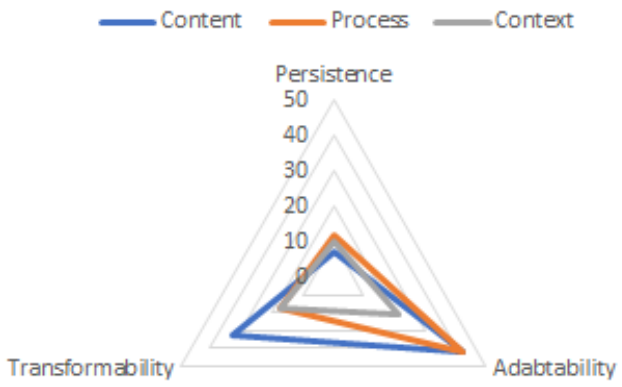
Fig. 7: Melbourne flood map (Holzer, 2021)

5.2.1 Flood management strategy: Port Phillip and Westernport

Melbourne Water prepared this strategy on flood management for the Port Phillip and Westernport region.

This strategy reflects the effort and activities of all organisations contributing to floodplain management across the region.

The absence of persistent strategies in the Melbourne strategic plan is evident. This can be explained in part by Melbourne's present low flood risk, as depicted in Figure 7. The strategy predominately addresses the reduction of flood consequences and the establishment of a shift in society towards dealing with floods. By doing so, the plan relies on expert and local knowledge and encourages public engagement.



5.2.1.1 Content

In pursuance of a persistent water management system to prevent floods, Melbourne plans to construct a new drainage infrastructure. stormwater capture and integrated water management enhance an adequate response to climate change.

Mitigation of the risk starts at organising urban growth and development in order to avoid creating new risks. Melbourne Waters developed flood maps and risk assessments to avoid floodplains and to manage new urban stormwater runoffs in the city. Subsequently, the maps indicate where the vulnerable communities are situated and where the priorities lie. The risk assessment supports flood emergency response and recovery activities (Melbourne Water, 2015).

Melbourne implemented community engagement activities to promote knowledge, boost resilience and preparedness, and decrease the repercussions of floods in order to prepare residents in the event of flooding. Many different stakeholders are taking part in the initiatives,

including state government departments, councils, emergency services, and communities. Melbourne Water communication programs aim for accessible sharing of processes and information on progress. Knowledge gained from delivering and evaluating these programs will be used to develop new education campaigns on flood risks and how to prepare for them (Melbourne Water, 2015).

5.2.1.2 Process

Melbourne's flood management strategy for Port Philip and Westernport is part of the ‘all hazards, all agencies’ approach to emergency risk assessment, prevention, preparedness, response and recovery. Melbourne Water, as a by the Victorian government-owned statutory authority, controls much of the water system in Melbourne is the designated floodplain manager for the region.

The agency plays a leading role in Coordinating the planning process and supplying of flood management and drainage services across the region. In cooperation with the Victorian state government, Melbourne waters developed flood mapping designs as the basis for sufficient and adequate risk assessment reports of the area. Engaging local communities in the process of developing flood management solutions are essential to ensure they are appropriate and to support communities to understand their risks (Melbourne Water, 2015).

5.2.1.3 Context

The history of Port Phillip and the Westernport region has been marked by many serious and damaging floods. In some locations, small, frequent flooding causes significant local damage, inconvenience and disruption. Therefore, it is crucial to prepare citizens for the events. Melbourne Water aims to forge so-called flood ready communities and individuals. The Plan of Port Philip and Westernport supplies the competencies to the individuals to be better prepared for, respond to, and transform from disruption. The concept of Resilience is a key in the pursuance to transform into a more sustainable, prosperous, liveable and healthy community (Melbourne Water, 2015).

5.3 Case study: Rotterdam

Rotterdam is one of the three major European ports and the second largest city of the Netherlands. The city lies along the banks of the New Meuse River, which is a northern distributary of the River Rhine.

Rotterdam as a delta city is especially vulnerable, as depicted in Fig: 8, to the consequences and effects of a changing climate. Increased extreme weather conditions of heavier rainstorms and rising water levels in the adjacent rivers present a great challenge to the city (Dirke, 2015).

Therefore, Rotterdam has, throughout recent centuries, developed efficient flood management. The effort in flood management makes Rotterdam one of the safest delta cities in the world.

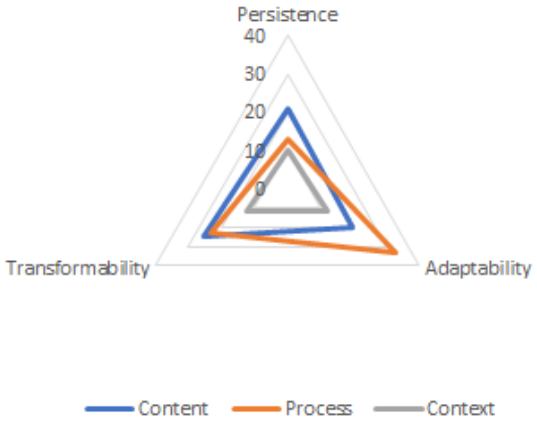
Nonetheless, a changing environment demands the city to continuously adapt. While the delta has brought Rotterdam its fair share of problems, it has also brought much more in the way of benefits (RCCAS, 2013).

Fig. 8: Flood map Rotterdam (Holzer, 2021).

5.3.1 Rotterdam Climate Change Adaptation Strategy

Rotterdam Climate Change Adaptation Strategy is an officially approved city policy, developed in cooperation with Rotterdam climate-proof, with the aim of making Rotterdam a resilient city by 2025. A climate-proof city is meant for all the people of Rotterdam with special attention to future generations and to maintain Rotterdams attractiveness and economic prosperity (Dirke, 2015).

The Rotterdam change climate adaptation strategy (RCCAS) draws back, unlike the name suggests, on a range of flood management measures. The balanced approach of persistent, adaptive and transformative measures and policies is definitely a strength in building a flood resilient strategy for the city.



5.3.1.1 Content

Rotterdam's climate adaptation strategy determines six main objectives which buildup on a climate-adaptive city. The first objective on the agenda is the protection of the city and its inhabitants from the rivers and the sea. Therefore, the city developed measures by which a persistent flood system can be achieved. Rotterdam has the capacity to rely on the current robust system of dikes, storm surge barriers and pumping stations.

In order to achieve an adaptive flood mitigation system, the city aims to implement the following measures. For the outer dike area in Rotterdam which is not included in the dike system, Flood proof buildings and flood-proof design of public areas such as incorporating local flood walls are meant to reduce the flood damages.

Part of an adaptive flood management system is the evacuation and emergency plans in case of storms. Therefore, the strategy plan incorporates emergency routes, the reassessing of evacuation plans (RCCAS, 2013).

The Rotterdam city council has emphasized in the strategic agreement to invest in the transformative approach to providing information about the risks of climate change and the direct consequences on the environment. The goal is to initiate the assumption of citizen responsibility, preparedness and empowerment. To achieve this, various projects have been started to build up a framework in which an understanding of the challenges and opportunities are communicated. The empowerment of citizens is meant to launch private investments in regard to flood resilience. For instance, most of the flood-proof building activity needs to take place in the private domain and can only be supported by subsidizing the state.

The recognisability of the dikes in the city plays a part in making the inhabitants more aware of

the risks of flooding (RCCAS, 2013).

5.3.1.2 Process

The Development of essential flood-proof infrastructure is the responsibility of Rijkswaterstaat and the utility network operators. The province is responsible for the urban and rural planning and in this role provides the integral policy framework for the outer-dike areas

The Ministry of Waterways and Public Works in cooperation with local water boards are supervising the reinforcement of the dikes and operation of storm barriers and sluices.

Water boards and national government, the province used to deal with flood protection and urban development on their own (RCCAS, 2013).

However, as the processes of public decision-making and the governing of society and economy changed from government to governance, the institutions are becoming active facilitators and initiators, as well as supporters and driving forces behind initiatives in the Rotterdam community (Lo, 2018).

5.3.1.3 Context

Rotterdam as a thriving port city continually adapts to new circumstances and anticipates and benefits from economic and social change.

Climate change adaptation is essential if Rotterdam is to be able to cope with these effects.

The strategy incorporates a future-oriented approach, not hesitant to transform with a changing environment.

The RCCAS aims to create a safe living and working environment for ‘water conscious’ inhabitants and businesses. As the strategy plan puts it ‘Living with the water threat is in our genes’ (RCCAS, 2013).

5.4 Assessment table

Assessment	Boston	Melbourne	Rotterdam
Persistence			
- Engineering measures	5	3	5
- Maintenance	4	3	5
Adaptability			
- Land use plan	5	3	5
- Evacuation	4	4	5
- Insurance	3	3	4
- Floodproof Building regulations	5	4	4
- Flood hazard maps	5	4	5
Transformability			
- Risk communication	5	5	4
- Water retention	4	4	3
- Education and information	4	5	5
- Preparedness exercise	5	4	5
- Empowerment of local citizens	5	4	4
- Local actors	5	5	4
- Social acceptance	4	4	4
Resilience level	4.5 coordinated	3.9 initial	4.4 coordinated

Fig. 9: Assessment table results

The results from the assessment table show that Boston and Rotterdam score highest in the overall assessment scheme and their strategies can be considered a coordinated resilience approach. Their strategies have been incorporated into a Flood risk management framework. Moreover, clear actions were undertaken to build up social and political capital. The strategy includes a range of Flood risk management measures and clearly defined the implementation processes. Boston and Roterdams flood risk management framework has reached a preparedness level for flood hazard and vulnerability, and they are progressing towards an integrated resilience strategy.

Melbourne, in third place, has scored less and therefore ended up in the category of initial maturity. This means that the Flood risk management policy and procedures are implemented partially. Some flood risk management tools and templates have been developed. However, the

implementation of flood risk management elements is yet limited to few stakeholders. Flood hazard zoning, land use planning and further procedures are not well coordinated or implemented. Sporadic measures are taken, however, institutional coordination is lacking.

More research should be done on how to improve the application of existing flood management frameworks and to make advanced tools available and incorporate best practices into the framework.

6.Conclusions

The concept of resilience introduces a new paradigm to the traditional flood management approaches in the form of urban environments living with the risks of flooding. The approach transforms the existing structure of flood risk management and creates a system that accepts the water as a valuable asset to the urban environment. Flood resilience evolves from a strong network to one that can not only recover from damage but also maintain a certain level of functionality during a flood.

The process of assessing flood resilience is a challenging mission that requires the recognition and involvement of many key stakeholders and relations. The dynamic feature of resilience challenges urban flood management and therefore, flood resilience measures should be implemented to achieve desirable levels of flood resilience in urban systems.

It is evident that in every case study city, flood management has evolved from the traditional flood management approach towards an integrated, resilient flood strategy. This regards not only the measures themselves but also the initiation of social and political capital through which the processes are applied to resilience building. Boston and Rotterdam scored respectively high maturity levels of 4.5 and 4.4 in their flood risk management. This is partly due to the fact that the two cities have developed a very strong urban land use plan, made up of various resilient measures. Melbourne scores an initial maturity level of 3.9. It takes a different approach to flood resilience management and focuses more on risk communication and active support of private actions and initiatives.

What are the lessons learned? How can they serve as recommendations for other cities?

It is evident that resilience is a highly contextual concept that does not create a single approach to a universal resilience flood management strategy. When comparing the Flood management strategies for Boston, Melbourne and Rotterdam it becomes clear that resilience is bound to a certain degree of subjectivity and context-dependency. On the one hand, the ability to control flooding, like in Rotterdam, can be considered a desirable resilience strategy for the present

situation. On the other hand, Boston's approach in absorbing and adapting to flooding also incorporates a resilient performance for their principles and geographical prerequisites.
The three cases illustrate the different approaches a city can take to develop resilient flood strategies. Although, the different historic backgrounds, path-dependent conditions and different geographical features, there are certain aspects each city has to pay attention to when aiming for a holistic resilience approach.

The current situation regarding a stakeholders place in the decision-making process focuses on different spatial levels and phases which is good, but there is still a detachment among stakeholders. The methodology of engaging Stakeholders should change in response to the government determination to improve the efficiency of flood risk management decisions. The shift towards community participation necessitates a reassessment of how stakeholders perspectives might be better included in decision-making. Stakeholder participation is a complicated process. There are variances in stakeholders interests when it comes to flood risk management planning. Participation and consultation are important aspects of the engagement process for various stakeholders to achieve the transformability dimension which is crucial to building up social capital.

Nonetheless, The three cases are able to guide other coastal, western cities in the efforts to manage urban flood resilience. The assessment showed that there are many different approaches to flood reliance that work in a context-dependent scenario. Other cities around the globe can learn from the evaluated cases. They present a variety of measures to the solution of the same problem namely to build up urban flood resilience.

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Pictures:
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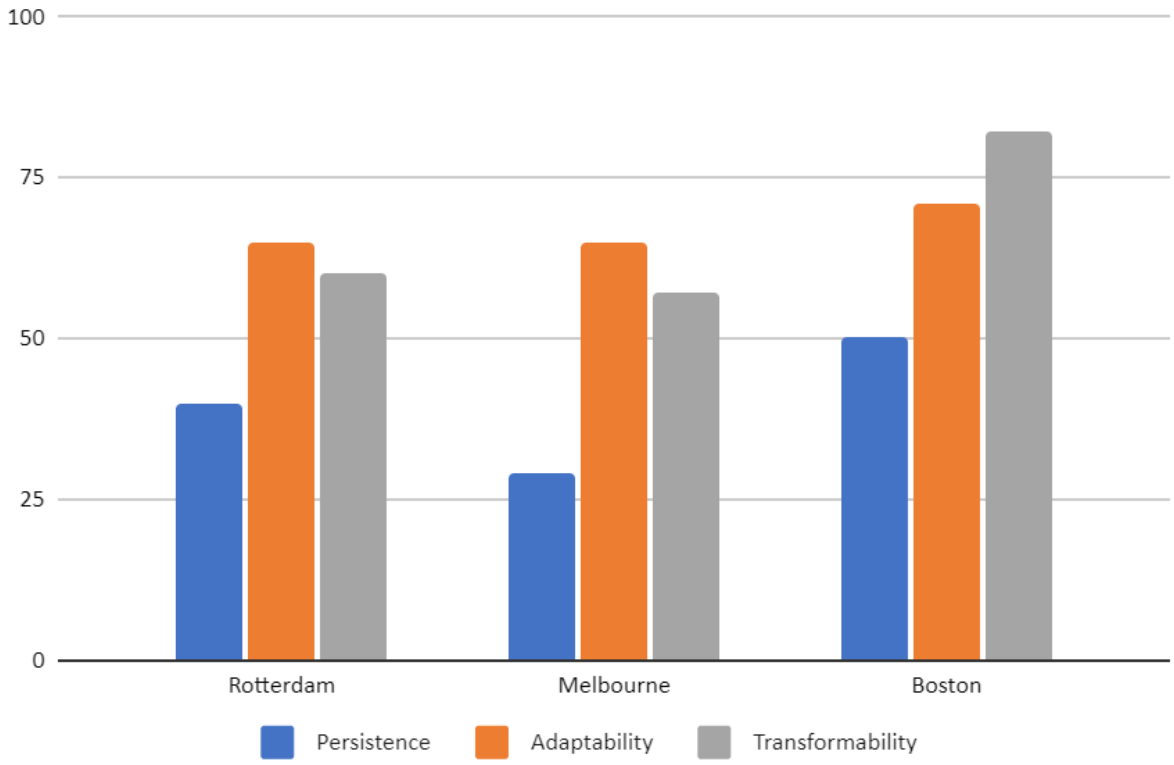
Appendix I

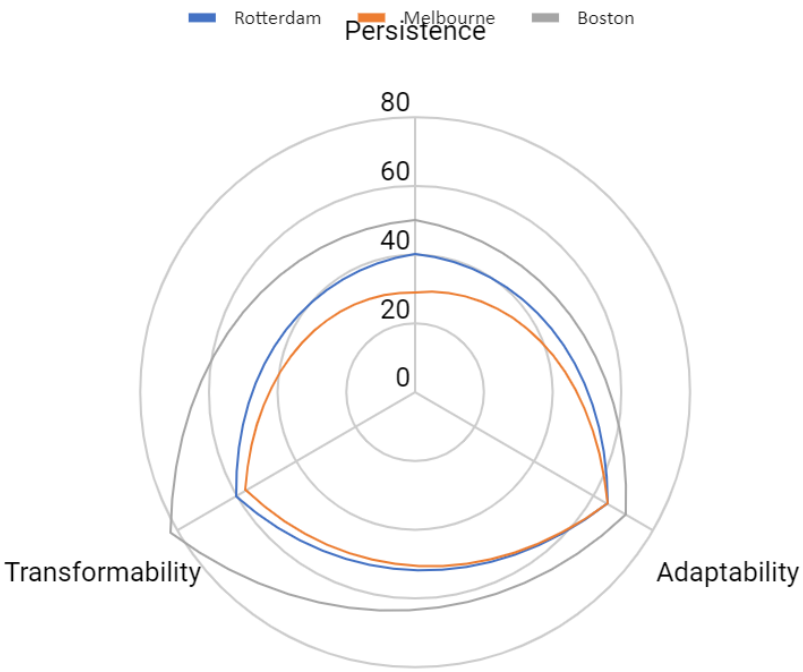
Assessment table

Level	Maturity level	Description
1	Informal	- Short term planning and risk communication - Flood risk management in not standardized - Missing expertise in flood risk management - Informal (no reports or monitoring of foods) - Missing institutional coordination
2	Basic	- Knowledge n floods is highly dependent on historic particles and individuals - Limited coordination, many individual stakeholders - Early stage flood management
3	Initial	- Midterm planning - Partial implementation of flood risk management and policies - Only few stakeholders involved - Limited flood management tools - Flood insurance scheme and flood maps are existent - Top down governance
4	Coordinated	- flooding as a risk is clearly identified - Working framework for flood risk management - Docs on capacity building - Availability of various Flood risk management measures - Implementation plan of named measures - Flood insurance scheme and flood maps are existent - Real time risk management
5	Integrated	- Concept of resilience is used in a variety of governance techniques. - Integration in legal framework - Capacity building is being fully utilized. - Lesson learning approach implemented in framework - Key processes included - Well developed Flood insurance scheme and flood maps - advanced real time risk management

Appendix II

Atlas.ti outcomes




Rotterdam
Melbourne
Boston
Persistence
80
60
40
20
0
Transformability
Adaptability