The Implementation of Characteristics of Transformative Adaptation into Spatial Planning to Decrease Pluvial Flood Risks – A Comparative Study

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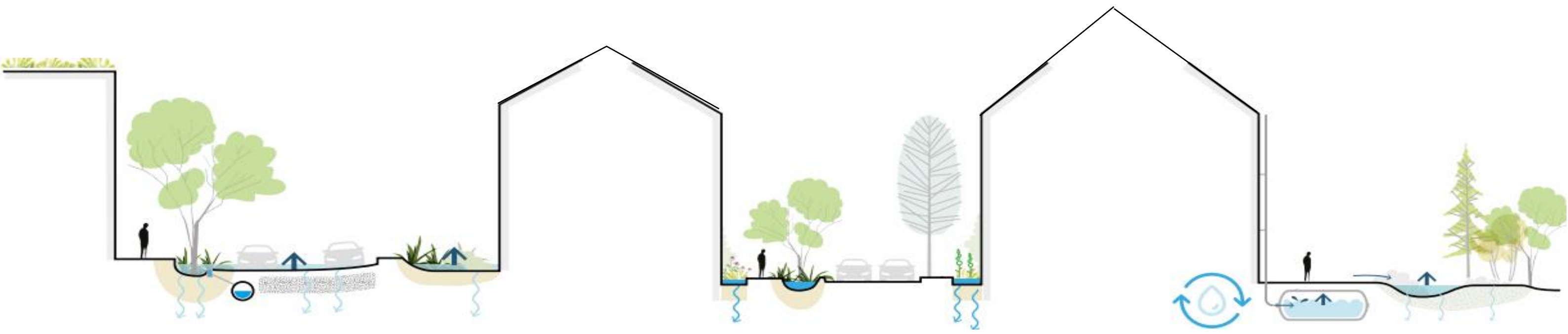

Colophon

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Table of Contents

List of figures and tables

Figures

Tables

Abstract

Due to increasing frequencies of extreme rainfall events and impermeable surfaces in urban environments, cities must deal with increasing pluvial flood risks (IPCC, 2021; Skougaard Kaspersen *et al.*, 2017). In response, London, Rotterdam and Antwerp drew up policies and adjusted the living environment to decrease the risks. It is researched to what extent characteristics of adaptive management and transformative adaptation have been implemented in the domain of spatial planning in these cities. Based on a policy analysis, an assessment of spatial designs and a literature review, results show that elements of adaptive management have been implemented to a larger extent than aspects of transformative adaptation.

Rotterdam has a communicative and innovative approach. Weaknesses are related to finances.

Antwerp implemented the most characteristics compared to the other cities, but the fragmented governance structure is challenging.

London has a multi-sectoral approach and focusses on monitoring and evaluating of processes and spatial projects. The attractiveness of the spatial designs can be improved.

Based on the results, lessons are drawn, and policy recommendations are formulated.

Chapter 1 Introduction

1.1 Background and societal relevance

In the summer of 2021, the Sixth Assessment Report of the IPCC was published. It states that extreme weather events are occurring in every region in the world, due to human-induced climate change (IPCC, 2021). In the same summer, the Netherlands, Belgium, Germany and Luxembourg suffered from intense rainfall and floods (Kennisportaal Klimaatadaptatie, 2021), resulting in financial damage of 30 billion euros in Germany only (NOS Nieuws, 2021).
Impervious surfaces in urban environments are only increasing the risks of pluvial floods, which are floods caused by extreme rainfall. This results in financial, social and ecological damage for European cities (Skougaard Kaspersen *et al.*, 2017; Brockhoff, Koop and Snel, 2019; Axelsson *et al.*, 2021). In addition, it affects human health, mobility and the provision of electricity. In other words, city attractiveness and the quality of life in cities might reduce in case of pluvial floods (Brockhoff, Koop and Snel, 2019; Axelsson *et al.*, 2021).

In reaction tot these developments, new strategies are needed to enhance the climate resilience of cities (Skougaard Kaspersen *et al.*, 2017). However, translating strategies into policies and into practice is facing several challenges (Axelsson *et al.*, 2021). Namely, the specific effects of climate change on extreme weather events are uncertain, as well as the consequences of urban planning on pluvial flood risks (Skougaard Kaspersen *et al.*, 2017; Axelsson *et al.*, 2021). To combat the uncertainties, management approaches should become adaptive (Pahl-Wostl, 2020).
Furthermore, the involvement of citizens is challenging, although it is crucial for making cities more adaptive (Brockhoff, Koop and Snel, 2019; Pahl-Wostl, 2020). Other barriers are related to finances, because of high investments and long-term benefits. Unfamiliarity with the approach, inequalities and different interests are related to political barriers. Another barrier is related to land uses, for instance the predominant land use and the land use rights (Fedele *et al.*, 2019; Pahl-Wostl, 2020).
Adaptive strategies could create new opportunities to tackle other problems as well (Axelsson *et al.*, 2021). For instance, green spaces are beneficial for the air quality, human health, biodiversity and the attractiveness of the urban environment. Also the urban heat island effect might be reduced (Brockhoff, Koop and Snel, 2019). Multiple forms of adaptive management can be applied. The most radical form is called transformative adaptation (Fedele *et al.*, 2019).
To summarize, studying adaptive strategies has societal relevance. It prevents a decrease in the quality of life in urban environments and a reduction of the attractiveness of cities. Moreover, other urban issues, besides pluvial flood risks, can be solved at the same time (Brockhoff, Koop and Snel, 2019; Axelsson *et al.*, 2021).

1.2 Scientific relevance

In literature, there is a call for adaptive management, specifically transformative adaptation, as an alternative way of governance (Fedele *et al.*, 2019). However, knowledge about the implementation of transformative adaptation into policies and management is limited and should be further researched (Fedele *et al.*, 2019; Pahl-Wostl, 2020; Axelsson *et al.*, 2021). Hölscher, Frantzeskaki and Loorbach (2019) conducted a case study about the implementation of transformative adaptation in the city of Rotterdam. They created a tool to understand and support shifts towards transformative adaptation. It was suggested to apply the framework to other cities as well to gain a better understanding about supporting the implementation of adaptive management (Hölscher, Frantzeskaki and Loorbach, 2019). However, this framework is applicabable for analysing governance in general and not specifically for spatial planning. Axelsson *et al.* (2021) recommended researching criteria to evaluate existing policies and to guide future plans.

The second research recommendation stated in literature is about policy-transfer. A new trend between cities is sharing information and experiences with each other (Axelsson *et al.*, 2021). Still, the possibility of drawing lessons from the translation of adaptive governance into policies in various urban environments is not researched. It is relevant to study, because it stimulates all urban environments to become more resilient (Pahl-Wostl, 2020; Axelsson *et al.*, 2021).
In this research, several existing frameworks will be adjusted and combined to one framework to make it suitable for evaluating existing policies and spatial designs. Furthermore, this study contributes to the insight of translating transformative adaptation into policies and to the possibility of lesson-drawing and policy-transfer between cities.

1.3 Research problem

A comparative study will be conducted about the implementation of elements of adaptive managemant and transformative adaptation into spatial planning to decrease pluvial flood risks in Rotterdam, Antwerp and London. Rotterdam is selected, for the reason that transformative adaptation is already to some extent implemented in governance in general (Hölscher, Frantzeskaki and Loorbach, 2019). Antwerp and London are selected, because they are facing similar pluvial flood risks as Rotterdam, which will be elaborated on in the Methodology.

This research has multiple objectives. The first objective is to explain to what extent characteristics of transformative adaptation is implemented into spatial planning to decrease pluvial flood risks. The second aim is to evaluate the policies and the spatial designs. The third objective is to draw lessons from the cities and to formulate policy recommendations based on the outcomes of the analyses. The central research question for this research is defined as follows:

''To what extent are characteristics of adaptive management and transformative adaptation implemented into spatial planning in Rotterdam, Antwerp and London to decrease pluvial flood risks and which lessons can be drawn?''

Out of this central question, the following sub-questions arise:

- *How do policies aim to decrease the risk of pluvial flooding in Rotterdam, Antwerp and London?*
- *Which characteristics of adaptive management and transformative adaptation can be recognised in these policies?*
- *Which spatial designs, adapting to pluvial flood risks, have been created to implement the policies in the cities?*
- *Which elements of adaptive management and transformative adaptation can be recognized in the spatial designs?*
- *Which policy recommendations can be provided to Rotterdam, Antwerp and London?*

Several steps will be taken to answer these research questions. First, the key concepts will be defined in the Theoretical framework. In the Methodology, the data collection process and the data analysis will be clarified. The outcomes of the analyses will be presented in the Results. The results will be discussed, and a reflection will be given in the Discussion. A summary of the research will be provided, and recommendations will be provided in the Conclusion.

Chapter 2 Theoretical framework

In this section, the key concepts in this research will be discussed: spatial planning, pluvial flood risk, adaptive management, transformative adaptation. These concepts are also visualised in a conceptual model. Finally, the expected results will be presented.

2.1 Spatial planning

Spatial planning can be described as the discipline that guides land uses to manage society and regulate spatial developments (Van Dijk, Van Kann and Woltjer, 2019). The term spatial planning in this research refers to spatial policies and plans giving direction to spatial development. It also refers to spatial designs that have been created to implement these policies. The designs should be attractive, functional and future-proof (Van Dijk, Van Kann and Woltjer, 2019). In other words, the quality of spatial designs could be assessed by using the three design principles of Vitruvius: venustas (beauty), firmitas (strength) and utilitas (utility) (Van Dijk, Van Kann and Woltjer, 2019). Policies and the design of the living environment are influencing the pluvial flood risks, which will be elaborated on in the next section.

2.2 Pluvial flood risk

Heavy rainfall results in pluvial floods when the urban drainage system is no longer able to process the rainwater (Guerreiro *et al.*, 2017). As mentioned before, the rise in intensity and frequency of extreme rainfall increases the risk of pluvial flooding (Skougaard Kaspersen *et al.*, 2017; Brockhoff, Koop and Snel, 2019; Axelsson *et al.*, 2021). The chance of flooding is determined by climatic zones, differences in height (topography), soil types and spatial planning, as cities can respond to flood risks by implementing spatial measures. These factors determine rainfall patterns, the run-off speed, infiltration rates and storage capacities. Impermeable surfaces, like concrete, result in less storage capacity or lower infiltration rates. On the other hand, adding green and blue spaces to the environment increases evapotranspiration, infiltration rates and storage capacities (Skougaard Kaspersen *et al.*, 2017).

In urban environments, floods will have impact on a high amount of people and on sizeable economies (Van Dijk, Van Kann and Woltjer, 2019). The consequences are only increasing, because of population growth and densification (Skougaard Kaspersen *et al.*, 2017). Due to rising chances and impacts, the vulnerability of cities to pluvial flooding is growing as well.

2.3 Adaptive management

To decrease the vulnerability to pluvial flooding, adaptive management is needed (Brockhoff, Koop and Snel, 2019). The objective of adaptive management is to meet the new demands in a changing environment (Pahl-Wostl, 2020). In this case, the ‘new demand’ is: decreasing the risk of pluvial flooding. This challenge arises out of the ongoing process of climate change. It is even argued in literature that adaptive management is a response to climate change (Fedele *et al.*, 2019). The question is: what makes governance adaptive? First, adaptive management is re-establishing. For instance, adjustments are made to ecological and social systems to decrease the vulnerability (Fedele *et al.*, 2019). Flexibility and stimulating learning processes are mentioned by multiple scholars as characteristics of adaptive governance. For instance, up-to-date knowledge, identifying high risk areas and evaluations are common practises (Koop *et al.*, 2017; Hölscher, Frantzeskaki and Loorbach, 2019). It is also multi-sectoral and communicative. For instance, multiple stakeholders, sectors and government layers are involved. Knowledge is available for all, understandable for non-experts and the objectives are clear and measurable in adaptive governance (Koop *et al.*, 2017; Fedele *et al.*, 2019; Hölscher, Frantzeskaki and Loorbach, 2019). The characteristics are summarized in figure 1.

2.4 Transformative adaptation

Different levels of adaptive management are distinguished by Fedele *et al.* (2019). The least radical form is making small changes to systems to decrease vulnerability, whereas the most radical form advocates for fundamental shifts to deal with the sources of vulnerability. This is called transformative adaptation or transformative climate governance (Fedele *et al.*, 2019; Hölscher, Frantzeskaki and Loorbach, 2019). In this research the term transformative adaptation will be used. Since transformative adaptation is a category of adaptive management, the characteristics of adaptive management are also applicable, see figure 1. Besides, transformative adaptation is innovative, for instance through the creation of new technologies, new policies or the generalization of lessons based on experiments. The fundamental shifts in different contexts makes transformative adaptation a reorganising strategy (Fedele *et al.*, 2019). It is also unlocking, because the sources of unwanted side-effects and maladaptation will be identified, and new solutions will be stimulated. Developing new models for feedback or establishing uncertainties and applying simple rules are typical for the resilience of this governance. The final characteristic that will be discussed is mediating. Examples are creating networks between actors, minimizing trade-offs and connecting resources to the goals (Hölscher, Frantzeskaki and Loorbach, 2019).

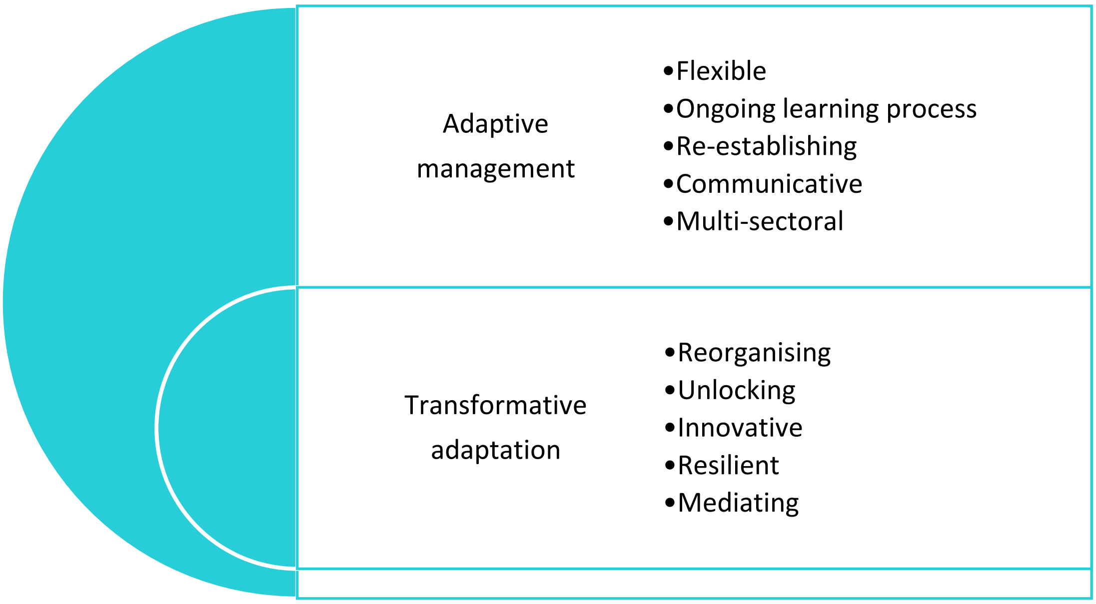

Figure 1: Characteristics of adaptive management and transformative adaptation

2.5 Trends in water management

The development towards adaptive management is already visible in the domain of water management worldwide. Centralised governance, top-down approaches and technical solutions were typical for the years between 1960 and 1980. Then, decentralization and privatisation started to play a significant role in governance. Around 2000, the society became more important in decision-making (Pahl-Wostl, 2020).

Water management is embedded as a sectoral specialism in spatial planning (Van Dijk, Van Kann and Woltjer, 2019), see figure 2. The shift in governance also took place in international planning practises. According to De Roo & Voogd (2019), planning practices developed from management strategies with central guidance and single goals towards management with participative interaction and multi-functional solutions (De Roo and Voogd, 2019).

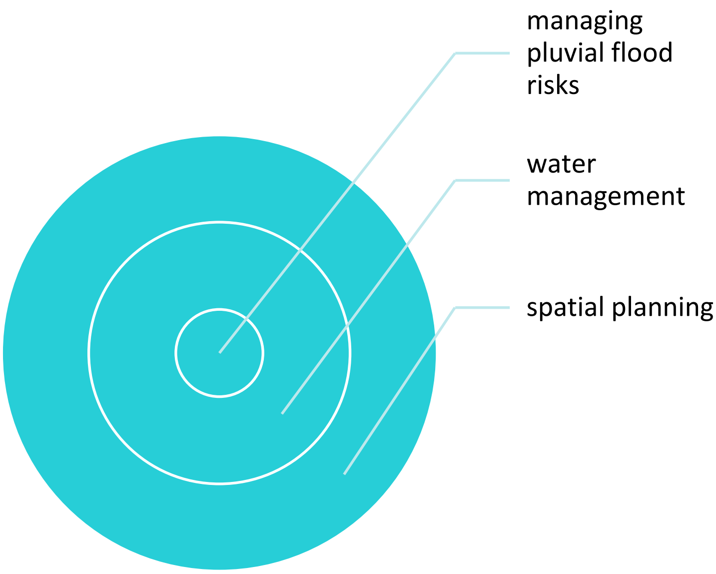

Figure 2: Relation between water management and spatial planning

2.6 Conceptual model

The relationships between the key concepts are visualised in the conceptual model in figure 3.
First, the effects of climate change and the spatial design of the city are influencing the pluvial flood risk in the city, as discussed in the previous sections. This is presented with the arrow between spatial planning and pluvial flood risk. Climate change as a factor is not included in the conceptual model, because this is not studied in this comparative research.
Second, it is expected that an increase in pluvial flood risks will result in the implementation of adaptive management or transformative adaptation. This assumption will be studied in this research, and it is visualised with the arrow between pluvial flood risk and adaptive management.
Third, it is expected that these types of governance are translated into policies or spatial plans, as visualized with the arrow at the bottom right. This will be researched as well.
Fourth, the policies are determining the spatial designs in the urban environment, as showed with the fourth arrow.

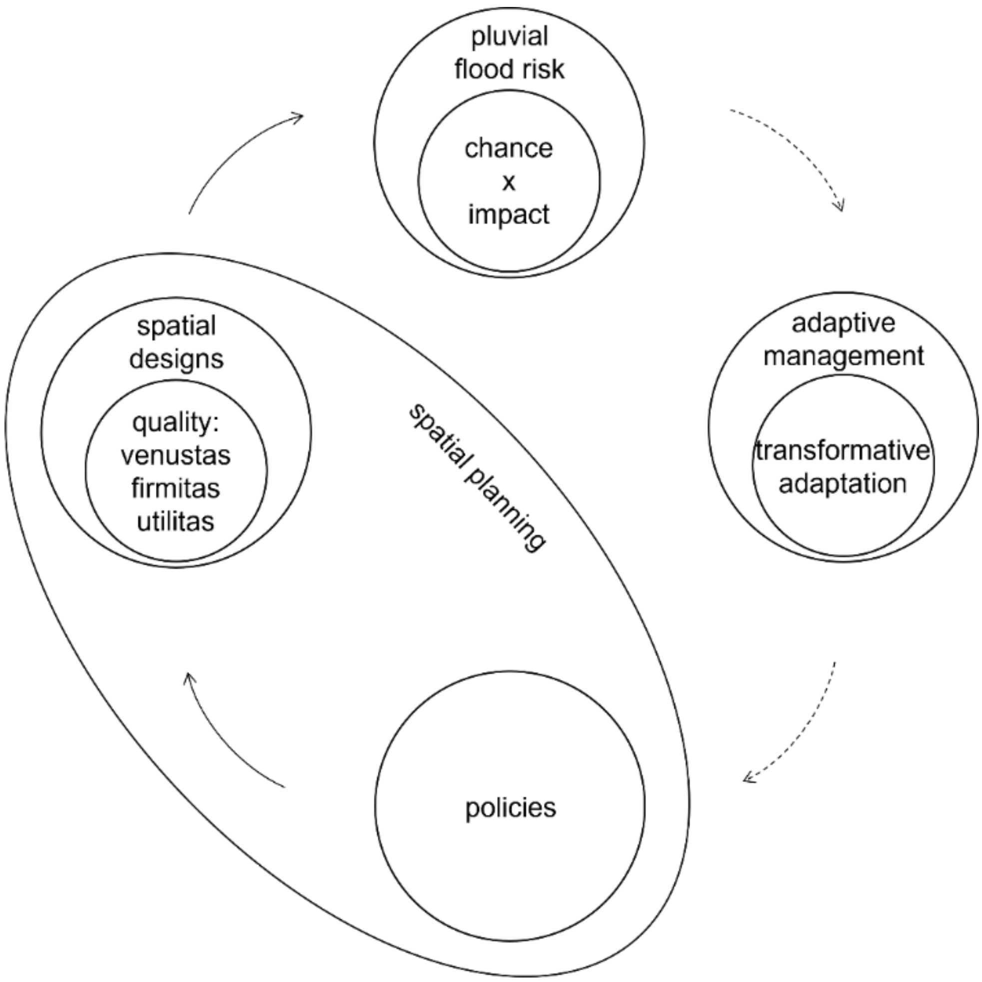

Figure 3: Conceptual model

Based on existing literature, it is supposed that the urgency to respond to the increased flood risk is acknowledged in all the policy plans and that the cities already integrated adaptive management strategies. Furthermore, it is expected that transformative adaptation is not translated in the cities completely. As Rotterdam is considered as the frontrunner of innovations to become climate resilient (Hölscher, Frantzeskaki and Loorbach, 2019), this Dutch city is expected to have implemented the most aspects of transformative adaptation into policies. For the same reason, Rotterdam is expected to have the spatial designs with the highest quality.

Chapter 3 Methodology

A qualitative data analysis has been conducted, to research three cities in-depth. The strengths and weaknesses of the three cities become clearer in a qualitative study compared to a quantitative study, as quantitative studies would have involved more cases that were studied less detailed. In addition, policy recommendations can be formulated more specifically in a qualitative research. The data analysis consists of a policy analysis, an assessment of spatial designs and a literature review.
In addition to policies and spatial plans, the implementation of these policies is also an aspect of spatial planning. This could have been researched by interviewing policymakers or project managers. Due to time constraints, this was not possible.
The research strategy has been visualised in figure 4 and will be described in the next sections.

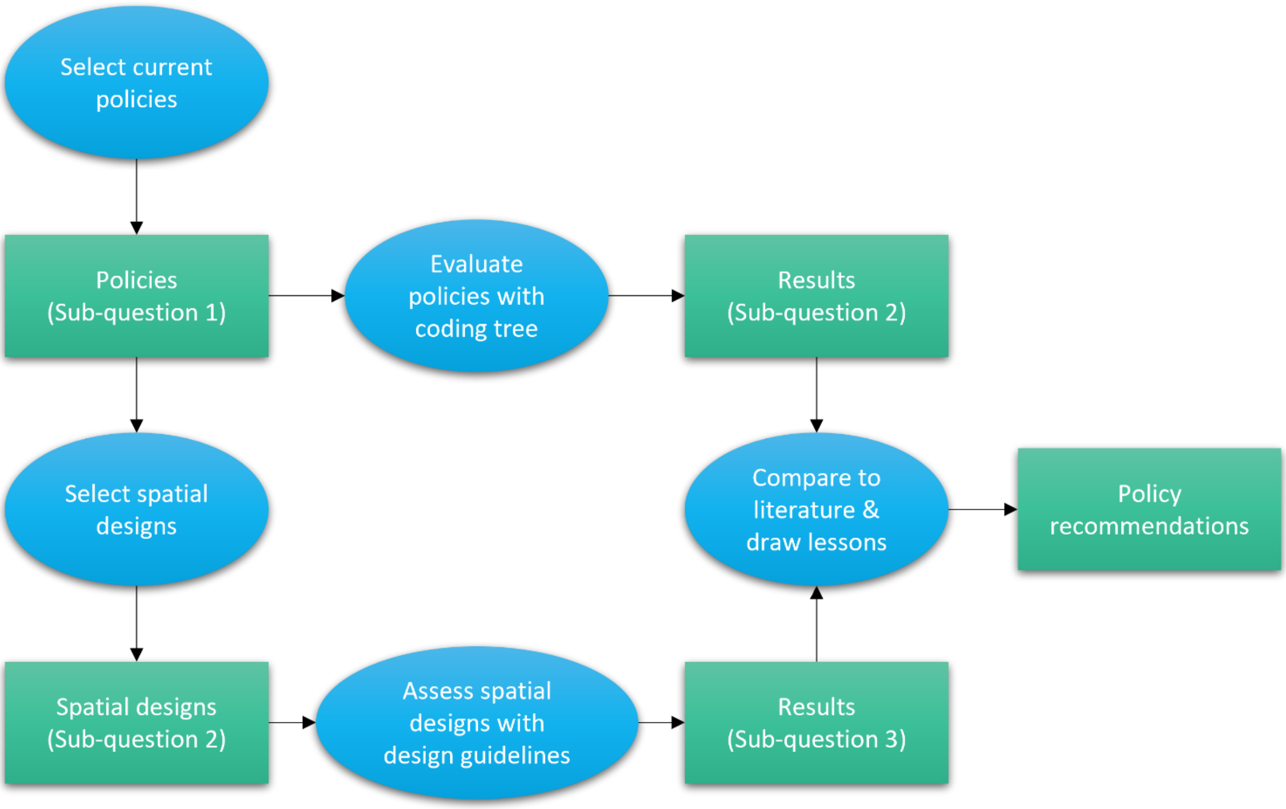

Figure 4: Research strategy

3.1 Case selection

The first selected city is Rotterdam, as the city already started to implement transformative adaptation into the governance (Hölscher, Frantzeskaki and Loorbach, 2019). The pluvial flood risks in this city are comparable to London and Antwerp, as can be seen in table 1. However, the three cities do have different planning cultures and different insitutional contexts, which makes it likely to get contrasting outcomes of the policy analysis. Three cases with various planning cultures makes the outcomes more generalizable compared to a single-case study or a comparative study within one planning culture. Because these cities are located in the Netherlands, Belgium and the United Kingdom, the data is expected to be in Dutch or English. This makes the data more accessible to the author.

Table 1: Characteristics of Rotterdam, Antwerp and London determening influencing pluvial flood risk

Characteristic	Rotterdam	Antwerp	London
Estimation of percentage of city that will be flooded in case of hourly rainfall for a 10-year return period (the impacts of adaptation measures are not considered) (Guerreiro *et al.*, 2017)	10%-15%	10%-15%	10%-15%
Hourly rainfall for a 10-year return period in mm/h (Guerreiro *et al.*, 2017)	25-30	25-30	25-30
Estimation of change in mean precipitation during the winter in 2050 (Schneider *et al.*, 2013)	Increase (5%-15%)	Increase (5%-15%)	Increase (5%-15%)
Estimation of change in mean precipitation during the summer in 2050 (Schneider *et al.*, 2013)	Decrease (5%-15%)	Decrease (15%-30%)	Decrease (5%-30%)
Climate zone (Schneider *et al.*, 2013)	Temperate oceanic	Temperate oceanic	Temperate oceanic
Drainage class of soil (ArcGIS Online, 2020)	Very poor – poor	Poor – moderately well	Poor – moderately well
Slope of the terrain (ArcGIS Online, 2021a)	0%	0%	0%
Planning culture (Van Dijk, Van Kann & Woltjer, 2019)	Comprehensive integrated approach/Napoleonic: decentralized, abstract legal norms	Land use management: emphasis on controlling changes in land use	Land use management/British Common Law system: control land use, little formalization

3.2 Data collection

The data was collected in three phases. First, the current policy documents of the governments at city level were gathered, see figure 4. This data is publicly available on the websites of the local authorities. Only the policies that were mainly dealing with effects of climate change were analysed. Documents mostly related to other policy domains or less relevant documents have not been analysed, see table 2. The sections of the policies that were not linked to pluvial flood risks have been read, but are not analysed.

Table 2: Overview of the policy documents

City	Title	Date of analysis (2021)	Pages	Analysed document
Rotterdam	Rotterdamse adaptatiestrategie (Municipality of Rotterdam, 2013)	4 November 5 November	138	Yes
Rotterdam	Rotterdam WeatherWise Urgency Document (Rotterdam WeatherWise, 2020a)	1 November	59	Yes
Rotterdam	Uitvoeringsagenda 2020-2022 (Rotterdam WeatherWise, 2020b)	2 November	55	Yes
Rotterdam	Voortgangsnotitie 2021 (Rotterdam WeatherWise, 2022)	2 November	13	Yes
Rotterdam	Rotterdam gaat voor groen (Municipality of Rotterdam, 2019)		11	No
Rotterdam	Rotterdams Klimaatakkoord (Rotterdamse Klimaat Alliantie, 2019)		23	No
Rotterdam	Naar een Rotterdams Daklandschap (Municipality of Rotterdam, 2019)		25	No
Rotterdam	Van Buis naar Buitenruimte – Gemeentelijk Rioleringsplan 2021-2025 (Municipality of Rotterdam, 2020)		72	No
Antwerp	Waterplan Antwerpen (summary[1]) (De Urbanisten, 2019)	29 October	108	Yes
Antwerp	Klimaatplan 2030 Stad Antwerpen[2] (City of Antwerp, 2020a)	26 October	304	Yes
Antwerp	Inspiration memorandum: Creating space for the city of tomorrow (City of Antwerp, 2018)		51	No
London	The London Plan 2016 Chapter five: London's Response to Climate Change (Greather London Authority, 2016)	30 October	48	Yes
London	London Sustainable Drainage Action Plan (Greater London Authority, 2016)	30 October	74	Yes
London	Climate Action Strategy 2020-2027 (The City of London Corporation, 2020)	1 November	10	Yes
London	City of London Corporation Local Flood Risk Management Strategy 2021-2027 (The City of London Corporation, 2021a)	1 November	38	Yes
London	Climate Action Strategy – A Year of Climate Action (2021-2022) (The City of London Corporation, 2021b)	1 November	6	Yes
London	The London Plan 2016 Chapter seven: London's Living Spaces and Places (Greater London Authority, 2016)		58	No
London	The London Plan 2016 Chapter eight: Implementation, Monitoring and Review (Greater London Authority, 2016)		14	No
London	The London Plan 2021[3] Chapter eight: Green Infrastructure and Natural Environment (Greater London Authority, 2021)		22	No
London	The London Plan 20214 Chapter nine: Sustainable Infrastructure (Greater London Authority, 2021)		66	No

[1] *The summary has been analysed, because the complete version was not available.*

[2] *The first and second appendix were also coded. The third appendix was not analysed, because it was about climate-proofing the harbour.*

[3] *The London Plan 2021 has not been published on time to analyse it.*

Then, three spatial designs that have been created to implement the policies, were selected for each city, see table 3. The projects have been categorized as follows: projects at street level, designs of community spaces and designs of green spaces. The locations and the categories of the selected designs are indicated in figure 5. Three main projects to implement 'Sustainable urban drainage systems' (SuDS), of the city of London were selected. Two out of these three have won several awards (Greather London Authority, 2021b). To prevent bias in the selection, much discussed projects in policies of Antwerp and Rotterdam have been selected as well. The data to assess the spatial designs were gathered by desk research and consists mainly of news articles and case studies. The sources are included in *Appendix 1.*

Table 3: Overview of the selected spatial designs

City	Spatial design	Category	Year (design phase – realisation)
Rotterdam	Raingarden ZOHO	Street level	2015 – 2018
Rotterdam	Benthemplein (water square)[1]	Community space	2011 – 2013
Rotterdam	Hofbogenpark	Greenery	2019 –
Antwerp	Tuinstraten (Lange Ridderstraat)	Street level	2017 – 2021
Antwerp	Gedempte Zuiderdokken	Community space	2015 –
Antwerp	Rozemaaipark	Greenery	2011 – 2019
London	Raingarden Alma Road	Street level	2015 – 2016
London	Bridget Joyce Square	Community space	2013 – 2015
London	Climate-proofing social housing landscapes	Greenery	2013 – 2016

[1] *The water square has been finished several years ago. However, this water square is an iconic design for Rotterdam and policies refer to this design multiple times.*

Finally, scientific articles have been used to create a framework to assess the policies and the designs. Literature about planning cultures, developments in water management and case studies have been gathered for a comparison with the results of the analyses, see figure 4.

The datasets with policies and literature are trustworthy, as they consist of official governmental documents and scientific articles. The data about spatial designs has a lower quality, as it is partly derived from non-governmental or non-scientific sources. In addition, not all the assessed spatial designs are also finished, which also might influence the completeness of the datasets.

Figure 5.1 Selected spatial designs in Rotterdam (basemap: ArcGIS Online, 2021b; De Urbanisten, no date; Studio Bas Sala, 2021; De Urbanisten, *et al.*, 2020)

Figure 5.2: Selected spatial designs in Antwerp (basemap: ArcGIS Online, 2021b; City of Antwerp, 2021; City of Antwerp, 2020c; City of Antwerp, no date a*)*

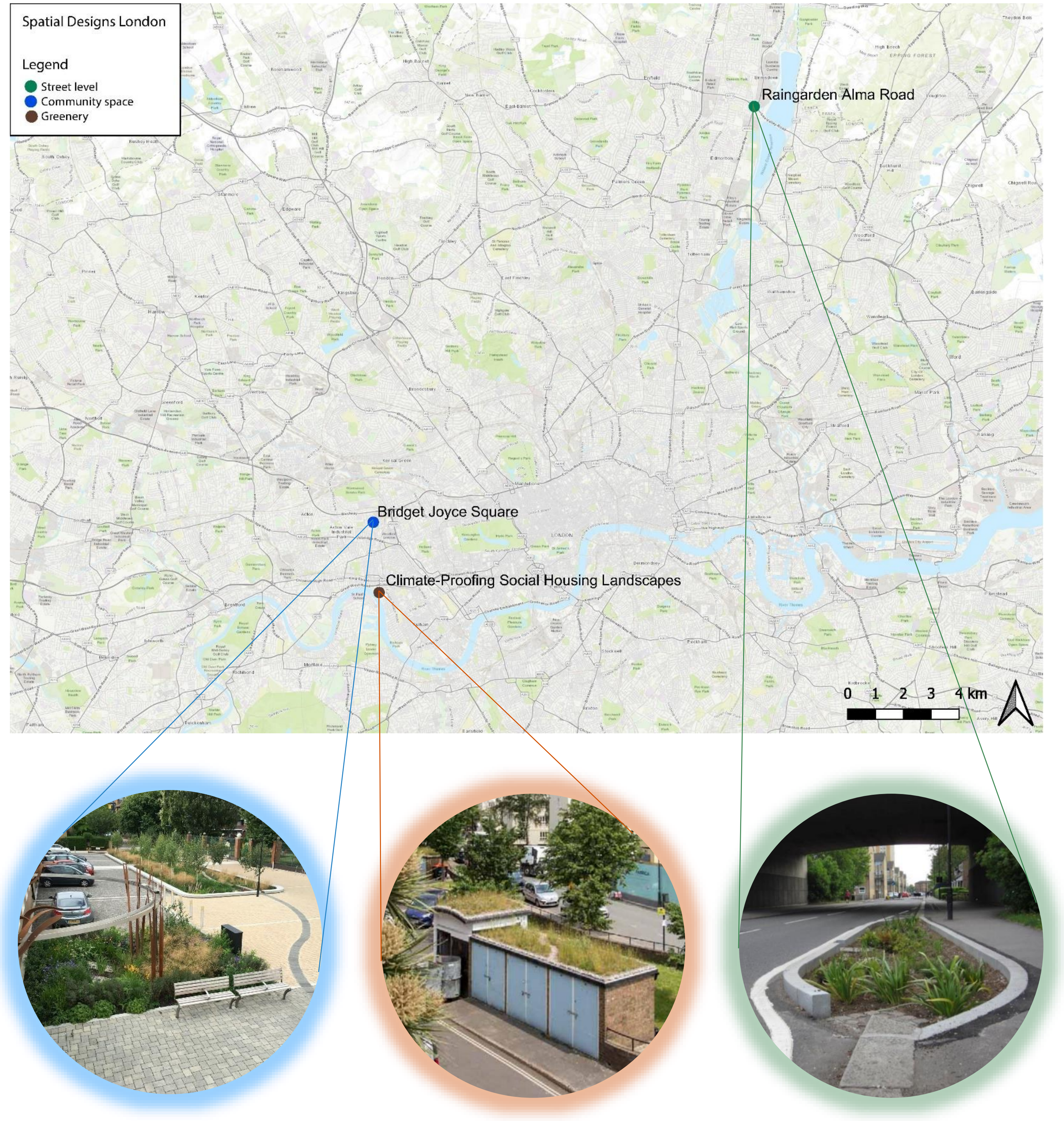

Figure 5.1 Selected spatial designs in Rotterdam (basemap: ArcGIS Online, 2021b; De Urbanisten, no date; Studio Bas Sala, 2021; De Urbanisten, et al., 2020)

3.3 Data analysis

To analyse the policies, a coding tree has been developed. Existing frameworks have been combined, adjusted, and supplemented with characteristics of adaptive management and transformative adaptation based on literature, as discussed in the Theoretical framework. The approaches are described with five variables and twenty-five indicators, see table 4. The policies have been read to make sure the framework would be useful. Then, each passage that demonstrated the implementation of an indicator was coded. It was counted how much indicators per variable were demonstrated in the policies for each city. These scores were visualized in radar charts and have been interpreted and discussed. References to the policies are made as follows: (Policy X, yyyy) instead of (Author, yyyy), because multiple policy documents are written by the same institution.

Table 4: Coding tree for adaptive management and transformative adaptation (based on: Koop et al., 2017; Fedele et al., 2019; Hölscher, Frantzeskaki and Loorbach, 2019)

Concept	Variable	Indicator/code (yes or no)
Adaptive management	Flexible	Up-to-date and relevant knowledge
		Response to new changes/insights
		Identification of high-risk situations/regions
		Preparation of unexpected changes/events
		Assurance of long-term financial support
	Ongoing learning process	Experimenting
		Monitoring
		Evaluation
		Underlying processes and theories explained
		Interaction between actors
	Re-establishing	Adjustments to management strategies/policies
		Adjustments to behaviour
		Spatial adjustments
		Willingness to take/manage risks
		Open to new opportunities/synergies with other sectors
	Communicative	Availability of knowledge for all actors
		Communication is understandable for non-experts
		Clear and measurable vision/objective
		Alternative pathways/scenarios taken into account
		Long-term oriented
	Multi-sectoral	Multiple stakeholders involved
		Multiple sectors involved
		Multiple governance layers involved
		Clear division of roles and tasks
		Clear division of accountability (who is responsible)
Transformative adaptation	Reorganising	Shift in normative context
		Shift in political/institutional context
		Shift in social/cultural context
		Shift in spatial context
		Affecting multiple generations
	Unlocking	Establish sources of unwanted effects of previous strategies
		Remove support for unsustainable technologies/processes
		Establish side effects of changes/solutions

		Foster political willingness and public sense of urgency
		Policy instruments introduced
	Innovative	Promotion of innovation
		New technologies
		Wide implementation of successful experiments
		Learn from experiments and make it generalizable
		Provide resources for wide implementation
	Resilient	Develop new models for feedback/monitoring
		Establish socio-economic causes of vulnerability (e.g., injustices, inequality)
		Establish and communicate uncertainties
		Open/simple institutions and rules (foster flexibility)
		Link past experiences with present and future
	Mediating	Link visions to continuous developments
		Connect resources to goals
		Create formal and informal space/networks to exchange knowledge and resources (and manage conflicts)
		Minimise trade-offs between actors
		Review institutional performance with regard to long-term vision

The spatial designs were subjectively assessed based on official design guidelines of the Dutch government and the authority of London and on design guidelines as discussed in literature. Only applicable design guidelines to decrease flood risks were selected. Then, the guidelines were classified according to the principles of Vitruvius: venustas, firmitas and utilitas. This resulted in the assessment scheme in table 5. The spatial designs scored for each design guideline a '--', '-', '0', '+' or '++'.

First, the 'best' indicators of a certain projects were given '++' or '+' and the 'worst' indicators of that project were given '--' or '-'. For instance, projects located in low-income neighbourhoods with a relatively high proportion of public spaces were graded with '++' on 'decrease socio-economic causes of vulnerability'. A '0' means that no information was available, or that an indicator was mentioned in the spatial plans without a clear substantiation.

Second, within the categories of 'street level', 'community space' and 'greenery' the indicators have been compared to each other. For instance, Rotterdam implemented the most 'innovative/new technologies' in the category 'street level' compared to Antwerp and London in this category. Therefor, Rotterdam has the highest score on this principle in the category 'street level', compared to the other cities. This resulted in a few small adjustments to the scores. The scores are visualised in radar charts.

Table 5: Checklist to assess spatial designs (based on: susDrain, 2021*;* Van Dijk, Van Kann and Woltjer, 2019; Klemm, Lenzholzer and Van Den Brink, 2017)

Concept	Principle	Design guideline: --, -, 0, +, ++
Spatial designs	Venustas (attractiveness)	Strengthen identity/reputation of place
		Connect greenery to a green network
		Combine diversity of microclimates (sun, shade, half shade) with furniture
		Gradients of open areas and shady areas close to each other
		Greenery with different heights
		Preserve heritage/historical characteristics of place
		Increase in biodiversity
		Shift in land-use/function/purpose
	Firmitas (future-proof)	Combat air/noise/soil pollution
		Innovative/new technologies
		Local residents involved in design phase
		Increase public greenery in neighbourhoods with minimal private spaces (decrease socio-economic causes of vulnerability)
		Beneficial for awareness raising
		Monitoring and evaluation of results/effectiveness
		Manage multiple climate risks at once (heat stress & flood risk & drought)
		Position in rainwater cascade is clear
	Utilitas (functionality)	Sediment/pollution retained on site
		Multiple land-uses/purposes/functions (besides decreasing flood risks)
		Green or permeable surface
		Infiltration/storage of rainwater
		Discharge of excessive rainwater to surface water (instead of sewage)
		Community space (place to meet)
		Clear division of accountability/responsibility
		Realisation incorporated in maintenance/development projects

3.3 Ethical considerations

This research is based on secondary data, which is publicly available. Hence, ethical issues regarding personal data were not involved. The five ethical principles of the Netherlands Code of Conduct for Research Integrity have been considered during the study. The principle of *Honesty* is applied by presenting the results as accurately as possible and by making a clear distinction between assumptions and proven statements. The principle of *Scrupulousness* is also applied through using a scientific method. Accurate referencing and a detailed description of the methods make the research more *Transparent*. The principle of *Independence* is guaranteed, because the methodology and the presentation of results is not chosen because of financial or political reasons. The principle of *Responsibility* is applied through conducting a research with scientific and societal relevance (Research Ethics Comittee, 2021).

Chapter 4 Results

In this chapter, the results of the policy analysis and the assessment of the spatial designs will be outlined and discussed. Then, the cities will be compared to each other, and lessons will be drawn.

4.1 Policy analysis

The framework as presented before is used for the policy analysis. Figure 6 visualises the amount of implemented indicators per city. A table with detailed information is included in Appendix 2. In general, elements of adaptive management (AM) are more recognized in policies than aspects of transformative adaptation (TA). The variable ‘AM, Communicative’ is implemented the most and the variable ‘TA, Mediating’ is implemented the least, see figure 6.

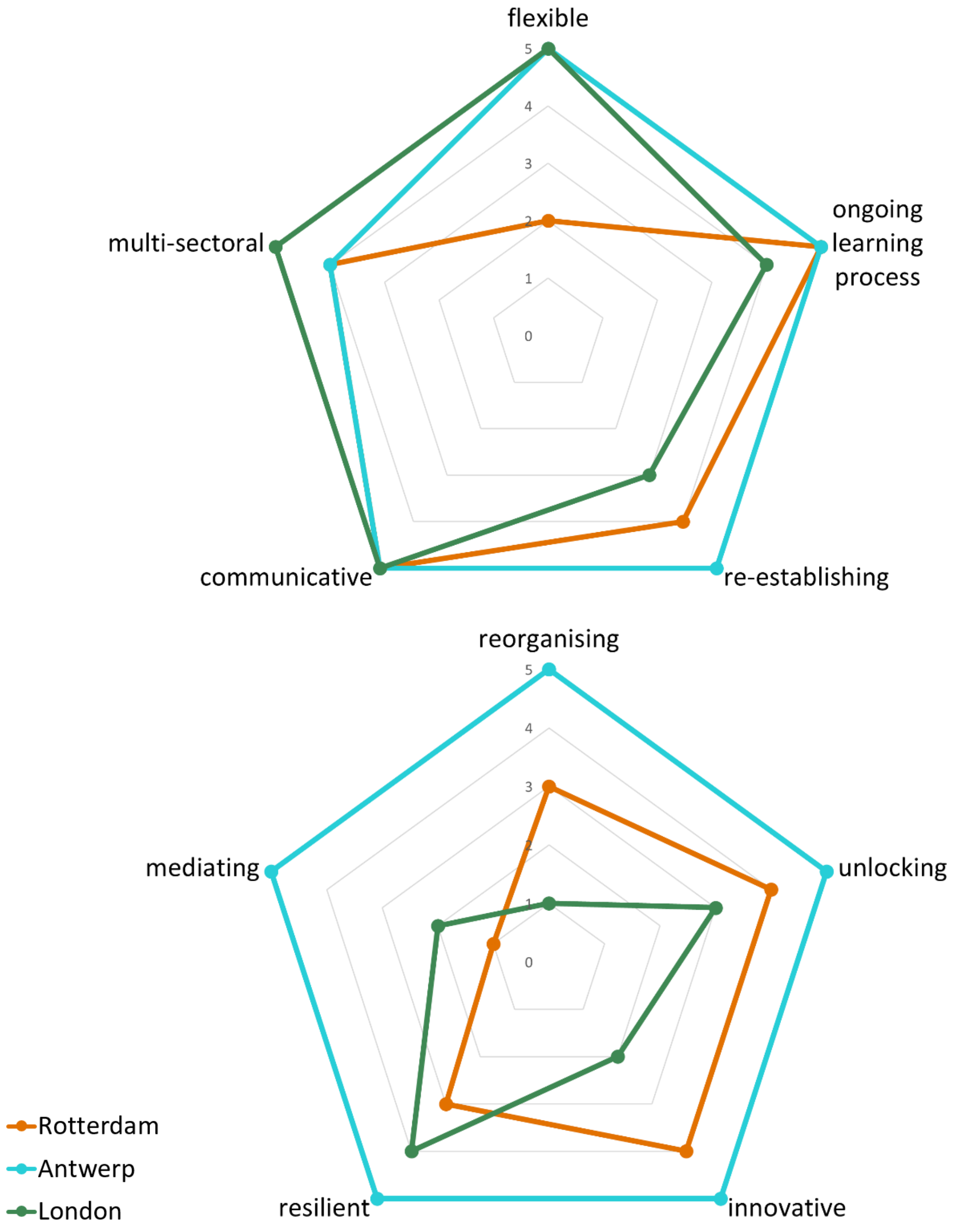

Figure 6: Translation elements of adaptive management (above) and transformative adaptation (below) into policies

Rotterdam
As delta city, Rotterdam always had to fight against water. Most strategies have been technical-based in the past (De Graaf-van Dinther, 2021). Then, a normative shift took place and living with the water became the new starting point. Therefore, the initiative Rotterdam WeatherWise started to engage the residents and local stakeholders, hence making the approach communicative and innovative (De Graaf-van Dinther, 2021). In the policies of Rotterdam, the communicative, multi-sectoral and innovative aspect of adaptive management is clearly visible, see figure 6.

The city aims to develop a communication strategy to get all stakeholders excited to be involved (Urgentiedocument, 2020). Before decision-making processes, the municipality has 'risk-dialogues' with residents (Uitvoeringsagenda 2020-2022, 2020). In addition, the vision of the city is clear and measurable: reducing the number of buildings that suffer from pluvial floods during cloudburst with 2% in 2020-2022. Therefore, the city developed a new model to monitor the progress (TA, Resilient). The model is called 'BlueLabel', and it gives all buildings a score between A and E, like energy labels, about the vulnerability to pluvial floods (Uitvoeringsagenda 2020-2022, 2020). Regarding the communicative aspect, the described strategies are not always specified and remain vague. To illustrate, in one of the policies it has been stated:

> Everyone will be aware of the urgency of climate adaptation, and everyone will act accordingly to it. Therefore, a shift in behaviour is one of the challenges of Rotterdam WeatherWise.
> (Uitvoeringsagenda 2020-2022, p. 22).

This statement has not been clarified and it is unclear which change in behaviour is expected.
The multi-sectoral character of Rotterdam's approaches is the result of the 'Dutch Diamond model', in which multiple actors support each other in developments and in the creation of new solutions (Centre for Liveable Cities and the Urban Land Institute, 2020).
The policies present Rotterdam as an innovative city. For instance, successful experiments or projects are implemented on other locations in the city as well. The concept of a water square started as an experiment, but the city created already seven water squares (Ruimtelijke Adaptatie Strategie, 2013; Rotterdam WeatherWise, 2021).

Weaknesses of the governance are related to the flexible character of adaptive management and the mediating element of transformative adaptation, see figure 6. It is unclear how Rotterdam will be prepared to unexpected events (AM, Flexible). A lack of assurance of financial support in the long term (AM, Flexible) makes the governance also less flexible. The mediating element is not visible yet, as visions are not linked to the continuous developments (TA, Mediating). The policies did not show efforts to minimise trade-offs between actors, to review institutional performance in the long term or to connect resources with goals (TA, Mediating).
The financial weaknesses have been recognized in literature as well. De Graaf-van Dinther (2021) states that the visions of Rotterdam are clear, but it is unclear how the objectives will be achieved in the long term regarding finances. A case-study conducted in 2020 concluded that the financial aspects need to be more transparent (Centre for Liveable Cities and the Urban Land Institute, 2020).

Antwerp
In Antwerp, water management also has been based on technical approaches followed by normative shifts. Nowadays, measures are more nature-based and storage capacity get more attention than fast discharge. Protecting the high-risk areas instead of the whole region is also a new strategy implemented in the past 20 years (Mees, Crabbé and Suykens, 2018). This shift justifies the references to multiple climate studies in the analysed policies to identify high risk areas (AM, Flexible), see Appendix 2.

Almost all elements of adaptive management and transformative adaptation are recognized in the policies, see figure 6. The policy 'Klimaatplan 2030' has a clear structure throughout the whole document. In every chapter, the current situation has been described, followed by the objectives (City of Antwerp, 2020a). Then, the measures and resources that are connected to the objectives will be discussed (TA, Mediating). Compared to other policies, the theoretical background in the 'Waterplan Antwerpen' are remarkable. The water system in Antwerp has been researched and a distinction has been made between the artificial water system (technical structures and measures), the natural water system (natural hydrological system) and the hidden water system (historical water system). The three water systems are brought together as three layers into one map. The vision for the city is based on this combined map (Waterplan Antwerpen, 2019), see figure 7. Moreover, an overview has been made of all spatial measures that are possible to decrease flood risks, including advantages and disadvantages of each. Financial resources assigned to all measures and projects for the upcoming five years have been made publicly available in the 'Klimaatplan 2030'.

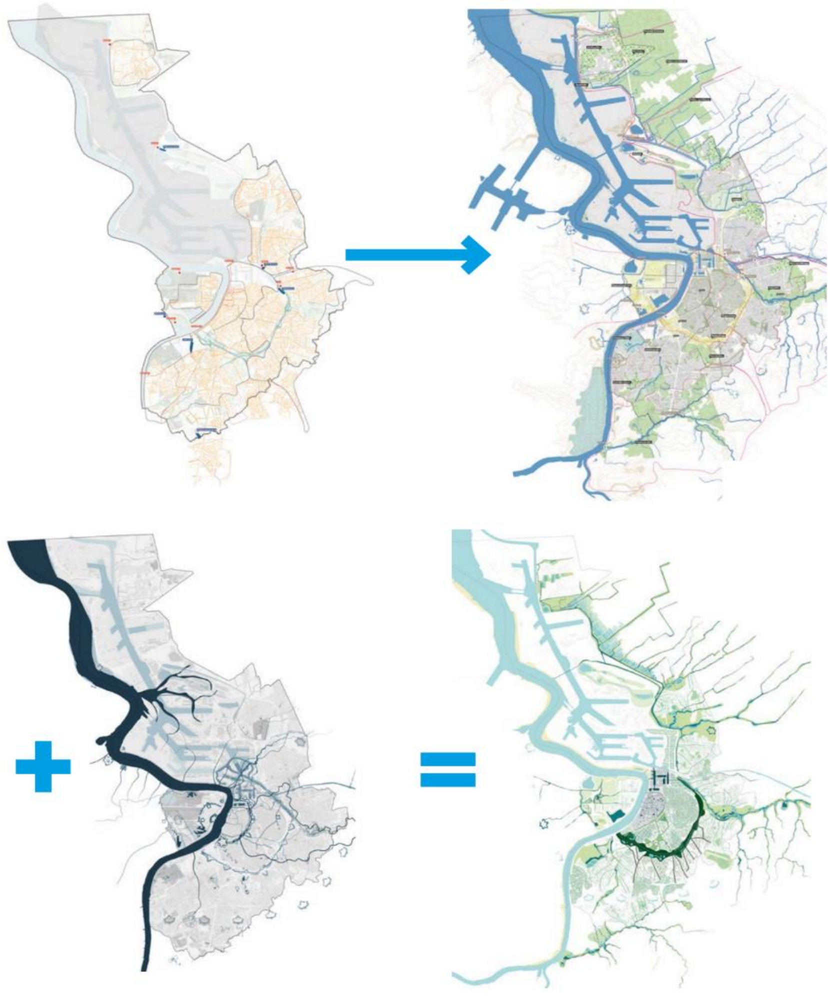

Figure 7: The artificial water system, the natural water system, the hidden water system and the combined map (Waterplan Anwerpen, 2019, p 26, 27.)

The multi-sectoral aspect of adaptive management is not completely implemented. The city does not have a clear division of roles and tasks (AM, Multi-sectoral). Regarding most projects, a contact person is assigned and published. However, it is not clear which sector or governance layer is responsible for the implementation of the policies (Klimaatplan 2030, 2020), see Appendix 2. This can be clarified by the highly fragmented governance structure of Belgium, which is a barrier to new innovations. New developments will not be implemented in all the governance layers immediately (Mees, Crabbé and Suykens, 2018). To deal with this fragmentation, Antwerp recently developed a governance model with new government bodies: the 'Antwerp Climate Counsel', a climate director and a stakeholder community. Their aim is to involve all the stakeholders in the decision-making processes and to implement the 'Klimaatplan 2030' into practise (Klimaatplan 2030, 2020). The question is to what extent the new government bodies will improve the clarity about the division of roles and responsibilities. It is also unclear whether the new governance model contributes to open institutions and simple rules. This aspect of transformative adaptation fosters flexibility.

London

The multi-sectoral, communicative, and flexible aspects of adaptive management are recognized the most, see figure 6. The newest policies scored higher than the older documents. For instance, the vision as been described in a policy document from 2016 is neither clear nor measurable:

By 2040, London will manage its rainwater more sustainable to reduce flood risk and improve quality and security. This will maximise the benefits for people, the environment, and the economy.
(London Sustainable Drainage Action Plan, 2016, p. 2).

In 2021, the vision became to decrease the risk and the impact of floods in the city. This overarching objective is substantiated with six measurable sub-goals about people, the environment, and the economy (City of London Corporation Local Flood Risk Management Strategy 2021-2027, 2021). The reorganising aspect of transformative adaptation, operationalised with indicators about shifts in several contexts, is the main weakness of London. Only a shift in normative context has been made. The city states that rainwater can no longer be seen as a waste product, but it should be considered as a valuable resource (London Sustainable Drainage Action Plan, 2016). Other shifts have not been observed, see Appendix 2. In addition, the innovative element is less implemented. However, the independent community 'Susdrain' has conducted case studies about all the realised spatial projects to draw lessons for wider implementation, which fosters innovation (susDrain, 2021c). The attention to monitore, evaluate, and draw lessons in London can be justified by the British Common Law system. It rather creates rules based on cases than regulate developments in advance (Nadin and Stead, 2008).

4.2 Assessment of spatial designs

The scores of the assessment of the spatial designs are visualised in figure 8, 9 and 10. The graphs demonstrate the average scores for the categories venustas, firmitas and utilitas. The other graphs visualise the scores of the individual indicators. A table with detailed information is included in Appendix 3. In general, the strengths are adding biodiversity (venustas), raising awareness (firmitas), increasing the infiltration rate and the storage capacity of the soil (utilitas), and disconnecting rainwater from the sewage system (utilitas). The main weaknesses are the connection to a green network and the creation of spaces with gradients of sunny and shady areas close to each other (venustas).

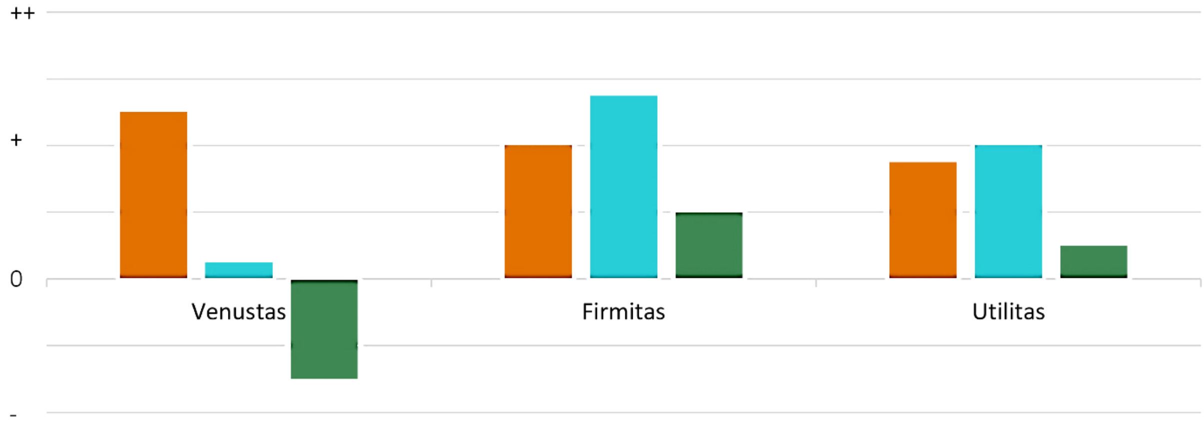

Figure 8.1: Average quality of spatial designs at street level in Rotterdam (orange), Antwerp (blue) and London (green)

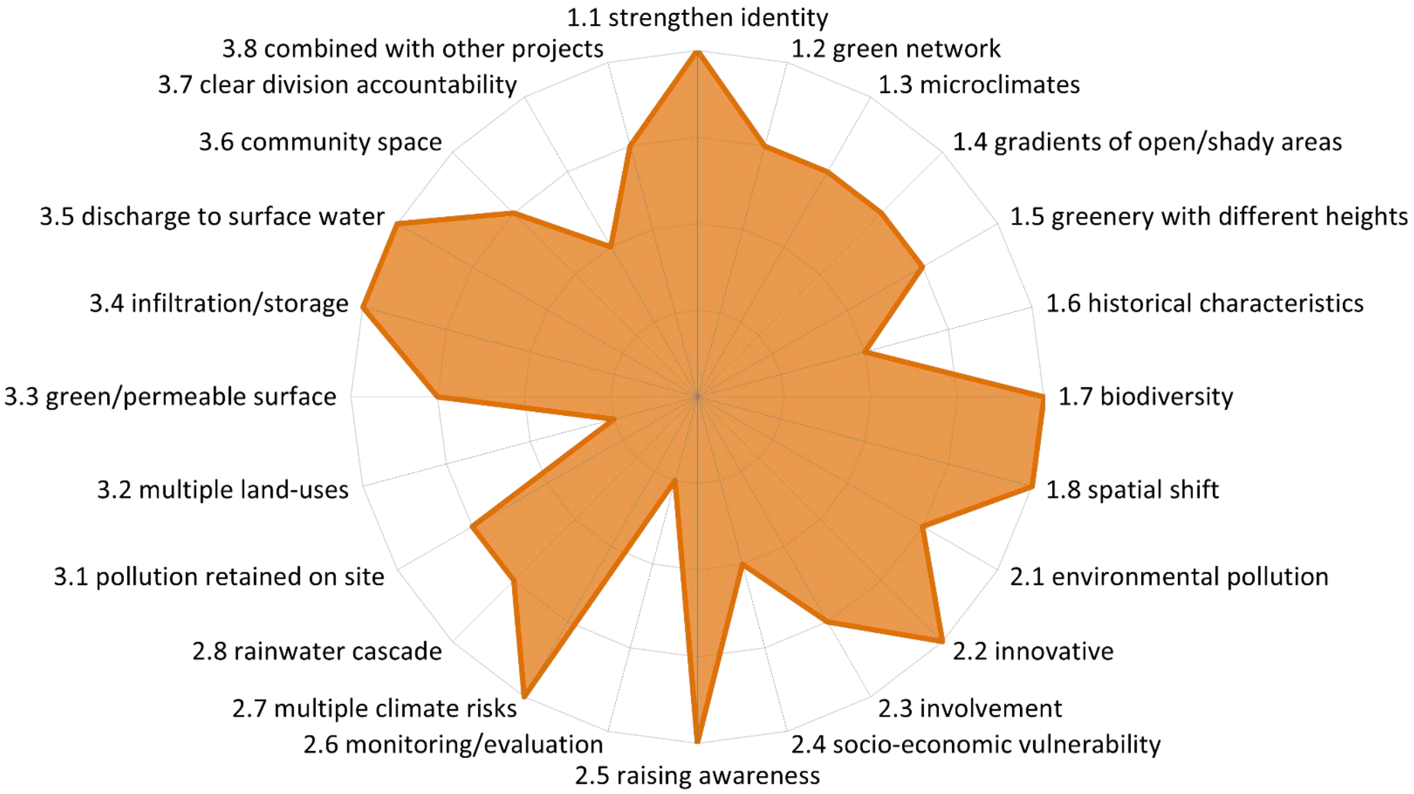

Figure 8.2: Quality of spatial designs at street level in Rotterdam

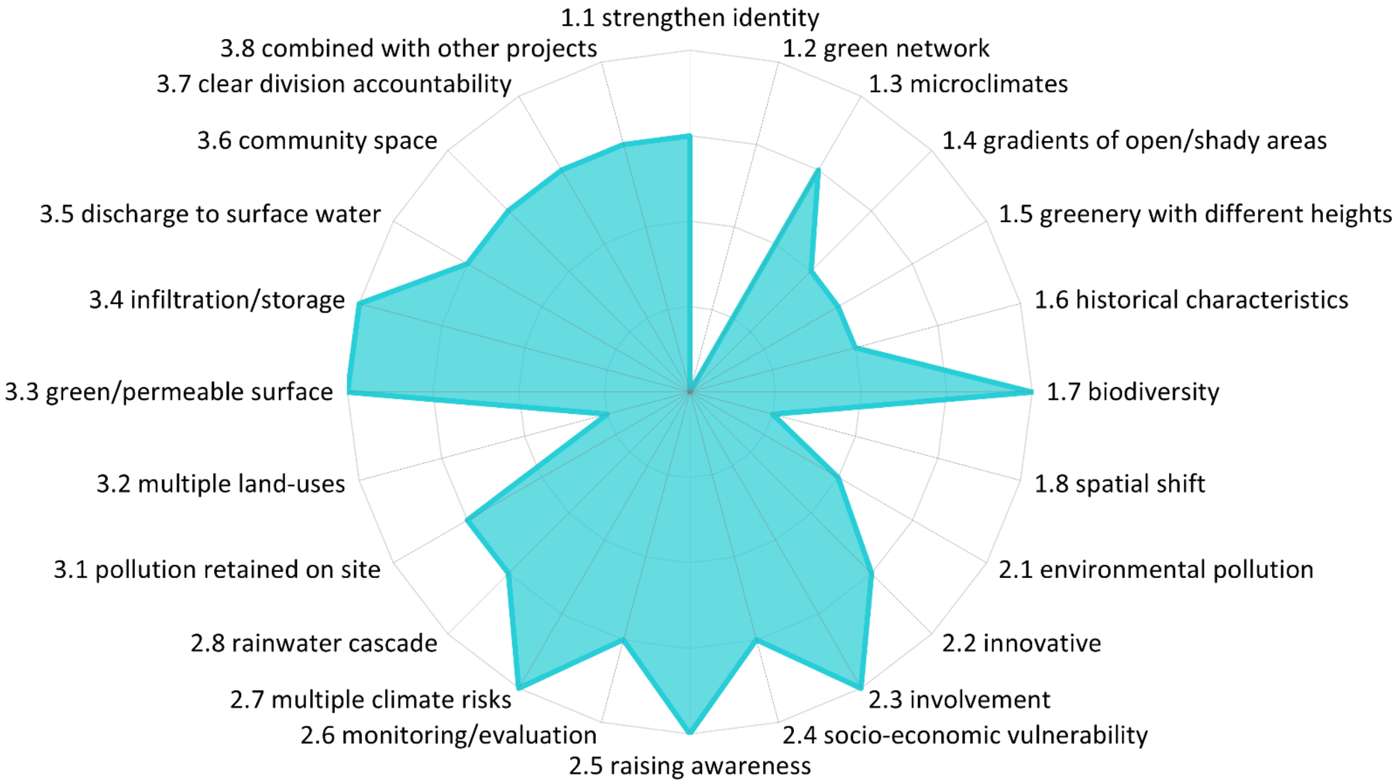

Figure 8.3: Quality of spatial designs at street level in Antwerp

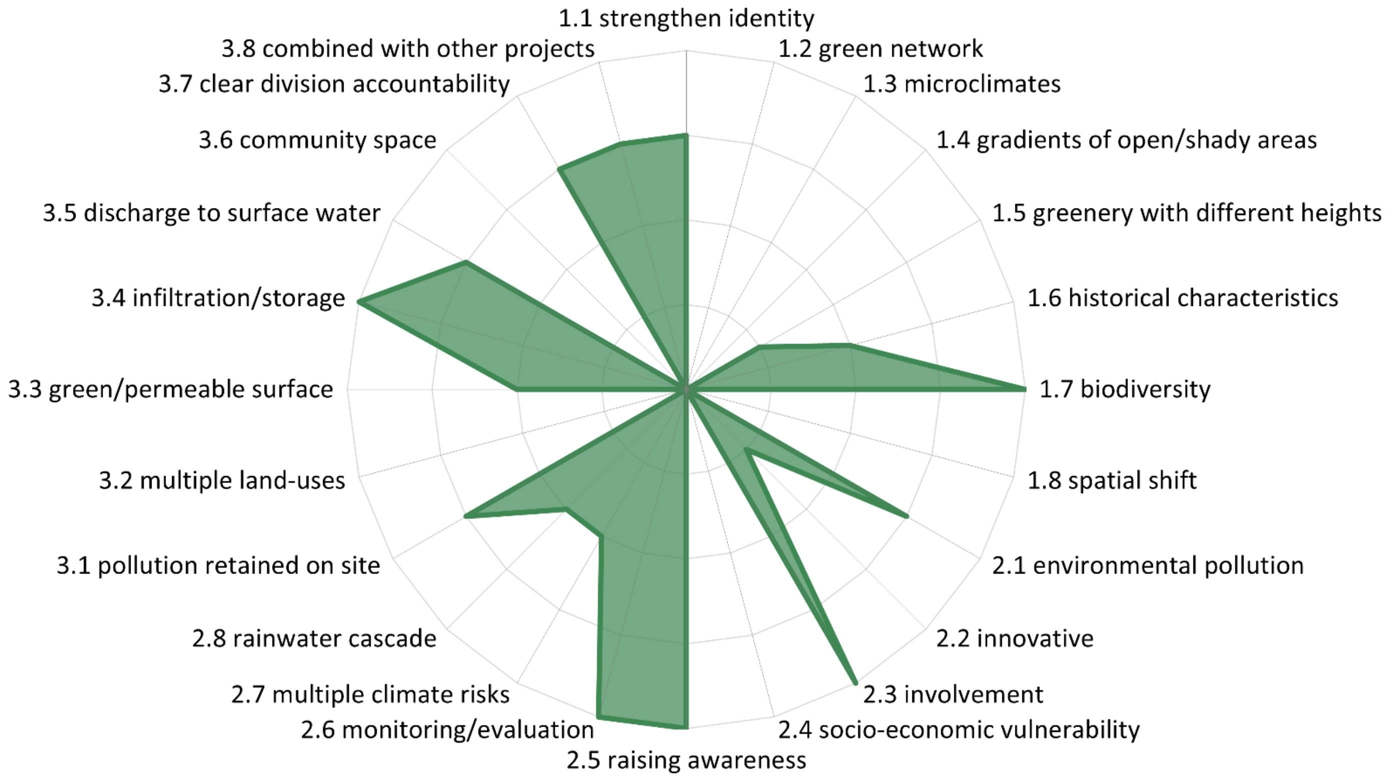

Figure 8.4: Quality of spatial designs at street level in London

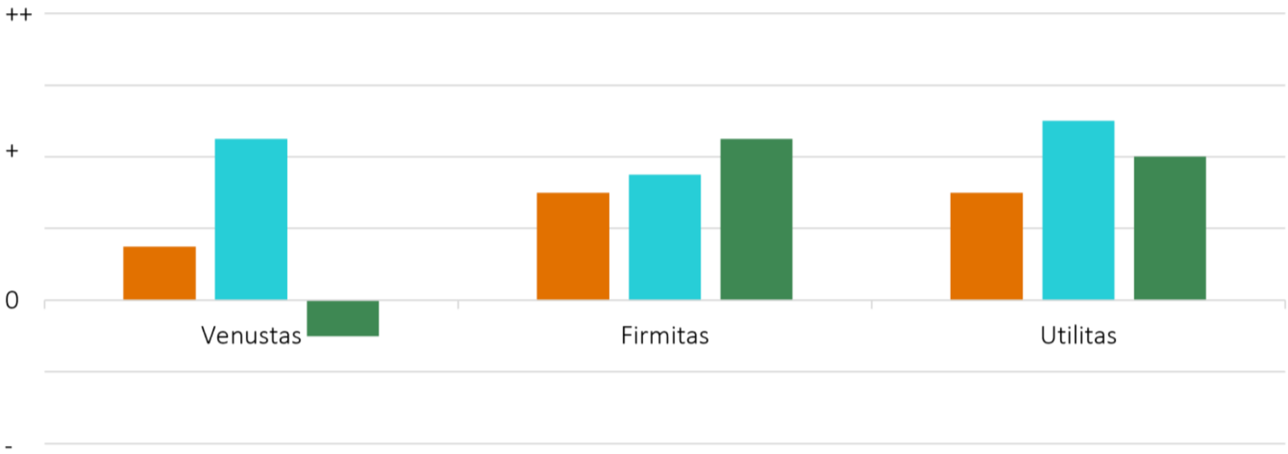

Figure 9.1: Average quality of spatial designs for community spaces in Rotterdam (orange), Antwerp (blue) and London (green)

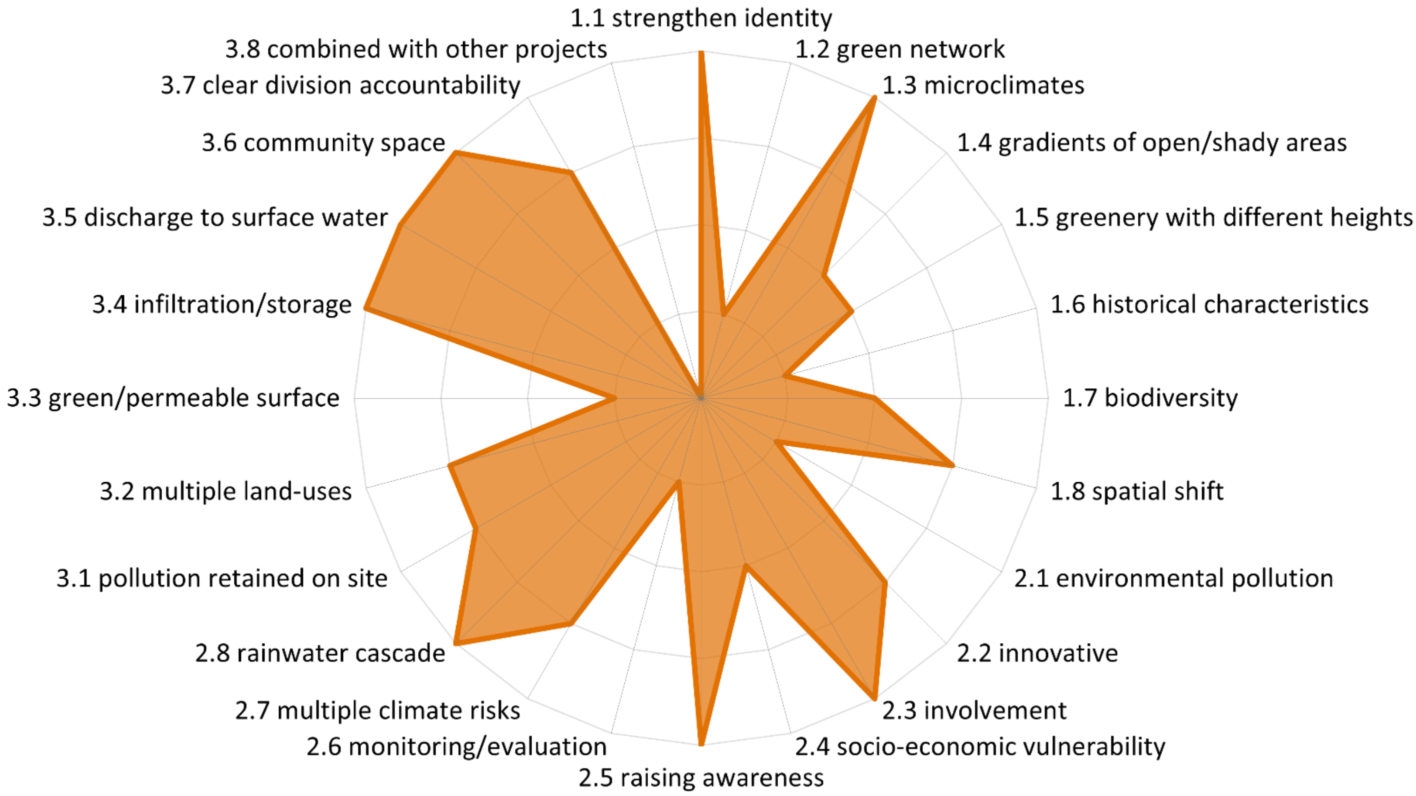

Figure 9.2: Quality of spatial designs for community spaces in Rotterdam

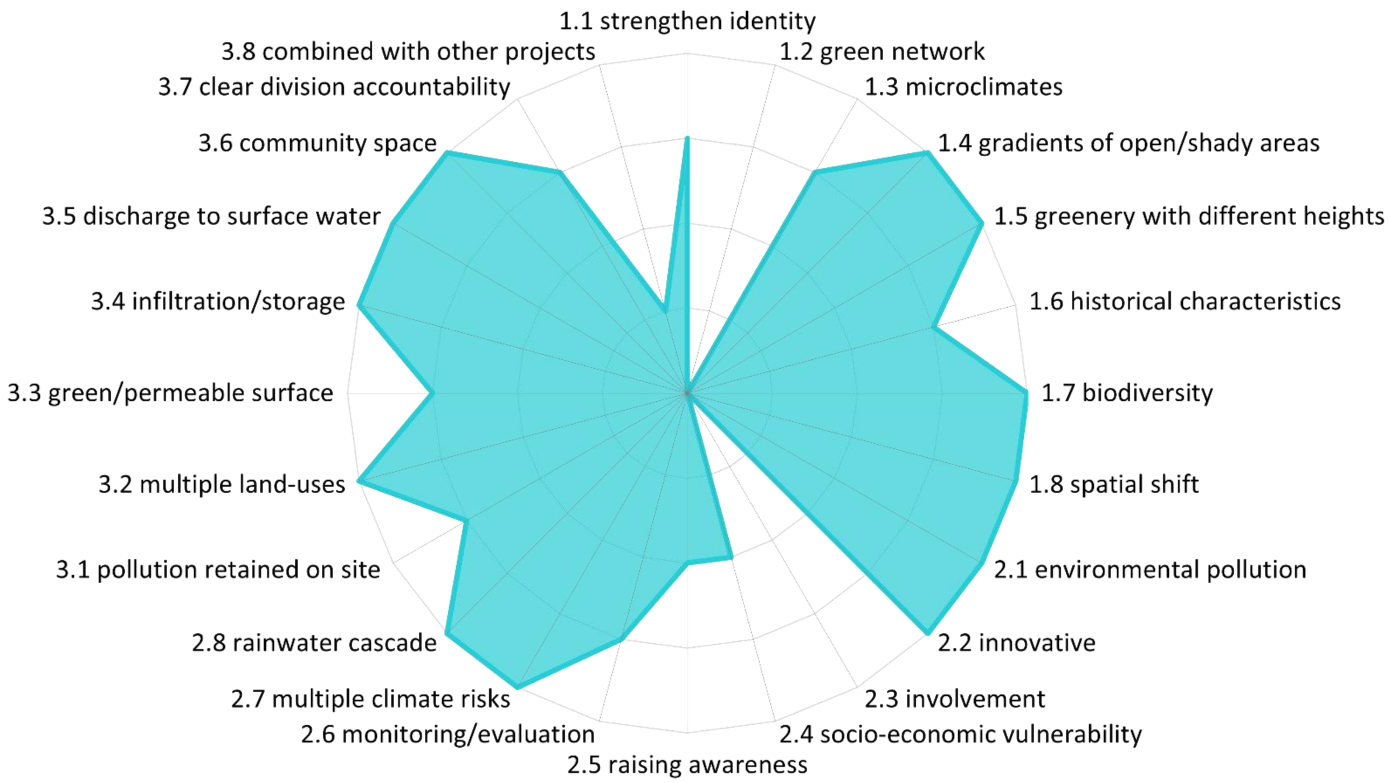

Figure 9.3: Quality of spatial designs for community spaces in Antwerp

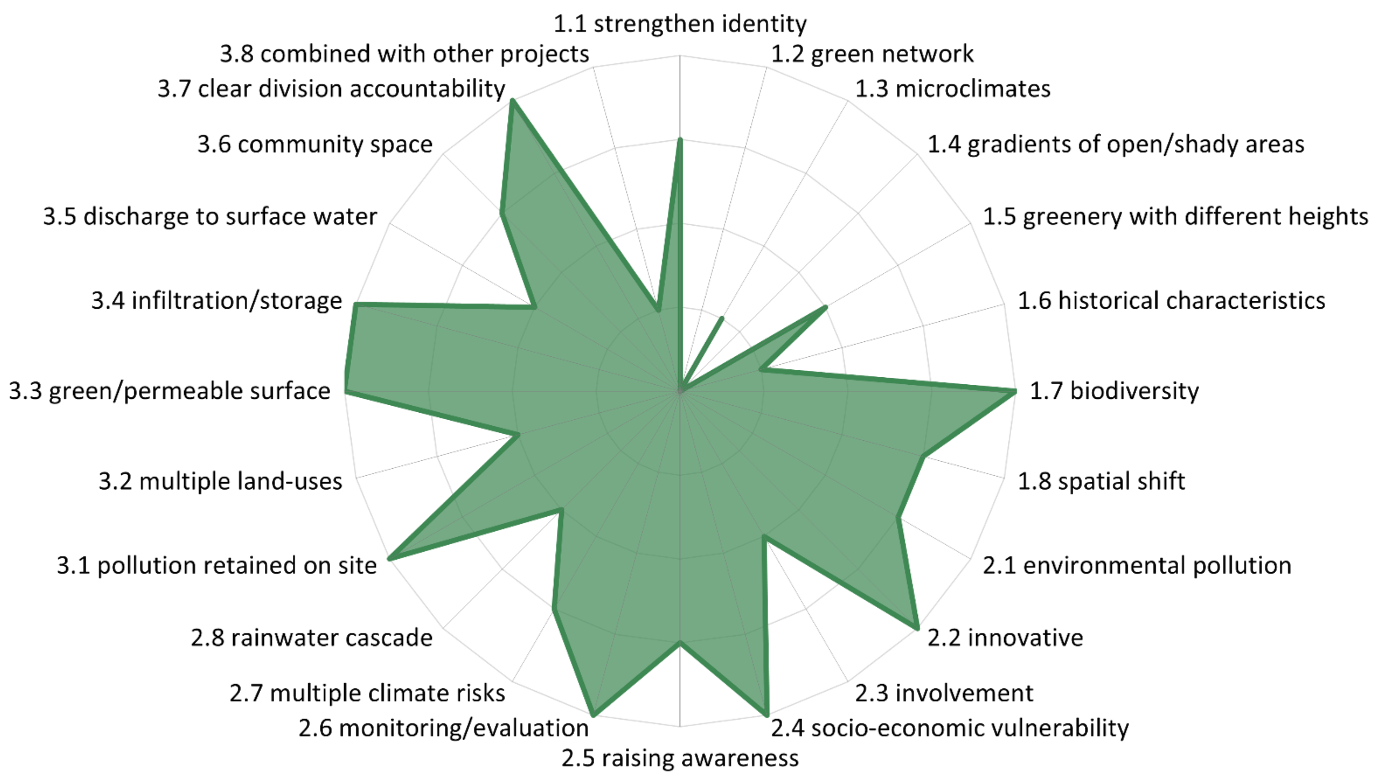

Figure 9.4: Quality of spatial designs for community spaces in London

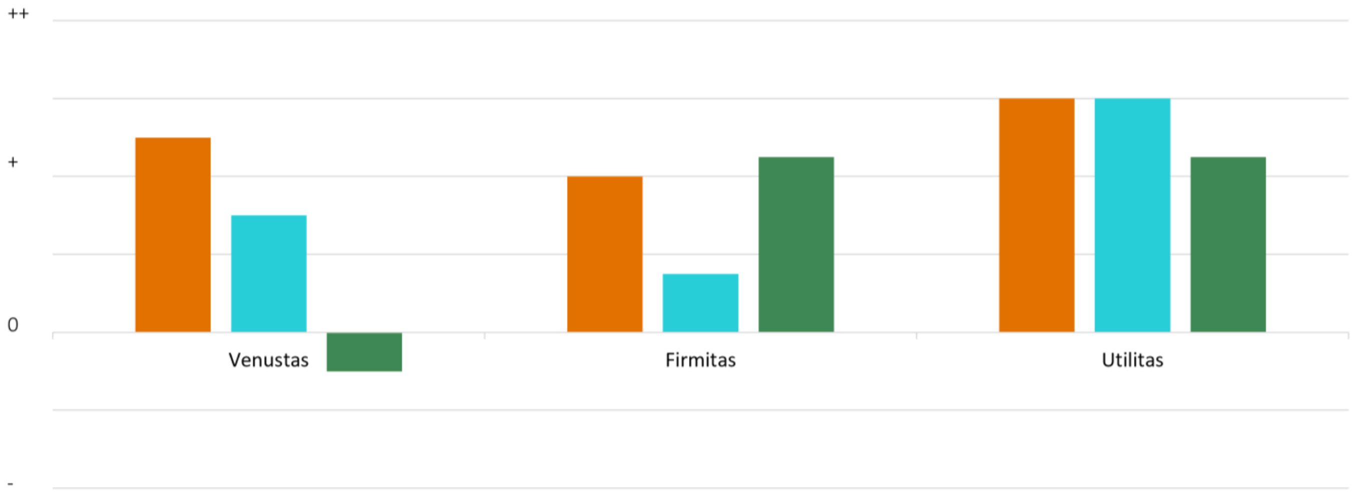

Figure 10.1: Average quality of spatial designs to add greenery in Rotterdam (orange), Antwerp (blue) and London (green)

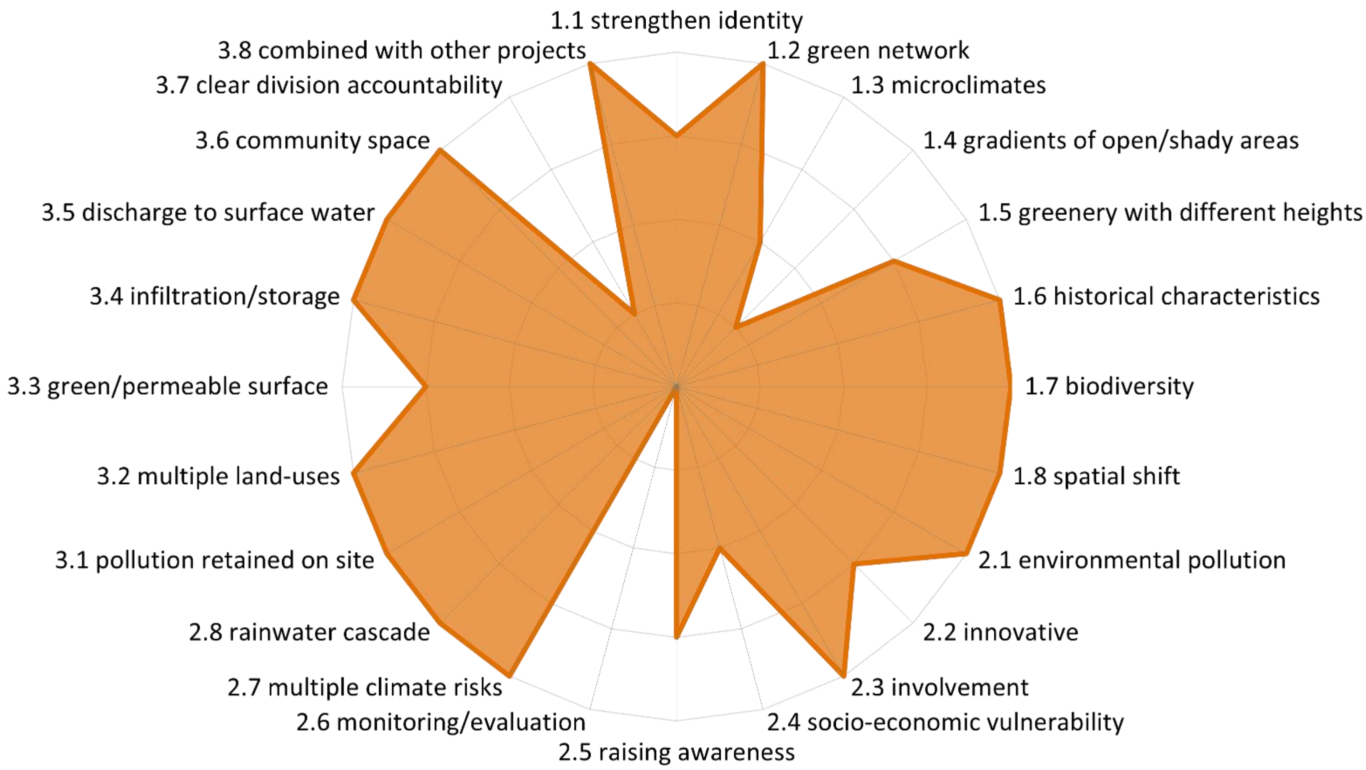

Figure 10.2: Quality of spatial designs to add greenery in Rotterdam

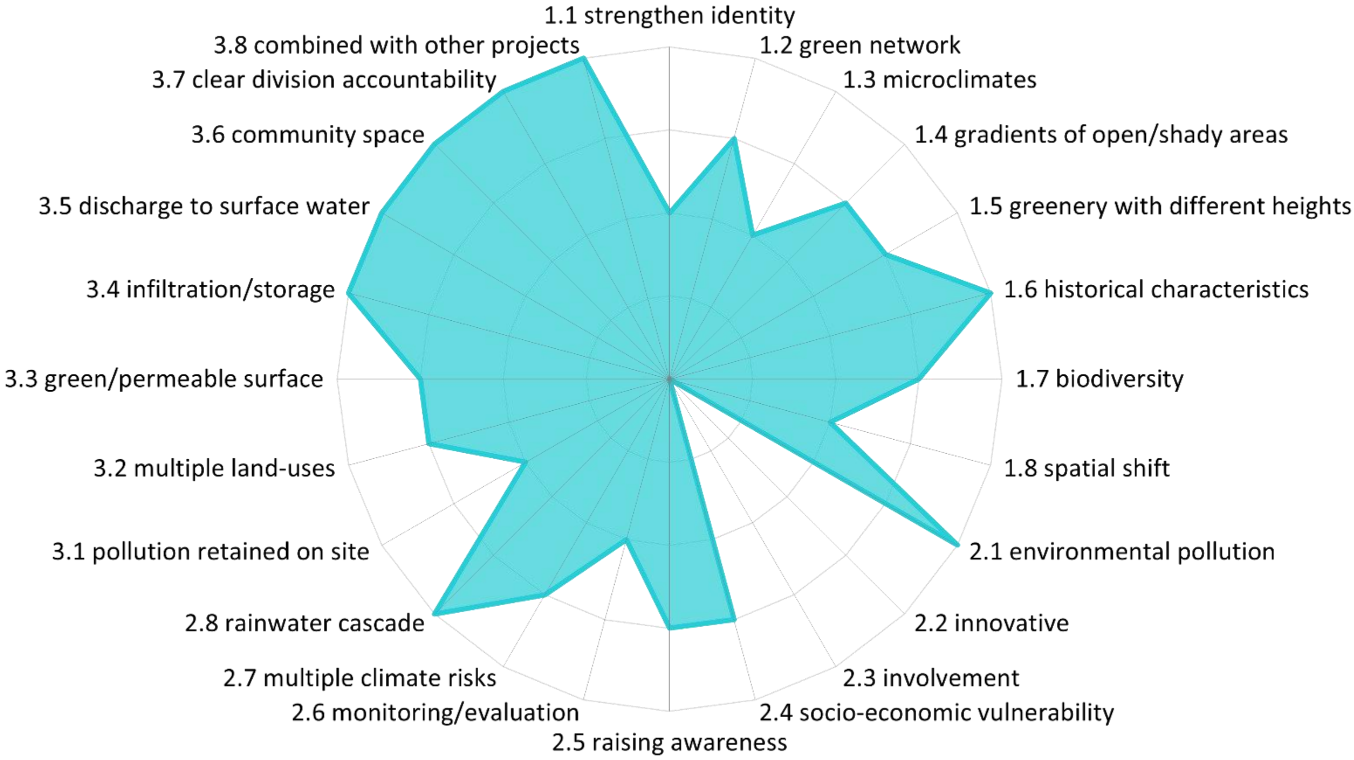

Figure 10.3: Quality of spatial designs to add greenery in Antwerp

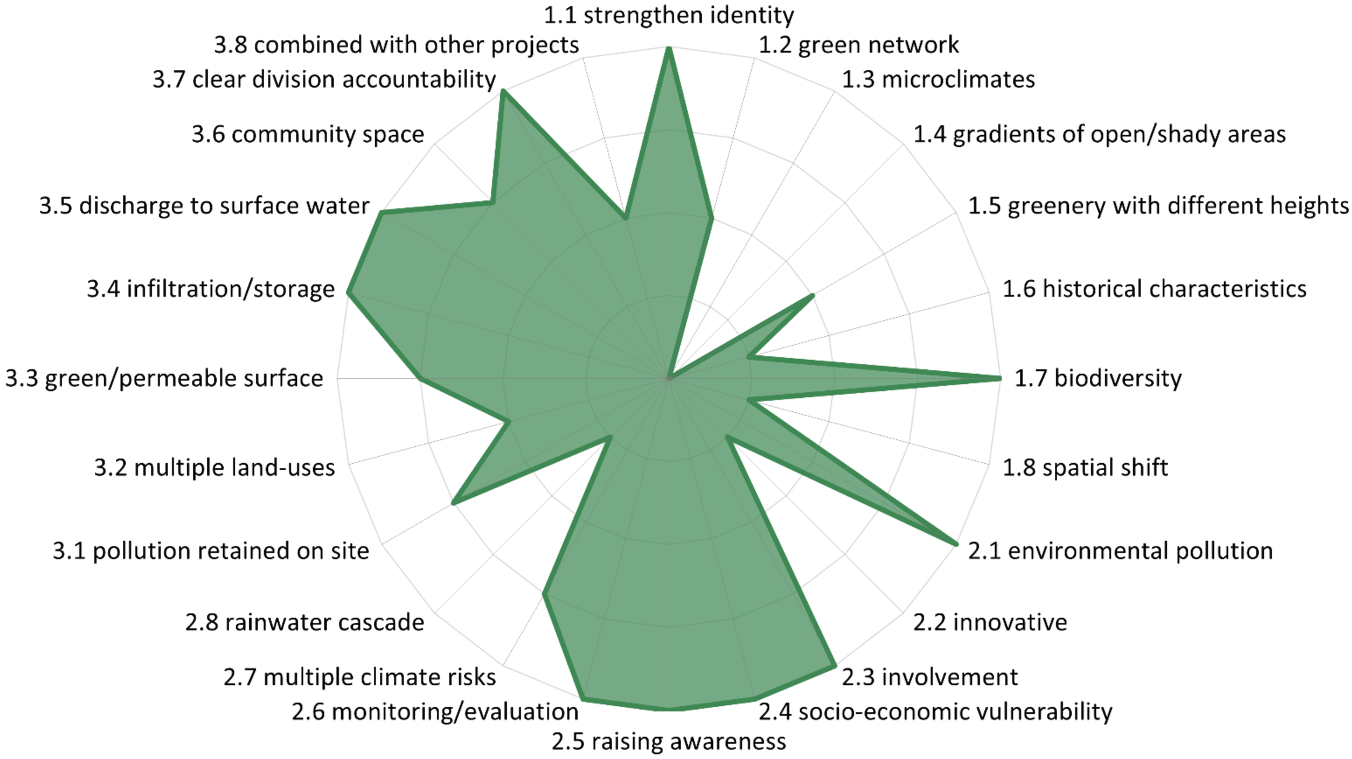

Figure 10.4: Quality of spatial designs to add greenery in London

Rotterdam
The city of Rotterdam strengthens the local identity by implementing spatial measures to decrease flood risks (venustas). For instance, the letters 'ZOHO' in the raingarden is an innovative rain barrel (figure 11). This might be the result of the Rotterdam Climate Proof program in 2008, aiming at making the city resilient in combination with increasing the attractiveness and the quality of the living environment (De Graaf-van Dinther, 2021). The spatial projects also created a shift in land-use (venustas), for example by transforming railway into an urban park (Municipality of Rotterdam, 2020). Another strength is implementing spatial projects that bring people together (utilitas). The water square Benthemplein is used to increase the storage capacity of the location, but the designs also allow people to sport together (Ruimtelijke Adaptatie Strategie, 2013).
Compared to the other cities, Rotterdam has the highest score on connecting greenery to existing spaces. Maps have been created, showing how locations are connected with regard to water, vegetation, and animals. As visualised in figure 8, 9 and 10, the main weaknesses of Rotterdam are monitoring and evaluation (firmitas), a clear division of responsibility (utilitas) and creating gradients with open and shady areas (venustas). In addition, Rotterdam is the weakest city with regard to decreasing socio-economic vulnerabilities (firmitas). In contrast to this result, literature states that Rotterdam started programs to raise awareness for socio-economic vulnerability and to develop projects in vulnerable neighbourhoods (De Graaf-van Dinther, 2021). The locations of the analysed designs in Rotterdam might be the cause of this contradiction. The spatial designs are in the same region of the city and have therefore a comparable, relatively low score. Therefore, this result of the assessment of the projects might not be representative for the whole city.

Figure 11: Innovative rain barrel to increase the identity of the neighbourhood (Brakkee, 2021)

Antwerp

The projects of Antwerp are multifunctional. Rainwater will be stored, infiltrated, or discharged to surface water (utilitas), multiple climate risks will be decreased (firmitas) and the places are transformed to community places (utilitas). The position of the locations in the rainwater cascade is clear at city scale (firmitas), as visualized in figure 12. The Tuinstraten are the first step of the rainwater cascade. The projects Rozemaai and the Zuiderdokken are the fourth step in the rainwater cascade (Waterplan, 2019). The weaknesses are the involvement of local residents (firmitas) in the decision-making process, as stakeholders had a voice after the presentation of the first design of de Gedempte Zuiderdokken (City of Antwerp, 2021). In addition, the connection between new greenery and existing green spaces can be improved (venustas), see figure 8, 9 and 10.

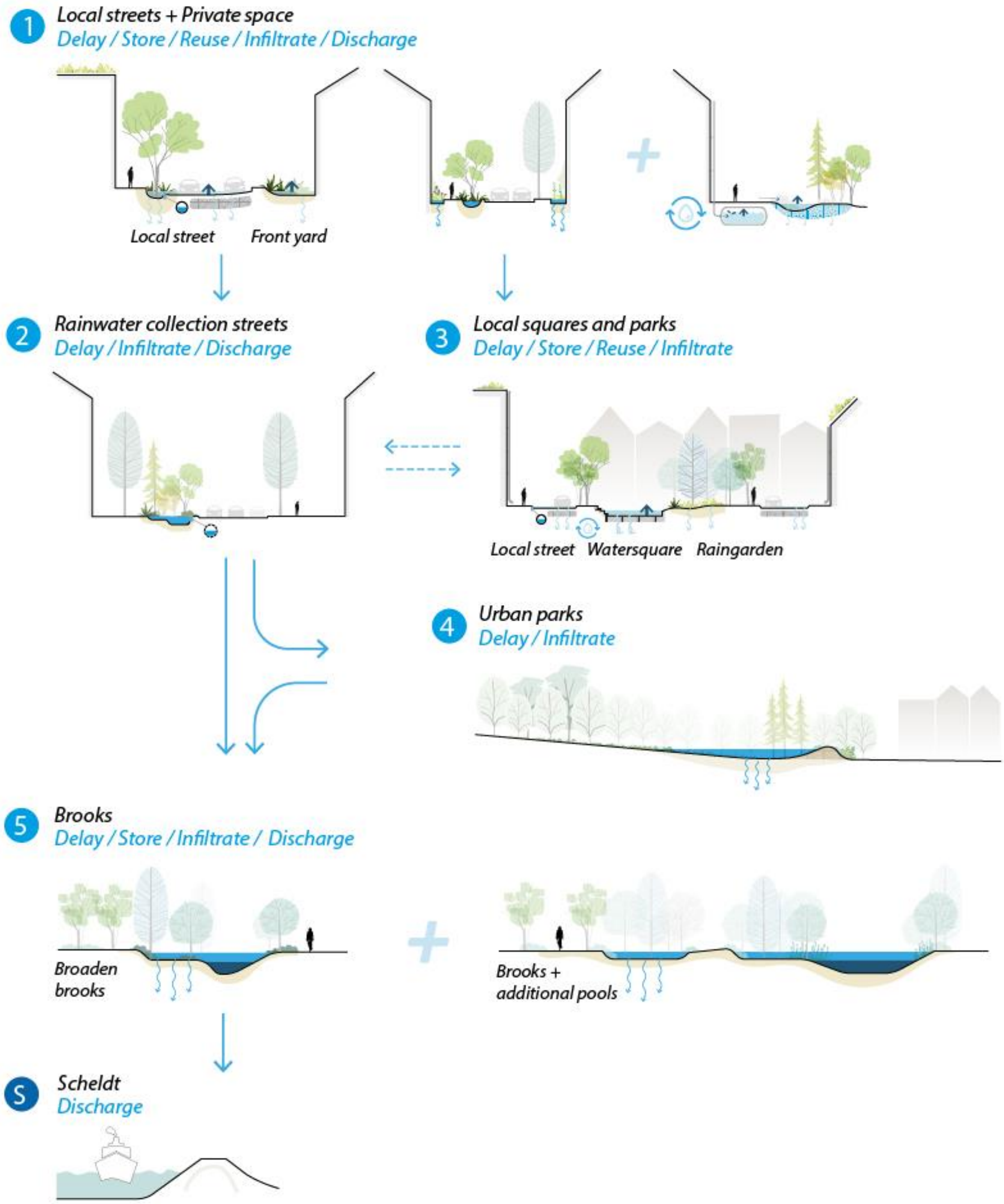

Figure 12: The rainwater cascade in Antwerp (Translated from Waterplan, 2019, p.20)

London
The spatial designs in London can be considered as future proof, see figure 8, 9 and 10. The city is creative in raising awareness for the necessary to decrease pluvial flood risks (firmitas). The raingardens at Alma Road created the occasion for sessions about the water cycle at the local primary school. In addition, a mural painting in a bridge about raingardens has been created by an artist, primary school students, residents and volunteers, see figure 13 (susDrain, 2021a). Another strength is the clear division of responsibility (utilitas). The responsible actors for the maintenance is made publicly available by the community Susdrain (susDrain, 2021a). The projects are decreasing socio-economic vulnerability as two of the projects are located in relatively low-income neighbourhoods with a high proportion of public spaces (Office for National Statistics, 2021a, 2021b). Increasing the attractiveness of locations by realising the projects is the weakness of the city, see figure 7.

Figure 13: The mural painting at the Alma Road (susDrain, 2021a, p. 8)

4.3 Lesson-drawing and policy recommendations
The governance approaches of Rotterdam can be described as communicative and innovative. Projects to decrease pluvial flood risks are considered as an opportunity to increase local identities and to connect green spaces with each other. Some proposed actions in policies remain a little vague. Lessons can be learned from Antwerp to elaborate on these actions in more detail. Rotterdam can learn about financial transparency form Antwerp. London can function as an example to increase transparency about responsibilities and to monitor and evaluate processes.

The policies and spatial designs of Antwerp are supported by strong underlying theories and detailed examples. The fragmentation of government bodies might hinder the implementation of the policies or projects. It can be learned from London how a clear division in responsible government bodies can be made. Antwerp can also learn from London how awareness among citizens can be raised, as citizen involvement in design phases of projects is relatively low. Rotterdam can be an example to connect green spaces with each other.

London is characterised by a multi-sectoral approach. The strengths are raising awareness among citizens, providing a transparent division in responsibilities and monitoring or evaluating processes and projects. The city can learn from both Antwerp and Rotterdam how to increase the attractiveness of spatial designs. Both cities can be used as examples to realise multifunctional projects at a larger scale. Finally, lessons can be learned from Antwerp how projects can be positioned in a rainwater cascade.

Cities in general can learn from Antwerp how to create theoretical backgrounds to support visions and to create rainwater cascades to position projects. Increasing transparency in finances can be learned from Antwerp as well. The city of Rotterdam can function as an example to implement communicative approaches and to consider challenges as opportunities. Cities can learn from London how awareness among citizens can be raised and how transparency in responsibilities can be improved.

Chapter 5 Discussion

The shift in water management from technical approaches towards multifunctional solutions has been discussed in the Theoretical framework. This shift has been recognized in policies of Antwerp, Rotterdam and London. Most of the spatial designs in Antwerp and Rotterdam are multifunctional. London and Antwerp mainly realised nature-based solutions to increase both storage capacities and infiltration rates. Rotterdam realised both nature-based and technical solutions, like the water square. Technical solutions with impermeable surfaces might not increase infiltration rates, but they can function as outstanding projects to draw attention and raise awareness (De Graaf-van Dinther, 2021). The technical solutions in Rotterdam can also be clarified by path-dependency, as water management used to be based on engineering (De Graaf-van Dinther, 2021). These choices fit in the wider debate about nature-based versus technical solutions.

Another difference between the cities is the extend to which projects and processes are monitored and evaluated. Monitoring and evaluating is considered the least important in Rotterdam. Meanwhile, London conducts case studies about every realised project. The various planning cultures can explain this difference. In England, laws are mostly based on cases. In the Netherlands, laws are mostly created in advance to steer developments (Nadin and Stead, 2008).

The shift from central governance guidance towards participation of multiple governance layers and stakeholders in decision-making processes have been recognized as well. London has a clear division in responsibilities, whereas the responsibilities in Antwerp are unclear. This can be justified by the institutional context of Antwerp, as the governance structure is highly fragmented.

Strategies to increase participation in decision-making processes differ per city. Citizens and students in London created the mural painting at the Alma Road (susDrain, 2021a). In Antwerp, residents could adopt parts of the greenery in streets to maintain the Tuinstraat (City of Antwerp, 2020c) and al new governance model has been created to involve all the stakeholders (Klimaatplan 2030, 2020). The municipality of Rotterdam conducts risk-dialogues with citizens (Uitvoeringsagenda 2020-2022, 2020). The choice of the measures to increase participation might be explained by the desired level of citizen participation. At this point, adaptive management interfaces collaborative planning approaches.

Reflection

During this research, some issues were encountered. The data analysis showed that Antwerp almost scored the highest score as possible. However, is it possible to completely implement elements of transformative adaptation into policies? Antwerp might have scored lower if more indicators were added to the analysis. In addition, when codes had been specified into more detail, Antwerp might have scored lower. For instance, one of the indicators of the multi-sectoral aspect of adaptive management is 'multiple governance layers involved'. This might suggest that the involvement of multiple governance levels is always an advantage. However, in case of the highly fragmented governance in Belgium, the amount of involved governance layers might be too much. Then, the multiple involved governance layers are a disadvantage and giving a score for this indicator would be unfair.

Another weakness is the difference in available knowledge about the cities. Much more research has been conducted about Rotterdam and less knowledge is available about London. Therefor, the results of Rotterdam were justified by literature in more detail compared to the results of London.

Generalisation

To some extent, generalisation of the results is possible. The physical and climatic conditions of the examined cities are comparable. Therefore, this study is the most representative for cities with similar physical and climatic conditions. The examined cities do have various planning cultures and institutional contexts, which increases the possibility of generalisation. In case of lesson-drawing, it is necessarily to consider whether the planning conditions of the 'learning city' are adequate to implement the lessons learned based on Rotterdam, Antwerp or London.

Chapter 6 Conclusion

London, Rotterdam and Antwerp are facing comparable pluvial flood risks. It has been examined how these cities respond to the vulnerability to pluvial flood risks. The cities drew up policies, in which the necessary to address the increasing pluvial flood risks are acknowledged, and implemented some characteristics of adaptive governance. Besides, the cities adjusted or reshaped the living environment to make it more resilient. A policy analysis has been conducted to research which characteristics of adaptive management and transformative adaptation are implemented in these policies. In addition, the spatial designs to implement the policies have been assessed and a literature review has been conducted.

In general, the policies are already communicative, multi-sectoral and are focussing on an ongoing learning process, which are elements of adaptive management. The mediating and reorganising aspects of transformative adaptation are the least recognised. Spatial designs at street levels, at community spaces and designs to add new greenery are created to implement policies. These projects are evaluated based on the design guidelines of Vitruvius: attractiveness, firmness and functionality. The strengths are increasing infiltrations rates and storage capacities in the cities and disconnecting rainwater from sewage systems are the strengths. In general, connections between new greenery and green networks or gradients of sunny and shady areas are lacking.
In contrast to the expectation that Rotterdam would have implemented the most aspects of transformative adaptation, most elements were recognised in policies of Antwerp. The different results per city have been explained by path-dependency, institutional contexts and planning cultures.

Based on the results, lessons were drawn and policy recommendations were provided. Rotterdam is recommended to be more specific and detailed in polices, to monitor and evaluate processes and to increase transparency in finances and responsibilities. Antwerp is advised to connect green spaces in the city and to clarify responsibilities of actors. In addition, Antwerp can learn how to raise awareness among citizens and to increase participation in design phases. London is recommended to increase the attractiveness of spatial designs, to implement multifunctional projects at a larger scale and to position projects in a rainwater cascade.

In this research, only policies and spatial designs have been analysed. The implementation of the policies into practice has still to be researched, for instance by conducting interviews. Some of the analysed projects are not finished yet. Therefore, another research recommendation is to study the implementation of elements of transformative adaptation in the process of realising the projects. It might also be relevant to study to what extend differences in political movements can clarify differences in the cities' approaches. Finally, insights about the effectiveness of the policies and the spatial projects to decrease pluvial flood risks are relevant to research in the future.

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Appendices

Appendix 1 Sources data to assess the spatial designs

Raingarden ZOHO (Rotterdam)	
https://urbanadapt.eu/nieuws/de-regentuin/	(Life UrbanAdapt, 2018)
https://rotterdamsweerwoord.nl/plekken/regentuin-zoho/	(Rotterdam WeatherWise, 2021b)
https://www.bassala.com/zohosign	(Studio Bas Sala, 2021)

Benthemplein (Rotterdam)	
http://www.urbanisten.nl/wp/?portfolio=waterplein-benthemplein	(De Urbanisten, no date)
https://www.rotterdam.nl/wonen-leven/benthemplein/	(Municipality of Rotterdam, no date a)
https://www.rotterdamarchitectuurprijs.nl/vorige-edities/2014/waterplein-benthemplein.html	(Air Rotterdam, no date)
https://www.watersensitiverotterdam.nl/plekken/waterplein-benthemplein/	(Barfoot, 2017)

Hofbogenpark (Rotterdam)	
https//www.hofbogen.nl/luchtpark/	(Miesman Design, 2021)
https://www.rotterdam.nl/wonen-leven/hofbogenpark/	(Municipality of Rotterdam, no date b)
https://rotterdam.raadsinformatie.nl/document/9529417/2/20bb16707	(De Urbanisten, *et al.*, 2020)

Tuinstraten – Lange Ridderstraat (Antwerp)	
https://www.pzc.nl/antwerpen/groene-oase-midden-in-de-stad-lange-riddersstraat-eerste-officiele-tuinstraat-van-antwerpen~adc3e650/	(Bral, 2021)
https://www.antwerpen.be/info/5abb4909a67793cbc17ccb74/lange-riddersstraat-wordt-tuinstraat	(City of Antwerp, 2020c)
https://www.antwerpen.be/info/5fe33dc0f67343100b5c2c52/lange-riddersstraat-wordt-tuinstraat-een-kijkje-tijdens-de-heraanleg-foto-s	(City of Antwerp, 2020b)
https://www.demorgen.be/nieuws/de-tuinstraat-als-wapen-tegen-de-klimaatopwarming-meer-groen-houdt-de-buurt-leefbaar~b771b0ac/?referrer=https%3A%2F%2Fwww.google.com%2F	(Michiel Martin, 2021)
https://stadincijfers.antwerpen.be/?var=natcube	(City of Antwerp, no date b)
Klimaatplan 2030	(City of Antwerp, 2020a)

Gedempte Zuiderdokken (Antwerp)	
https://www.antwerpenmorgen.be/nl/projecten/gedempte-zuiderdokken/over	(City of Antwerp, 2021)
https://stadincijfers.antwerpen.be/?var=natcube	(City of Antwerp, no date b)
Klimaatplan 2030	(City of Antwerp, 2020a)

Rozemaaipark (Antwerp)	
https://www.antwerpenmorgen.be/nl/projecten/rozemaai/over	(City of Antwerp, no date a)
https://dbpubliekeruimte.info/project/rozemaaipark/	(databank Publieke Ruimte, 2020)
https://stadincijfers.antwerpen.be/?var=natcube	(City of Antwerp, no date b)
Klimaatplan 2030	(City of Antwerp, 2020a)

Raingarden Alma Road (London)	
https://www.london.gov.uk/file/10643264	(Greather London Authority, 2021a)
https://www.susdrain.org/case-studies/pdfs/alma_road_rain_gardens_london.pdf	(susDrain, 2021a)
https://crystalroof.co.uk/report/postcode/SW181AA/affluence?tab=social-grade	(Office for National Statistics, 2021b)

Bridget Joyce Square (London)	
https://www.susdrain.org/case-studies/case_studies/bridget_joyce_square_london.html	(susDrain, 2021b)
https://regenerativedesign.world/bridget-joyce-square/	(Robert Bray Associates, 2017)
https://crystalroof.co.uk/report/postcode/W127DE/overview	(Office for National Statistics, 2021a)

Climate-proofing social housing landscape (London)	
https://climate-adapt.eea.europa.eu/metadata/case-studies/climate-proofing-social-housing-landscapes-2013-groundwork-london-and-hammersmith-fulham-council	(European Climate Adaptation Platform Climate-ADAPT, 2021)
https://lifevideos.eu/videos/?id=LIFE12_ENV_UK_001133_01_EN_CLIMA.mp4	(Groundwork London, no date a)
https://www.urbangreenbluegrids.com/uploads/121018-SPONGE-Ben-Coles-Groundwork-London.pdf	(Coles, no date)
LIFE+ Climate-Proofing Social Housing Landscapes Layman's Report	(Groundwork London, no date b)
FINAL Report Climate-Proofing Social Housing Landscapes LIFE12ENV/UK/001133	(Groundwork London, 2016)
https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=4752	(European Commission, 2021)

Appendix 2 Results of policy analysis

Concept	Variable	Indicator (yes or no)	R	A	L
Adaptive management	Flexible	Up-to-date and relevant knowledge	X	X	X
		Response to new changes/insights		X	X
		Identification of high-risk situations/regions	X	X	X
		Preparation of unexpected changes/events		X	X
		Assurance of long-term financial support		X	X
	Ongoing learning process	Experimenting	X	X	X
		Monitoring	X	X	X
		Evaluation	X	X	X
		Underlying processes and theories explained	X	X	
		Interaction between actors	X	X	X
	Re-establishing	Adjustments to management strategies/policies	X	X	X
		Adjustments to behaviour	X	X	
		Spatial adjustments	X	X	X
		Willingness to take/manage risks		X	
		Open to new opportunities/synergies with other sectors	X	X	X
	Communicative	Availability of knowledge for all actors	X	X	X
		Communication is understandable for non-experts	X	X	X
		Clear and measurable vision/objective	X	X	X
		Alternative pathways/scenarios taken into account	X	X	X
		Long-term oriented	X	X	X
	Multi-sectoral	Multiple stakeholders involved	X	X	X
		Multiple sectors involved	X	X	X
		Multiple governance layers involved	X	X	X
		Clear division of roles and tasks			X
		Clear division of accountability (who is responsible)	X	X	X
Transformative adaptation	Reorganising	Shift in normative context	X	X	X
		Shift in political/institutional context	X	X	
		Shift in social/cultural context		X	
		Shift in spatial context		X	
		Affecting multiple generations	X	X	
	Unlocking	Establish sources of unwanted effects of previous strategies		X	X
		Remove support for unsustainable technologies/processes	X	X	
		Establish side effects of changes/solutions	X	X	X
		Foster political willingness and public sense of urgency	X	X	X
		Policy instruments introduced	X	X	
	Innovative	Promotion of innovation	X	X	X
		New technologies	X	X	
		Wide implementation of successful experiments	X	X	
		Learn from experiments and make it generalizable	X	X	X
		Provide resources for wide implementation		X	
	Resilient	Develop new models for feedback/monitoring	X	X	X
		Establish socio-economic causes of vulnerability (e.g., injustices, inequality)		X	X
		Establish and communicate uncertainties	X	X	X
		Open/simple institutions and rules (foster flexibility)	X	X	

		Link past experiences with present and future		X	X
	Mediating	Link visions to continuous developments		X	
		Connect resources to goals		X	
		Create formal and informal space/networks to exchange knowledge and resources (and manage conflicts)	X	X	X
		Minimise trade-offs between actors		X	
		Review institutional performance with regard to long-term vision		X	X

Appendix 3 Results assessment spatial designs

Variable	Indicator: --, -, 0, +, ++	1	2	3
Venustas (attractiveness)	Strengthen identity/reputation of place	++	++	+
	Connect greenery to a green network	+	-	++
	Combine diversity of microclimates (sun, shade, half shade) with furniture	+	++	0
	Gradients of open areas and shady areas close to each other	+	0	-
	Greenery with different heights	+	0	+
	Preserve heritage/historical characteristics of place	0	-	++
	Increase in biodiversity	++	0	++
	Shift in land-use/function/purpose	++	+	++
Firmitas (future-proof)	Combat air/noise/soil pollution	+	-	++
	Innovative/new technologies	++	+	+
	Local residents involved in design phase	+	++	++
	Increase public greenery in neighbourhoods with minimal private spaces (decrease socio-economic causes of vulnerability)	0	0	0
	Beneficial for awareness raising	++	++	+
	Monitoring and evaluation of results/effectiveness	-	-	--
	Manage multiple climate risks at once (heat stress & flood risk & drought)	++	+	++
	Position in rainwater cascade is clear	+	++	++
Utilitas (functionality)	Sediment/pollution retained on site	+	+	++
	Multiple land-uses/purposes/functions (besides decreasing flood risks)	-	+	++
	Green or permeable surface	+	-	+
	Infiltration/storage of rainwater	++	++	++
	Discharge of excessive rainwater to surface water (instead of sewage)	++	++	++
	Community space (place to meet)	+	++	++
	Clear division of accountability/responsibility	0	+	-
	Realisation incorporated in maintenance/development projects	+	--	++

1: Raingarden ZOHO
2: Benthemplein
3: Hofbogenpark

Variable	Indicator: --, -, 0, +, ++	4	5	6
Venustas (attractiveness)	Strengthen identity/reputation of place	+	+	0
	Connect greenery to a green network	--	--	+
	Combine diversity of microclimates (sun, shade, half shade) with furniture	+	+	0
	Gradients of open areas and shady areas close to each other	0	++	+
	Greenery with different heights	0	++	+
	Preserve heritage/historical characteristics of place	0	+	++
	Increase in biodiversity	++	++	+
	Shift in land-use/function/purpose	-	++	0
Firmitas (future-proof)	Combat air/noise/soil pollution	0	++	++
	Innovative/new technologies	+	++	--
	Local residents involved in design phase	++	--	--
	Increase public greenery in neighbourhoods with minimal private spaces (decrease socio-economic causes of vulnerability)	+	0	+
	Beneficial for awareness raising	++	0	+
	Monitoring and evaluation of results/effectiveness	+	+	0
	Manage multiple climate risks at once (heat stress & flood risk & drought)	++	++	+
	Position in rainwater cascade is clear	+	++	++
Utilitas (functionality)	Sediment/pollution retained on site	+	+	0
	Multiple land-uses/purposes/functions (besides decreasing flood risks)	-	++	+
	Green or permeable surface	++	+	+
	Infiltration/storage of rainwater	++	++	++
	Discharge of excessive rainwater to surface water (instead of sewage)	+	++	++
	Community space (place to meet)	+	++	++
	Clear division of accountability/responsibility	+	+	++
	Realisation incorporated in maintenance/development projects	+	-	++

4: Tuinstraten (Lange Ridderstraat)
5: Gedempte Zuiderdokken
8: Rozemaaipark

Variable	Indicator: --, -, 0, +, ++	7	8	9
Venustas (attractiveness)	Strengthen identity/reputation of place	+	+	++
	Connect greenery to a green network	--	--	0
	Combine diversity of microclimates (sun, shade, half shade) with furniture	--	-	--
	Gradients of open areas and shady areas close to each other	--	--	--
	Greenery with different heights	-	0	0
	Preserve heritage/historical characteristics of place	0	-	-
	Increase in biodiversity	++	++	++
	Shift in land-use/function/purpose	--	+	-
Firmitas (future-proof)	Combat air/noise/soil pollution	+	+	++
	Innovative/new technologies	-	++	-
	Local residents involved in design phase	++	0	++
	Increase public greenery in neighbourhoods with minimal private spaces (decrease socio-economic causes of vulnerability)	--	++	++
	Beneficial for awareness raising	++	+	++
	Monitoring and evaluation of results/effectiveness	++	++	++
	Manage multiple climate risks at once (heat stress & flood risk & drought)	0	+	+
	Position in rainwater cascade is clear	0	0	-
Utilitas (functionality)	Sediment/pollution retained on site	+	++	+
	Multiple land-uses/purposes/functions (besides decreasing flood risks)	--	0	0
	Green or permeable surface	0	++	+
	Infiltration/storage of rainwater	++	++	++
	Discharge of excessive rainwater to surface water (instead of sewage)	+	0	++
	Community space (place to meet)	--	+	+
	Clear division of accountability/responsibility	+	++	++
	Realisation incorporated in maintenance/development projects	+	-	0

7: Raingarden Alma Road
8: Bridget Joyce Square
9: Climate-proofing social housing landscapes