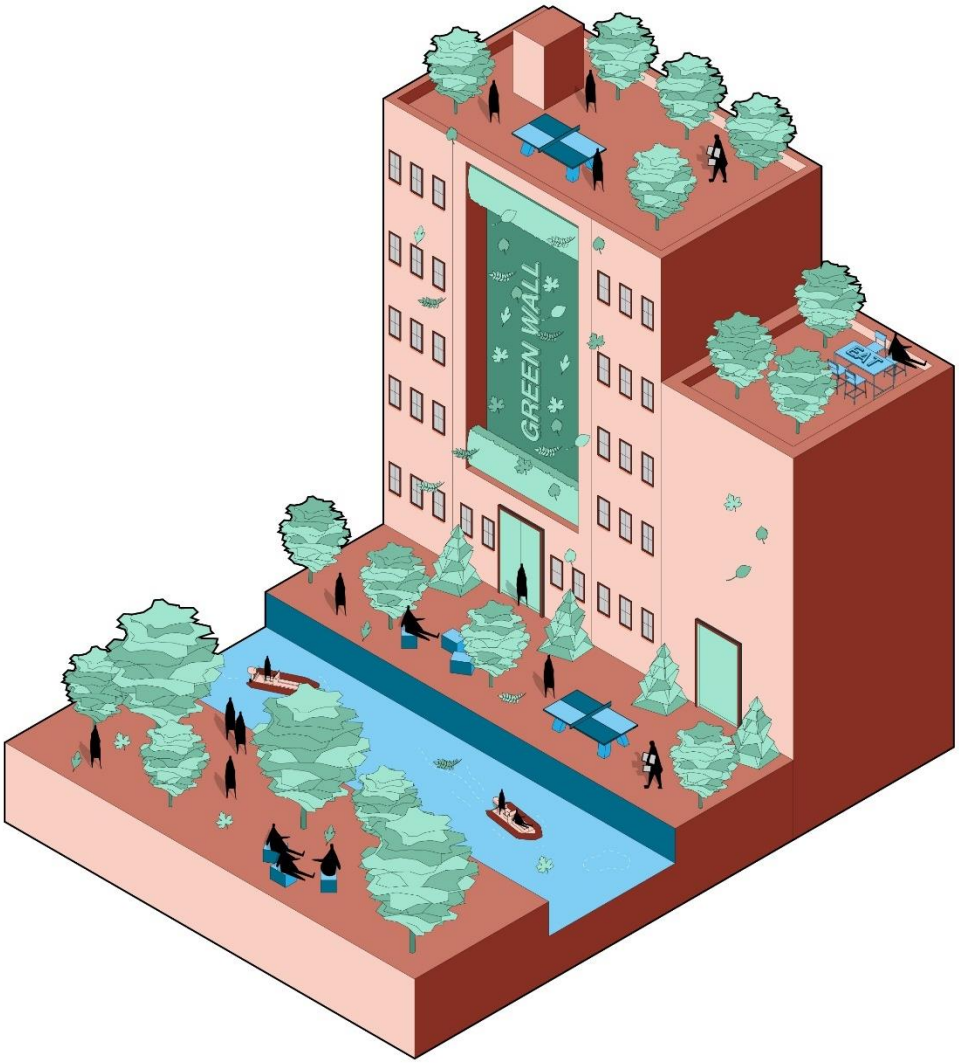
Pressing The Accelerator For Urban Climate Adaptation: Identifying Critical Factors For Success Among Europe's Frontrunner Cities



George Parsons
Faculty of Geosciences: MSc Water Science and Management
5688523
30 ECTS
Academic Supervisor: Dr Carel Dieperink (c.dieperink@uu.nl)
Academic 2nd Reader Prof. Kees van Leeuwen (c.j.vanleeuwen@uu.nl)
Sweco Supervisor: Enrico Moens (enrico.moens@sweco.nl)
Title page figure, source: Simpson, 2020.

Universiteit Utrecht

SWECO

Abstract

Contemporary cities face common trends that are bringing new challenges and opportunities. Water-related climate change hazards, like pluvial flooding and drought, alongside demographic change and urbanization, require adaptation to create healthy, sustainable cities. Planning for adaptation is widespread but there remains inertia in implementation of climate change adaptation measures. As cities look increasingly towards collaborative learning and municipal networking, frontrunners for adaptation may provide insights on how to accelerate adaptation and generate successful, multi-functional interventions to mitigate risk and build resilience to climate change. The objective of this research is therefore, to compare and identify critical factors for accelerating adaptation success in frontrunner cities and to facilitate the translation and actionability of best practices into a variety of urban contexts. Using the concept of adaptive capacity as an analytical frame, a qualitative assessment of adaptation implementation in London, Copenhagen, Rotterdam, Berlin and Warsaw was undertaken. An analytical framework was developed to analyse adaptive capacity, consisting of six sub-capacities: legal, institutional, resource, social, learning and transformative. Via semi-structured interviews and content analysis of key municipal policy and strategy literature, city-specific characteristics, alongside inter-city similarities and differences, could be identified.

Comparative analysis showed that inspirational leadership, horizontal coordination, financial availability, adaptation expertise and community initiatives were strong enabling and critical factors for adaptation success. In addition to these, the pursuit of ambitious, holistic adaptation targets, and innovation and experimentation processes are also highly important. Success may be constrained by insufficient policy instruments for adaptation, a lack of financial continuity, and inadequate learning practices, via community marginalization or non-existent monitoring and evaluation. Critical adaptive capacity interconnections emerge between adaptive expertise and innovation and experimentation; socio-environmental equity redistribution and multi-benefit solutions; and adaptation policy cohesion and the embeddedness of adaptation across multiple sectors and stakeholders. Actionability assessment identified factors viable for rapid improvement, namely community initiatives, monitoring and evaluation, and statutory compliance. Translating weaker adaptive capacities into actions for implementation can prove a valuable guide for generating momentum in broader transformation of cities towards sustainability. It is concluded that critical adaptive capacity factors facilitate adaptation success in frontrunner cities. Strategic development and improvement of adaptive capacities should carefully consider the role of factor interconnections and identify actionable factors in order to optimize the acceleration of urban climate change adaptation practices.

Keywords: urban climate change adaptation, water-related hazards, adaptive capacity, actionability

Table of Contents

List of Figures

List of Tables

List of Boxes

Abbreviations

ACF: Adaptive Capacity Factor
BGI: Blue-Green Infrastructure
BWB: Berlin Wasserbetriebe
CAP: Climate Action Planning
CBF: City Blueprint Framework
CCA: Climate Change Adaptation
CCC: Climate Change Committee
CMP: Cloudburst Management Plan
EA: Environment Agency
EC: European Commission
EEA: European Environmental Agency
EU: European Union
GCF: Governance Capacity Framework
GLA: Greater London Authority
IPCC: International Panel on Climate Change
IUR: Integrated Urban Renewal
LA: Local Authority
LCCP: London Climate Change Partnership
LES: London Environment Strategy
SDG: Sustainable Development Goal
SETS: Socio-Ecological-Technical Systems
SUDS: Sustainable Urban Drainage Systems
TEA: Technical and Environmental Administration
UAP: Warsaw Urban Adaptation Plan
UN: United Nations

Acknowledgements

I have long held the conviction that we have more than enough potential and capacity to keep our communities cool and our doorsteps dry. Writing this MSc these has reinforced this, giving me the opportunity to explore the stories of several cities, learn from experts and glean some knowledge for myself.

I would like to thank my supervisor, Carel, for his patience, willingness to brainstorm, and ability to conjure up a smile even in the face of the toughest question. And from Sweco, I was grateful to have the experience and insights of Enrico, Maarten, and Amy who provided sage advice and plenty of encouragement. It was a pleasure working on my thesis in such a fun team.

A big thanks to my parents, for poring over pages of ramblings, and my cousin Ben for creating the brilliant graphic for the cover. Lastly, the support, wisdom, and tea & biscuits provided by Daisy that kept me going, I'll always be hugely grateful.

Amidst this chaotic year, it was always the perfect respite to dive back into my thesis, so hopefully you enjoy reading it!

George Parsons
June 2020
Utrecht, the Netherlands

1. Introduction

1.1 Climate challenges in global cities

Global cities will house nearly 6 billion people by 2050 (UN DESA, 2018), cementing their status as dominant focal points for environmental and socio-economic challenges. Climate risks and hazards, such as urban flooding, drought and extreme heat, will become more acute in these densely populated and high-value landscapes, in which potential socio-economic impacts could become increasingly severe (McKinsey & Company, 2020).

It is widely acknowledged that mitigation of greenhouse gas emissions is imperative, however it is also accepted that existing emissions have "locked-in" climate warming, thus making more extreme climate impacts inevitable in the near-future (IPCC, 2014a). The International Panel on Climate Change (IPCC) Fifth Assessment Report identifies the importance of investigation into climate change adaptation (CCA) and mitigation at the urban scale (IPCC, 2014a), given their strategic importance nationally and globally, yet there remains inertia within developed and less-developed global cities, as stakeholders seek optimal strategies for planning and implementation (Bulkeley, 2013). Amidst this, urgency for significant and costly adaptation interventions demands difficult decisions and choices for the physical, socio-economic and cultural environments that our urban societies are based upon.

Many challenges facing urban areas are water-related, such as pluvial and fluvial flooding, drought, biodiversity loss, public health management, and resource and energy availability (EC, 2019; EC, 2018a; IPCC, 2014a). Analysing the relations between water, society and urban infrastructure will be essential to provide adaptation practitioners with a holistic appreciation of the conditions and processes that underlie the implementation of urban adaptation measures.

The ability of urban stakeholders to deal with climate hazards and seize opportunities is known as their "adaptive capacity" (IPCC, 2014b). Adaptive capacities relate to legislative, socio-economic, geographic and political conditions within the complex urban landscape, which exhibit interactions at differing scales (EEA, 2015). This makes understanding the role of adaptive capacities in climate adaptation particularly relevant. However, the contextual basis for success in climate adaption action is significant and variable across different urban areas. Additionally, there has been infrequent analysis of the adaptation capacities linked to success and failure across multiple cities (Solecki *et al.*, 2015; EC, 2018a). Using adaptive capacity as a metric to investigate adaptation implementation could provide new insights for CCA decision-makers and practitioners.

1.2 Capacities for accelerating adaptation

This research will deal with adaptive capacity, which relates specifically to action and implementation of adaptation interventions, and the critical conditions that dictate this "ability" to successfully adapt to climate change impacts. The specific impacts of interest are urban water-related challenges, such as extreme rainfall events, extreme heat and drought. These are challenges facing many cities across Europe (C40, 2019), thus a multitude of case study interventions at the urban scale exist.

> Adaptive Capacity (IPCC, 2014a, p.118) :
> *"The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences"*

In recent years, climate adaptation planning has emerged as a priority at national and international scales (IPCC, 2014a). However, successful climate adaptation is dependent on contextual facilitating conditions and factors, across multiple scales and networks in the urban system, which may or may not be functional and transferable between cities (Eisenack *et al*., 2014). To reveal the extent to which specific adaptation capacities are relevant within differing cities, it is necessary to explore the criteria defining successful adaptation and the underlying processes, relationships and structures that enable success. Whilst researchers have identified this action gap (Measham *et al,* 2011; Rauken, Mydske & Winsvold, 2015), there is limited empirical analysis of the precise factors that dictate transitions from good planning to implementation. By targeting projects from frontrunner cities, it may be possible to illuminate the conditions and specific capacities required to implement successful adaptation at the city-scale.

Cities are complex social-technical-ecological systems (Bulkeley, 2013; Bai *et al*., 2010). The functioning of these complex systems is related to their socio-economic development, political and institutional structure, geographical setting, and socio-cultural norms and values (Bulkeley, 2013). The flexibility and breadth of adaptive capacity is therefore well suited as a tool for assessing the significance of the contexts (Gupta *et al*., 2010). Identification of universal "critical" adaptive capacities, appreciating their actionability across city contexts, may aid the re-framing and translation of adaptation policy and best practices.

Thus, the acute knowledge gaps that feed into the research aims and objectives are:

- Lack of empirical analysis of stimulating and critical factors for transitioning from adaptation policy to implementation.
- Lack of empirical identification of shared critical adaptive capacity factors across successful adaptation measures in frontrunner cities.
- Uncertainty over the interrelatedness and actionability of critical adaptive capacity factors across different city contexts.

1.3 Research Objectives

Implementation of climate change adaptation is cited to face many barriers, including technical, governmental, psychological or financial (Adger *et al*., 2005; Eisenack *et al*., 2014). The mechanisms with which cities overcome such barriers are therefore of interest, and the underlying capacities that facilitated this successful implementation can provide insight into which components, practices or measures within the urban system were significantly influential.

Cities are unique and individual. Comparative analysis of their adaptive capacities is required to provide more detailed and descriptive understanding of their individual contexts. This is particularly relevant for adaptation to water-related hazards that require strategic management to deal with their environmental and socio-economic implications. Thus, the identification of "success" factors can be used to guide effective planning and implementation of future climate adaptation programs within other cities.

The urgency of adaptation action is accompanied by challenges in the identification and prioritization of action pathways. In attempting to identify the essential capacities and factors for success, practitioner insights may aid the prioritization of urban climate adaptation measures or highlight where best practice could be used optimally. The operationalisation of critical factors may enable those cities to accelerate adaptation via multiple means; the lack of information regarding this transferability or actionability of efficient best practices is what this research aims to address.

The **research aim** is, therefore:
To provide lessons and recommendations for decision-makers and practitioners for targeting critical adaptive capacity factors to accelerate successful urban climate adaptation to floods and drought.

In addition, the **research objective** of this thesis is:
To identify and evaluate the underlying enabling adaptive capacities within climate adaptation projects in frontrunner cities across the EU, and analyse their interrelatedness and actionability for utilization in generating successful climate change adaptation.

1.4 Research Questions

This research project intends to, firstly, assess existing scientific theory relating to processes of urban climate adaptation and, secondly, empirically verify the extent to which implementation of such interventions depends upon, or relates to, specific adaptive capacities, and their interrelations. As such, the **main research question** is:

What are critical factors for successful implementation of urban climate adaptation to flood and drought challenges in European cities?

This question is addressed using an exploratory approach combining a literature review and an applied analysis of specific case studies. This approach allows for the testing and evaluation of literature-derived conclusions in practice. The primary outcomes will be:

1. *Descriptive:* outlining the relative capacities of urban municipalities in relation to climate adaptation.
2. *Explanatory:* relating to the factors and processes that may explain the successfulness of climate adaptation interventions within urban municipalities.
3. *Prescriptive:* regarding the creation of recommendations for adaptive capacity development and best practice sharing within urban systems.

The following framework was used to guide this research project.

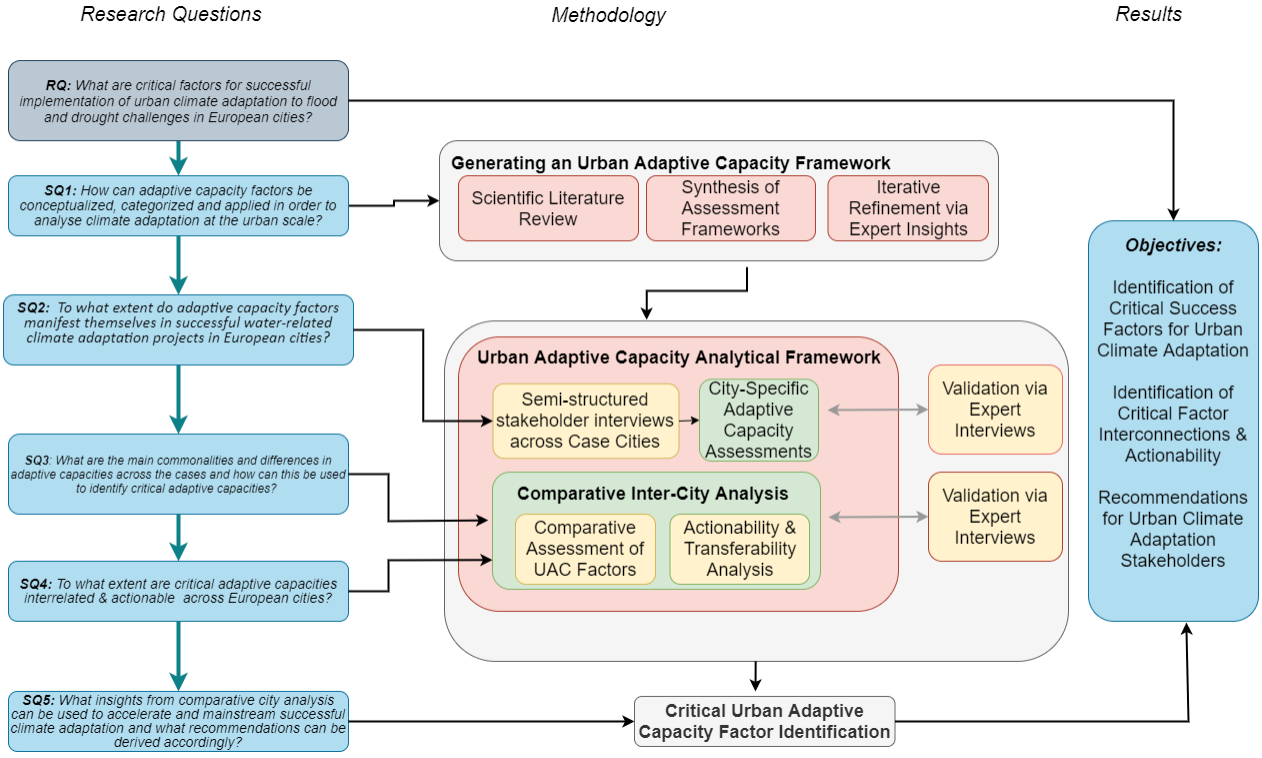


Figure 1: Research Framework, outlining the stepwise progression from problem definition to data collection and analysis and final recommendations for city stakeholders

1.4.1 Sub-Questions

The concept of adaptive capacities may be valuable for analysing the dynamics of successful planning-implementation transitions (Berrang-Ford *et al*., 2011). SQ1 aims to approach this, by conceptualizing and operationalizing adaptive capacities into an analytical framework, founded upon existing literature and adaptation policies.

SQ1: How can adaptive capacity factors be conceptualized, categorized and applied in order to analyse climate adaptation strategies at the urban scale?

Urban climate adaptation is occurring at different scales across European cities. Identifying, via an analytical framework, the form, timing, and scale of adaptive capacity manifestation in successful water-related adaptation projects may elucidate optimal strategies and trajectories for CCA implementation.

SQ2: To what extent do adaptive capacity factors manifest themselves in successful water-related climate adaptation projects in European cities?

Contextual conditions and variables in urban environments influence climate adaptation. Understanding the influence of contextual conditions on the manifestation of critical adaptive capacities may foster enhanced knowledge and learning. SQ3 aims to bridge this challenge, utilizing comparative analysis of city case studies to identify critical adaptive capacity factors.

SQ3: What are the main commonalities and differences in adaptive capacities across the cases and how can this be used to identify critical adaptive capacities?

Investigating critical adaptive capacities, with subsequent expert validation, may enable the correlation of pre-existing urban conditions to the transfer of best practice or capacities. SQ4 aims to identify and communicate these opportunities for knowledge transfer.

SQ4: To what extent are critical adaptive capacity factors interrelated and actionable across European cities?

Translating the relationships between adaptive capacities and successful urban climate adaptation may offer insights to guide future climate action planning and target specific capacity development opportunities. Therefore, through the triangulation and verification of critical adaptive capacities for urban climate adaptation to flooding and drought, the translation of analytical insights into key recommendations will be realized, via SQ5.

SQ5: What insights from comparative city analysis can be used to accelerate and mainstream successful climate adaptation, and what recommendations can be derived accordingly?

1.5 Thesis Outline

Chapter 2 will explore the theoretical basis of urban climate adaptation and adaptive capacities by outlining theories of implementation, transitional governance, mainstreaming and acceleration. It will also provide an overview of the operationalization of adaptive capacity as an analytical tool. Chapter 3 details additional methodological approaches, whilst Chapters 4 to 9 explore each city individually and elaborate their results. Chapter 10 synthesizes and outlines the results of comparative analysis, whilst Chapter 11 & 12 discuss the results of the research questions and provide conclusions and recommendations.

2 Success Factors for Climate Adaptation: Theoretical Background

2.1 Introduction

This chapter details relevant theoretical concepts that underpin this empirical research. Section 2.2 elaborates relevant definitions within the field of climate adaptation and translates them for practical application as an analytical tool. Section 2.3 and 2.4 address how accelerating successful urban climate adaptation, including actionability and transferability, relates to principles of transitions thinking and implementation science. Sections 2.5 and 2.6 address sub-question 2, by discussing how the analytical framework was developed through critical climate adaptation literature review, and creating a final selection of adaptive capacities. Section 2.7 outlines their operationalisation for use as an analytical tool to explore climate adaptation case-studies from European cities.

2.2 Exploring Urban Climate Change Adaptation Success

Adaptation is "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities." (IPCC, 2014a). Adaptation can take multiple forms, in which incremental adaptation refers to actions "where the central aim is to maintain the essence and integrity of a system or process at a given scale." In contrast, the concept of transformational adaptation refers to actions that "change the fundamental attributes of a system in response to climate and its effects." (IPCC, 2014a, pg. 1758). Most cities are active with incremental adaptation to water-related hazards (Figure 2) and this array of adaptation measures were the focus of this research, although more transformative adaptation interventions have also been targeted within city-specific discussions.

The local-scale of CCA implementation conflicts with the national-level governance perspective that typically dominates climate adaptation (Bulkeley, 2013). Applying a multi-level perspective enables an interpretation of adaptation implementation across the different system regimes and niches within a city (Geels & Schot, 2007; Geels, 2019). Framing adaptation governance as the "full range of means for deciding, managing, implementing and monitoring policies and measures" (IPCC, 2014a), is beneficial as this effectively incorporates CCA planning, implementation and monitoring phases. This aligns with the aim and objectives of this research, in which successful action is analysed in terms of what a system "does" to enable it to adapt, alongside what that system "has" to do so (WRI, 2009).

Successful CCA is generally dependent on whether the measure or decision meets pre-defined implementation objectives, and how it interacts and influences the ability of other measures to meet their pre-defined goals (Adger *et al*., 2005). This includes considerations of the *effectiveness*, *equity*, *legitimacy*, and *efficiency* of the adaptation measure. These terms are used herein to evaluate successful adaptation interventions. These metrics critically depend on the abilities, or capacities, of adaptation practitioners, decision-makers, and SET systems themselves, to adapt to the climate change impacts that arise in space and time (Adger *et al*., 2005).

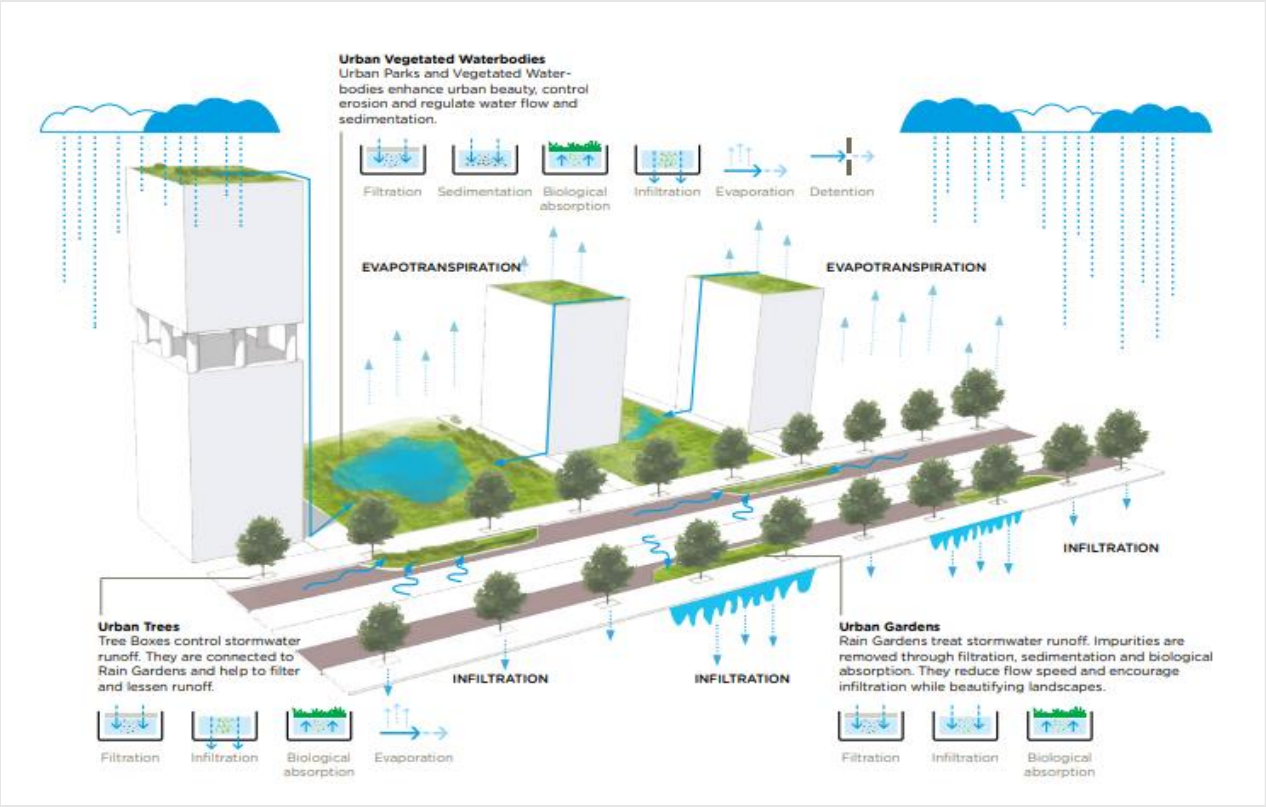


Figure 2: A representation of the variety of incremental and transformative adaptation measures for pluvial and urban heat hazards commonly utilised as best practices in European cities (Ramboll, 2016)

2.3 Developing an Analytical Framework for Urban Adaptive Capacities

The following section outlines the theoretical basis and development of the analytical framework.

2.3.1 Characterising Urban Adaptive Capacity

Adaptive capacity has previously been utilized as an analytical tool across diverse disciplines, ranging from ecological perspectives in the urban and natural environment (Engle, 2011; Smit & Wandel, 2006), to political and institutional capacities in relation to adaptation (Gupta *et al*., 2010; Biesbroek *et al*., 2017). Critically, adaptive capacity can be seen to connect these domains in response to changes in the SET system, thus forming a valuable frame for assessing how adaptation implementation processes emerge and evolve through time and space.

The analytical framework utilized in this study aims to build upon critical components of planning and governance, such as legitimacy, accountability, effectiveness, decentralization, innovation and learning (Gupta *et al*., 2010; Adger *et al*., 2005). Components of the implementation processes will be integrated including leadership, management, monitoring and evaluation, and

stakeholder involvement (Eisenack *et al*., 2014; Adger *et al*., 2005; Berkes, 2009), and will be further elaborated below.

2.3.2 Adaptive Capacities for Successful Climate Change Adaptation

An extensive review of academic and grey literature was undertaken to develop an analytical framework for this research. Scientific literature relating to climate adaptation, adaptation governance, blue-green infrastructure, urban transitions and adaptation mainstreaming was targeted. Desk research using Google Scholar and Scopus, alongside policy literature and reports, resulted in the synthesis of scientific insights into a broad array of capacities related to CCA in cities (Table 1). These formed the basis of the analytical framework for urban adaptive capacities.

These capacities aim to capture the conditions and processes that occur within CCA implementation. They are therefore not definitive nor comprehensive. Their related factors, and indicators for their presence and influence, were refined in relation to interviewee and expert insights, and the emergence of new scientific insights during the research process. Iterative refinement allows for improved representation of critical adaptive capacity factors, and their relevance in the contexts and relationships that underpin successful CCA.

Table 1: An overview of the academic background relating to adaptive capacities and their relevance for adaptation implementation

Capacity	Context	Sources
Legal	Equity of strategies and measures; presence of constitutional laws; access and understanding of laws	Folke *et al*., 2005; Biermann, 2007; van Rijswick *et al*., 2014
Institutional	Polycentric governance, Multi-actor partnerships, organisational structure, responsible leadership, collaborative institutions, operational flexibility, trust and transparency in decision-making	Koop *et al*., 2017; Biesbroek *et al*., 2014
Resource	Local knowledge availability, economic resource availability, diversity of actors, diversity of resources, connection to expertise, quality of information	Biesbroek *et al*., 2014; Creutzig *et al*., 2019; Bulkeley, 2013; Koop *et al*., 2017; Ostrom, 2005
Learning	Triple loop learning, institutional memory, flexibility to learn; access to information and resources, monitoring and evaluation processes	Pahl-Wostl, 2009; Folke *et al*., 2005; Biesbroek *et al*., 2014; Hegger *et* al., 2017; Mees *et al*., 2017; Cinner *et al*., 2018
Social	Co-creation opportunities; fair and equitable participation; diversity of participants; accountability and transparency, opportunities for participation	Pahl-Wostl, 2009; Mees *et al*., 2017; Browder *et al*., 2019 ; Mortreuz & Barnett, 2017
Transformative	Appreciation of co-benefits, adaptive planning processes, targeting of synergies, fostering of innovation and experimentation	Abson *et al*., 2017; Engle, 2011; Webb *et al*., 2018

2.4 Operationalising the Urban Adaptive Capacity Analytical Framework

Figure 3 depicts the six urban adaptive capacities, which will be further elaborated below. The process of analytical framework creation will be outlined and integrated with a detailed operationalisation of each capacity.

A semi-qualitative analytical framework was created to assess urban adaptive capacities. Capacities were refined to incorporate key "conditions" for success, which were further operationalised into adaptive capacity "factors" (ACF's) to encompass the manifestation of capacity conditions in practice. Qualitative assessment of the factors enabling or constraining adaptation enables a broader analysis of the nature of adaptive capacities within differing contexts. This methodology is appropriate for understanding the intent of the system, and its actors, within adaptation processes (Verschuren & Doorewaard, 2010).

The nature of the framework was influenced by existing methodologies for analysing complex socio-environmental phenomena. The City Blueprint framework (CBF) developed by Koop and van Leeuwen (2015), as well as the complementary Governance Capacity Framework (GCF) (Koop *et al*., 2017) specifically targets water management in urban areas. It integrates practical considerations on water management alongside critical drivers, pressures and governance considerations, providing the holistic oversight required for assessing urban adaptive capacities. Key features from the CBF & GCF utilized include assessing climate adaptation practices, identifying action plans and evaluating public participation practices (Koop & van Leeuwen, 2015; Koop *et al*., 2017). This semi-qualitative approach proves valuable for assessing cities where data sources may be fragmented, or where respondents may lack quantitative data.

Gupta *et al.'s* (2010) research relating to institutional adaptive capacity, namely the Adaptive Capacity wheel, was also used as a guiding framework for the operationalization of adaptive capacities. The authors identified six critical capacity dimensions, namely: variety, learning, room for autonomous change, leadership, resources, and fair governance. Grotholt (2017) also found these capacities as appropriate for the city-scale nature of climate adaptation, incorporating the legal, institutional, resource, learning and social capacities of stakeholders and decision-makers that support the development and evolution of adaptation measures. Lastly, the analytical framework was formulated to capture a multi-level perspective (Geels & Schot, 2007), which enables understanding of interrelations between scales and actors and facilitates the evaluation of important factor relationships in successful CCA.

Figure 3:Analytical framework for adaptive capacity, inspired by Gupta et al., (2010), Koop & van Leeuwen, (2015), and Grotholt (2017). The nested framework places the sub-capacities as key features of Urban Adaptive Capacity, with the outer circle framing the sub-conditions for success.

2.4.1 Legal Capacity

Governance and policy implementation are explicitly aligned with the legal system and its associated values of legality and compliance, typically involving formal and informal modes of self-regulation by stakeholders (Biermann *et al*., 2010). The modes of regulation require specific instruments that facilitate legal management and control of adaptation, and specific considerations to the resulting socio-environmental impacts of policy implementation (Mees *et al*., 2019). Two conditions were identified, *Presence of Adaptation Policy Instruments* and *Socio-Environmental Equity*, which have subsequently been operationalised into five capacity factors, elaborated further in Table 2:

Presence of Adaptation Policy Instruments

1. Adaptation Policy Instruments
2. Policy Cohesion
3. Statutory Compliance

Socio-Environmental Equity

1. Awareness of Socio-Environmental Equity
2. Redistribution of Socio-Environmental Equity

Table 2: Operationalisation of the Legal Sub-Capacity

Factor	Indicator(s)	Clarification
Adaptation Policy Instruments	Existence of Multi-Level Policies Existence of Legislative Standards Extent of Legal Certainty on CCA policy instruments	• Policy instruments and regulations that operate across multiple levels of governance account for the complex processes, and scales, of adaptation planning and implementation (Mees *et al*., 2014). Policy instruments are particularly relevant at the implementation scale, where they can motivate will to act, generate diverse support and support broader capacity development such as funding or expertise acquisition (Hoppe, van den Berg & Coenen, 2014; Bulkeley & Betsill, 2003). • The presence and clarity of universal standards helps to account for consensus and synergy amongst stakeholders in relation to implementation of adaptation interventions (Gupta *et al*., 2010). • Legal clarity can be paired with the presence and implementation of technical and legislative standards that work to guarantee effective climate adaptation.
Policy Cohesion	Level of Policy Synergy	• Climate change governance is complex and usually fragmented. Common barriers to adaptation are conflicting policy agendas and regulations and differing legislative power across governance scales (Moser & Ekstrom, 2010). • Policies that work synergistically ensure common standards across disciplines and institutions. This concept stems from resilience thinking, in which climate adaptation is supported by overlapping political and legal

	Level of Alignment with Multi-Sectoral Standards	measures, which mitigate implementation failure if one or more policies are undermined or circumvented (Wardekker, 2016). • Standardised legislation and regulation ensure that stakeholders and institutions have clear guidelines for adaptation implementation and can work to minimum standards and targets (Sussman *et al*., 2010).
Statutory Compliance	Level of Respect & Compliance to Policy Regulations and Instruments among stakeholders	• Climate adaptation involves a variety of stakeholders. Policy legislation and regulation is inherently political, often resulting in institutional policy being undermined, circumvented or even ignored in the implementation phase (van Rijswick *et al*., 2014). Adaptation, particularly when related to change in infrastructural or social urban environment, should avoid negative "lock-in" of maladaptive technologies, institutional structures or socio-economic practices. • The capacity of actors, irrespective of hierarchical level, to demand and enforce compliance to legislation and policy is critical for successful adaptation (van Rijswick *et al*., 2014).
Awareness of Socio-Environmental Equity	Level of awareness of socio-environmental inequality within practitioners and decision-makers Existence of Policy instruments for integration of CCA & socio-environmental equity issues	• Vulnerabilities can be evaluated in terms of climate change impacts, both experienced and expected, and the relative effects of climate change adaptation interventions on those impacts, for all social groups (Adger *et al*., 2005). • Poor adaptation decision-making and implementation can bring unforeseen implications for specific groups, whilst differing interpretations of intervention outcomes may result in differing perceptions of vulnerability reduction amongst stakeholder groups (Chu, Aguelovski & Roverts, 2017). • Practitioners should therefore account for the socio-environmental vulnerabilities that inevitably result from adaptation, and incorporate these into planning and implementation practices accordingly, both during implementation and longer-term monitoring phases (Mees et al., 2014).
Redistribution of Socio-Environmental Equity	Existence of instruments and mechanisms for socio-environmental equity redistribution	• Vulnerability should be modelled and assessed for multiple climate hazards at the city-scale in order to integrate targets for vulnerability reduction into policymaking and practice. The creation of standardised and compulsory processes for this assessment can work to improve awareness of inequality of socio-environmental impacts (Pelling & High, 2005). • The distribution and communication of such information to a diverse range of stakeholders beyond institutional experts is important for fostering accountability and transparency (Adger, Arnell and Tompkins, 2005).

2.4.2 Institutional Capacity

Societal institutions are primary agents for the management of complex systems (Gupta *et al.*, 2016). Young (2002, p5.) defines institutions as *"constellations of rules, decision-making procedures, and programs that define social practices, assign roles to the participants in such practices, and govern the interactions among the occupants of those roles".* The organisation, flexibility and procedural characteristics of these institutions can be influential, alongside the level of embeddedness of adaptation, for CCA effectiveness (Koop *et al*., 2017). Institutional capacity can be categorized to contain three conditions, *Organisational Structure, Responsibility & Accountability* and *Embeddedness of Adaptation Discourse*, further operationalised into nine capacity factors, elaborated further in Table 3:

Organisational Structure

1. Leadership for Climate Adaptation
2. Organisation of Adaptation Planning and Implementation
3. Vertical and Horizontal Coordination of Implementation
4. Flexibility and Innovation

Responsibility & Accountability

1. Institutional Responsibility
2. Institutional Transparency
3. Institutional Accountability

Embeddedness of Adaptation Discourse

1. Embeddedness of Adaptation Discourse
2. Ambition and Adaptation Goal Setting

Table 3: Operationalisation of the Institutional Sub-Capacity

Factor	Indicator(s)	Clarification
Institutional Leadership for Adaptation	Existence of "Adaptation Champions" Existence of methods of leadership coordination across sectors	• Organisations must invest in the principles of CCA, often with the help of "leaders" or "champions" (Carmin *et al*., 2013). "Leaders" or "champions" are important in driving action, mobilising resources and prioritising climate adaptation within the policy domain (Koop *et al*., 2017). • The rhetoric and preferences of city leaders for climate change adaptation can also be critical for navigating institutional inertia and conflicting agendas amongst departments (Kern & Bulkeley, 2009).
Organisation of Adaptation Implementation	Level of coordination and integration on CCA within institutions	• The planning and implementation of CCA requires an integrated approach. Many different institutions, actors and stakeholders are typically involved in adaptation projects, causing inadequate distribution of responsibility, funding, strategic planning and equity (Leck & Roberts, 2015).

	Existence of tools and methods for coordination of CCA implementation	• Cross-sectoral management of adaptation challenges would likely bring greater consistency and coherence to adaptation, as well as better mobilising relevant resources and expertise (Biesbroek *et al*., 2009). • Tools and measures to connect organisational actors via synergy identification, coalition generation, or working groups can prove effective in improving efficiency of CCA coordination (Bellinson & Chu, 2018).
Vertical Coordination of CCA	Level of vertical coordination between different hierarchies of government	• Vertical coordination refers to the interactions taking place between differing governmental scales, which captures the operational institutional interactions that occur in relation to implementation of adaptation interventions (Bauer, Feichtinger & Steurer, 2012). • The alignment of national adaptation strategies with municipal or local strategies is important to drive effective and coherent action (Bauer, Feichtinger & Steurer, 2012). • Investigated in terms of the inclusivity of decision-making, the fragmentation of institutional scales, and the presence of representative coalitions and networks from different sector or scales.
Horizontal Coordination of CCA	Level of coordination across and within institutional sectors Existence of tools and methods for coordination of multi-sectoral CCA implementation	• Horizontal coordination refers to interactions between municipal or local authorities, and external stakeholders. This form of cooperation focuses on practical considerations relating to adaptation, such as local resource or knowledge deficits, potential conflicts and localised short- and long-term impacts of adaptation (Carmin *et al*., 2013). • Can be effective for fostering improved stakeholder involvement within climate adaptation, whilst also acting as a tool for mobilising resources and knowledge from across governance scales (Bulkeley, 2010).
Flexibility and Innovation	Existence of internal project teams and committees dedicated to multi-disciplinary climate adaptation planning and implementation Existence of dedicated climate adaptation partnerships or networks at the municipal scale	• The linear and rigid organisational and decision-making structure of municipal institutions is not compatible with the challenges posed by climate change (Moser & Boykoff, 2013). • Innovation of institutional operations can help to improve coordination and cooperation between relevant municipal actors and provide greater flexibility and creativity when problem-solving for adaptation implementation (Bauer, Feichtinger & Steurer, 2012). • Climate change demands a more rapid and substantial change in institutional approach, thus the degree of flexibility, and tools for innovation and evolution, are important adaptive capacities (Sussman *et al*., 2010).
Embeddedness of Adaptation Discourse	Existence of short- and long-term strategic planning for CCA implementation	• The framing of climate change and climate adaptation, in terms of the discourse and conceptualisation of problems and solutions, can shape how climate adaptation is considered and integrated within institutions and policies (van Rijswick *et al.,* 2014). • The embeddedness of climate adaptation, and specific adaptation action plans, within discourse or public policy is a proxy of the relative consideration and importance allocated to adaptation implementation. Action is generally dependent on legislation that initiates adaptation action either at the municipal or local scale (Dannevig *et al*., 2012). • This relates to the importance allocated to climate change adaptation, and to the relative urgency and prioritisation of action or implementation.
Institutional Responsibility	Existence of identifiable departments or	• Clear responsibilities and accountability can work to increase trust and improve collaboration in implementation projects (Adger, Arnell & Tompkins, 2005).

	individuals responsible for CCA implementation	• Allocation of responsibility and accountability is critical both during and after implementation of adaptation options to ensure longer-term effectiveness and equity (Anguelovski & Carmin, 2011). • Specific to implementation, responsibilities should also be clearly defined for the monitoring and evaluation phase of a project (Boven, Schillemans & Hart, 2008).
Institutional Transparency	Existence of readily available information on decision-making within planning & implementation	• The implementation phase can typically be expert dominated. Transparency in decision-making and responsibility allocation can be important in guiding stakeholder satisfaction and participation (Biermann *et al*., 2012). • Information availability can relate to resource management, funding, stakeholder interests and legal or regulatory consideration. • The broader transparency of decision making, and processes is important, but also the tools to ensure these that are important for adaptation implementation (Koop *et al.,* 2017).
Institutional Accountability	Existence of tools and methods for evaluation of accountability ex- and post-ante of CCA implementation	• Unlike the planning phase, implementation requires careful management during and after the initial action processes of intervention. • Accountability enables stakeholders to ensure governmental or institutional representatives are publicly scrutinized in relation to the performance of climate adaptation processes (Tanner *et al*., 2009).
Ambition and Goal Setting	Existence of clearly defined and realistic goals and targets for CCA implementation	• Uncertainty and complexity of climate change impacts challenges creation of formalised ambitions and goals for climate adaptation (Keskitalo, 2010). • Ambitions can be assessed in terms of their presence within specified goals, which can be further evaluated in terms of being realistic and appropriate. For more transformative adaptation, ambitions and goals may be unique or innovate beyond technical or legislative standards (Koop *et al*., 2017). • Implementation requires coherent goal setting, with sufficient intermediate flexibility and options to manage complexity and uncertainty (Haasnoot *et al*., 2015).

2.4.3 Resource Capacity

The availability, appropriateness, and mobilisation of resources is cited as a key barrier to CCA planning and implementation (Adger *et al*., 2005). The implementation phase, whilst not extensively covered within literature on adaptive capacity and urban planning, is heavily reliant on a variety of resources. There is a breadth of resource types including social, institutional, human, natural, economic & political (Pelling & High, 2005; Gupta *et al*., 2010). Social, political and institutional capacities are addressed in as individual capacities in this research, therefore the focus will target resources for adaptation implementation. These three adaptive capacity conditions; *Economic Resources, Human Resources* and *Technical Resources*, have been operationalised as eight capacity factors, elaborated further in Table 4:

Economic Resources

1. Finance Availability
2. Willingness to Pay
3. Financial Continuity

Human Resources

1. Human Manpower available for adaptation planning & implementation
2. Adaptation Expertise
3. Organisational Resource Flexibility

Technical Resources

1. Diversity of Solutions
2. Integration of Adaptive Planning Principles

Table 4: Operationalisation of the Resource Sub-Capacity

Factor	Indicator(s)	Clarification
Finance Availability	Level of budget availability for implementation of CCA interventions	• Public funding primarily facilitates adaptation, which is increasingly stretched by competing agendas (Moser & Ekstrom, 2010). • The availability of sufficient financial resources for short-term interventions, such as those cited as no-regret measures, is critical for tackling increasingly urgent climate hazards such as extreme storms or heatwaves. (Carmin *et al*., 2013 • Longer-term hazards require more significant structural interventions. Longevity and security of financial resources should also be prioritized by stakeholders, especially relating to processes of monitoring and evaluation (Eisenack *et al.,* 2014).
Willingness to Pay	Extent of multi-level stakeholder willingness to pay for adaptation measures Evidence of identification of co-benefits to catalyse willingness to pay	• Mobilisation of financial resources can be incentivized by perceived benefits of intervention. Primarily, these are communicated in terms of risk reduction or financial performance, but also socio-economic and environmental impacts (C40, 2016) • Broader socio-environmental benefits are also powerful motivating factors for driving willingness to pay, especially as these benefits may address existing socio-economic and environmental issues facing urban areas (Hallegatte et al., 2007; C40, 2016).

Financial Continuity	Extent of financial budget continuity for long-term or dynamic adaptation interventions Existence of tools and mechanisms for the creation of internal and external funding resources	• Continuity of financial resources to account for dynamic change to SET systems in the future, or facilitate learning and improved planning and development of adaptation is important. • The acquisition of financial resources may exist internally, via policies that mandate financial budgeting for long-term adaptation planning, or externally via the creation of public-private partnerships or the engagement of private investment into adaptation projects (Bauer, Feichtinger & Steurer, 2012).
Human Manpower	The number of stakeholders actively involved on CCA implementation The number of actors actively involved in M&E for CCA interventions	• The quantity of actors involved in climate adaptation is important. Implementation requires sufficient time and impetus from a variety of dedicated practitioners in order to effectively connect planning to implementation (Koop et al*.,* 2017) • This may also entail the recruitment or partnerships with experts in the fields of urban drainage, urban greening or green roofing.
Adaptation Expertise	Level of skill and knowledge of involved stakeholders Extent of strategic utilisation of expertise within planning and implementation phases	• Knowledge and expertise in relation to CCA implementation is highly important. This is required to drive efficiency and effectiveness in project delivery (Carmin *et al*., 2013) • Expertise also works to foster organisational embeddedness of CCA and greater legitimacy and trust from the perspective of external stakeholders (Adger *et al*., 2005). • The inclusion of a broad variety of experts can result in improved validity of knowledge and greater perceptions of trust and legitimacy in knowledge and adaptation strategies (Nowotny, 2003; Hegger *et al*., 2012).
Organisational Resource Flexibility	The level of adaptiveness and flexibility of resources within stakeholder organisations	• CCA is a relatively new concept within highly siloed municipal organisations and practitioners. Therefore, it is critical that practitioners are sufficiently adaptive and flexible to the requirements that accompany integrating CCA into developments or delivering specific CCA interventions (Carmin *et al*., 2013). • This is relevant for more transformative interventions, which may require new or modified approaches to planning and implementation (Abson *et al*., 2017)
Diversity of Solutions	Extent of technical and social scientific knowledge on CCA implementation Extent of generation and communication of a variety of potential solutions	• The complexity of climate change impacts typically renders single adaptation solutions void. The development of a variety of potential technologies and solutions towards climate impacts has several benefits (de Bruin *et al*., 2009). • A focus on singular solutions can lead to lock-in or maladaptation in the future, whilst the communication of multiple approaches can facilitate improved debate and consensus-building amongst stakeholders. • Development of several potential solutions also guarantees assessment of solutions which can help to identify synergies and trade-offs in relation to the impacts and benefits of implementation (de Bruin *et al*., 2009).
Integrated Adaptive Planning	Evidence of inclusion of future scenario and risk assessment in CCA planning and implementation	• Implementation should incorporate principles of robustness and resilience into the development and maintenance plans. • Haasnoot *et al*. (2015) propose a dynamic adaptive pathway approach, which helps planners and stakeholders to identify synergies and potential lock-ins. • This process demands the identification of a variety of pathways and viable solutions within the implementation phase, with a focus on "no-regret" options (Haasnoot *et al.,* 2015).

2.4.4 Social Capacity

Climate adaptation literature emphasises the importance of stakeholder involvement across governance scales. Social capacity refers to the processes that emerge from social interactions between urban actors in CCA planning and implementation (Pelling & High, 2005). Factors relating to social capacity can relate to formalised and informalised systems of stakeholder cooperation, the dynamics of stakeholder inclusion, and the socio-environmental benefits that emerge from adaptation implementation. Three conditions were identified; *Network Relatedness, Stakeholder Engagement* and *Community Engagement*, from which five capacity factors have been operationalised, elaborated further in Table 5:

Network Relatedness

1. Active Network Participation
2. Integration of Network Knowledge and Innovation in Implementation

Stakeholder Engagement

1. Stakeholder Participation in Decision-Making

Community Engagement

1. Cooperation with the Community
2. Community Initiatives

Table 5: Operationalisation of the Social Sub-Capacity

Factor	Indicator(s)	**Reasoning**
Active Network Participation	Extent to which municipality actively participates in CCA networks Existence of dedicated municipal actor & tools to connect networks to local adaptation implementation	• Participation may be in the form of knowledge and best practice contribution, or utilisation of information from other network members (C40, 2019) • Municipalities that can utilise best practices may be better equipped to implement novel or successful adaptation interventions.
Integration of Network Knowledge & Innovation in Implementation	Extent to which network knowledge and innovation is formally integrated into implementation of CCA	• Best practices and knowledge sharing are valuable for cities to develop and adapt in similar ways in relation to climate hazards. • Implementation of such knowledge is not guaranteed however, with barriers to action likely relating to the local socio-environmental context, differing political agendas or differing resource availability (Berrang-Ford *et al*., 2011). • Despite this, networks can be useful tools for refining implementation methodologies via formalised comparisons of successful (inter)national projects, and the utilisation of a broader diversity of expert stakeholders (Bulkeley, 2013)
Stakeholder Participation in Decision-Making	Existence of tools & measures to catalyse stakeholder awareness and engagement	• Participation can foster shared ownership of adaptation interventions, and smooth agreement on core decisions and processes (Sherman *et al*., 2014).

	Level of stakeholder involvement at implementation and monitoring phase Level of consensus amongst stakeholders on short- and long-term decision making	• Participation should be meaningful, as perceived by stakeholders and ensured by institutional actors, to develop stakeholder satisfaction with participation processes (Few *et al*., 2007). • Adequate inclusion of stakeholders has been correlated with timely information provision, regular participation in decision-making, and regular review and evaluation of participation methods (Carmin & Dodman, 2013). • Engagement helps to build support during the design and implementation phases of policies and projects and it facilitates involvement of stakeholders in decision-making and implementation (Dovers & Hezri, 2010). • Inequality within stakeholder participation can inhibit the value of public involvement within planning and implementation processes (Few *et al*., 2007).
Cooperation with the Community	Existence of communication tools to share information and resources on adaptation planning and implementation Existence of formal regulations and measures to promote community-led adaptation Existence of educational tools & measures to deeply engage and educate community citizens	• Citizens may require greater awareness and capacity building to facilitate their meaningful participation in decision-making, thus measures should exist to provide adequate information and drive deeper engagement with a diversity of community representatives. • This may require novel formulations of climate knowledge, effective communication of risk and uncertainty, and the transfer of relevant climate adaptation concepts to the local or community level (Pahl-Wostl, 2009). • Formalised processes and roles for public actors in adaptation processes are important for achieving legitimate and effective community involvement (Moser & Pike, 2015). • Communities' local experiences and knowledge can also prove valuable within planning and implementation processes (Chu, Anguelovski & Roberts, 2017). • The tools or measures may increasingly require customization to community diversity, given the nature of population aging, cultural diversification and spatial intensification (Meerow & Newell, 2019)
Community Initiatives	Existence of formal tools for supporting CCA-focused community initiatives Existence of measures and tools for supporting long-term implementation and monitoring practices in the community	• Community-led initiatives are increasingly driving localised adaptation intervention in their proximal surroundings (Dai *et al*., 2018) • These initiatives often mobilise novel resources and methodologies, whilst also proving valuable for increasing broader awareness and engagement with climate adaptation. • Initiatives may require expert advice, alternative financing methods and importantly also require careful consideration of longer-term monitoring and evaluation processes (Moser & Pike, 2015).

2.4.5 Learning Capacity

Learning relates to processes of experimentation and innovation, which can be directly related to the ability of systems to cope and adjust to change, thus influencing overall adaptive capacity (Gupta *et al*., 2010). Learning is influenced by several key variables, such as information relating to policy formulation, uncertainty, and knowledge sharing tools. Building upon knowledge sharing, social learning measures; those processes which initiate and guide community learning and knowledge co-creation, are significant for creating collective ownership and transparency (Tschakert & Dietrich, 2010). Pahl-Wostl (2009) argues for targeting double-loop learning, requiring reflection and evaluation within the planning cycle., and triple-loop learning that demands a transformation of the assumptions, structure and frameworks that direct implementation. Two conditions were identified for Learning Capacity; *Information Resources* and *Social Learning*, which have been operationalised into six capacity factors, elaborated further in Table 6:

Information Resources

1. Local Knowledge
2. Risks and Vulnerability Assessments
3. Adaptation Policy Assessments

Social Learning

1. Collaborative Learning
2. Monitoring and Evaluation Processes with Adaptation Intervention
3. Reporting and Application

Table 6: Operationalisation of the Learning Sub-Capacity

Factor	Indicator(s)	**Reasoning**
Local Knowledge	Existence of measures to identify spatial and temporal climate hazards and their socio-environmental impacts Level of utilisation of expert and local knowledge within CCA implementation	• Clarity regarding hazard and risk identification is essential for setting project targets. • Identifying these impacts via local knowledge and experience is important for translation into practical solutions. • Successful decision-making is usually grounded in a diverse base of information sources, integrating scientific and technical expertise from stakeholders, scientists and policymakers (Hegger *et al*., 2012).
Risk & Vulnerability Assessments	Existence of measures and tools for risk and vulnerability assessing Level of formal measures and procedures for the communication and utilisation of assessment results	• Risk and vulnerability reduction is a principle aim of adaptation and thus assessment also aids with the identification of opportunities to move beyond simple risk reduction towards greater adaptive capacity (C40, 2018). • Tools and measures that assist with these assessments should be available to private and public stakeholders, with the results readily communicated to citizens. Thus, risk and vulnerability assessment requires appropriate and effective tools for execution and subsequent communication and utilisation of results (van Aalst, Cannon & Burton, 2008).

Adaptation Policy Assessments	Extent of adaptation policy assessments for adaptation implementation Existence of formalised tools and processes to guide adaptation policy assessment Extent to which multi-stakeholder assessment processes occur within adaptation implementation	• The capabilities of underlying policies to stimulate action, maximise benefits and minimise costs of implementation, and to guide and manage sustainable adaptation interventions requires expert assessment. • Policy assessment would ideally be a multi-stakeholder process to guarantee aforementioned principles of transparency, legitimacy and equity, although increasingly assessing is externalised and fragmented (Fussel, 2007).
Collaborative Learning	Existence of measures to drive knowledge sharing on adaptation implementation Extent to which stakeholders co-produce knowledge and solutions regarding planning and implementation of CCA	• Co-creation of knowledge and decisions is cited as a critical component of stakeholder cooperation and learning (Hegger *et al*., 2012). • The integration of a variety of expert and non-expert knowledge helps to provide multidisciplinary insight and allows the emergence of optimum solutions. Such a style of learning can embed adaptation within the core principles of stakeholders and improve general understanding of the challenges and opportunities associated with adaptation (Comin *et al*., 2013).
Monitoring & Evaluation	Existence of formal monitoring & evaluation frameworks and procedures using defined targets for CCA implementation Extent of monitoring & evaluation procedures during and after implementation	• Processes of monitoring and evaluation have multiple benefits. They provide improved understanding for all stakeholders of the processes and phenomena occurring during adaptation, which allows for iterative, or more systematic, improvement of adaptation planning and implementation. • Monitoring and evaluation also enable the assessment of efficiency and effectiveness, in relation to predefined targets and ambitions that align with the local context (Dinshaw *et al*., 2014). • The monitoring component also facilitates a more flexible and ongoing approach to planning and implementation that is more sensitive to emerging challenges and opportunities. This sensitivity may enable improved project flexibility but can also work to avoid maladaptation or locked-in interventions (Lamhauge, Lonzi & Agrawala, 2012).
Reporting & Application	Extent to which lessons or evaluative information are reported for current or future use Existence of measures and tools to guide changes in practices and behaviours amongst adaptation stakeholders in relation to CCA implementation	• Learning processes may not necessarily manifest themselves in change, however. There are many barriers to changing behaviours and practices, such as psychological, resource or physical constraints. To understand the role of learning in improving adaptation processes, reporting of process performance is important (Dinshaw *et al*., 2014). • Furthermore, tools that facilitate the continuous application of this information are required to ensure that optimum results can be attained in the implementation and monitoring phases of interventions, such as the inclusion of specific learning cycles with a MER process (Dinshaw *et al.,* 2014).

2.4.6 Transformative Capacity

Transformational adaptation targets broader systematic change to urban systems (Kates *et al*., 2012) that helps prepare cities for risks that exceed the capabilities of more incremental adaptation, either in terms of urgency or scale (Craig, 2010). By targeting specific capacities that relate to the ability of urban areas to adapt more transformatively, it is hypothesised that urban systems may be better prepared for potential future climate impacts (Kates *et al*., 2012). Transformative capacity typically relates to the ability to combine innovative approaches synergistically, stimulate new modes of behaviour and thinking across societal sectors, and the mobilisation of new modes of adaptation planning and implementation (Kates *et al*., 2012; Pelling & Schipper, 2009). Two conditions were identified for Transformative Capacity; *Synergistic Approaches* and *Innovation and Experimentation*, which were operationalised via three capacity factors, further elaborated in Table 7:

Synergistic Approaches

1. Multi-Benefit Interventions
2. Synergy Optimization

Innovation and Experimentation

1. Innovation and Experimentation

Table 7: Operationalisation of the Transformative Sub-Capacity

Factor	Indicator(s)	Reasoning
Multi-Benefit Intervention	Existence of tools and measures for calculating multi-benefit outcomes and synergies	• Many adaptation measures to water-related hazards bring co-benefits (CIRIA, 2015). These can be powerful motivating factors for mainstreaming solutions (Bulkeley, 2013; CIRIA, 2015) • Identification and communication of adaptation co-benefits could be valuable for initiating broader sustainable development in cities (C40, 2018).
Synergy Optimization	Existence of regulations and policy instruments that synergize adaptation across multiple sectors Extent of research into mechanisms and opportunities for synergies in transformative adaptation	• Silo thinking, linear hierarchies and community exclusion commonly constrain adaptation success (Gupta *et al*., 2010; Eisenack *et al*., 2014). • Tools and measures that look for synergies across sectors and actors can be used to drive cohesive systematic change in cities. (Kates *et al*., 2012). • Synergy is required in all elements of the implementation process, from governance to technical delivery, requiring monitoring and research into how valuable partnerships can be maintained and optimized.
Innovation & Experimentation	Existence of incentives for innovation and experimentation in adaptation implementation	• Experimentation provides a means of translating potential future adaptation measures and pathways into tangible

	Existence of innovative instruments and methods for mobilising resources and evaluating transformative interventions	short-term actions and practices (Karvonen & van Heur, 2014). • Cities can learn, innovate and experience new modes of practice or governance, via experimentation, accelerating best practice and mainstreaming adaptation within resources, agendas and institutional sectors (Bulkeley & Castan Broto, 2013; Marvin *et al*., 2018). • Innovation and experimentation should not be assumed to naturally result in transformative change. Rather, the iterative and flexible nature of upscaling interventions closely aligns with principles of adaptive planning and incremental systemic change (Evans *et al*., 2016; von Wirth *et al*., 2019). • New modes of learning and development may be required in the practical implementation phases of interventions, especially as the scales of intervention change away from typical incremental approaches (Wise *et al*., 2014).
	Existence of innovative instruments for learning and knowledge sharing relating to transformative interventions	

2.5 Conclusions

This research explores successful water-related CCA in frontrunner cities. Whilst these cities are likely to still exhibit diverse adaptive capacity characteristics, it is useful to propose an ideal or optimal scenario to guide assumptions on the relations between success and specific adaptive capacity factors. Optimal success is hypothesised to be reliant on the presence and mobilisation of these adaptive capacities, and careful appreciation of their interconnections and actionability.

Section 3 will introduce the methodologies used to apply the Urban Adaptive Capacity analytical framework, elaborate upon data collection methods and justify case-study selection.

3. Research Methodology

3.1 Introduction

This chapter will outline the research methodology. Section 3.1 details the broad research approach, Section 3.2 outlines the selection of case cities, and Sections 3.3 & 3.4 the data collection and analysis approaches.

This investigation applies a semi-qualitative methodology via a cross-national comparative case study approach. Comparative analysis allows the elucidation of themes across different cases and offers a means of validating emergent patterns and conclusions, given that qualitative comparative analysis is a common approach for connecting broader variables beyond a case-specific context (Rihoux & Ragin, 2008). Assessing the actionability and interconnectivity of adaptive capacities further enables the adoption of best practices within urban climate change adaptation.

3.2 Case Study Selection

Within existing academic and grey literature, multiple European cities have emerged as prominent adopters of adaptation to various water-related climate hazards (C40, 2019). These cities have established adaptation strategies and planning documents and have an existing body of project examples, such as green roofing, SuDS or split-sewage systems, from which to gain insights. Subsequent refinement of city selection applied the “minimum number of differences” approach, which enables easier comparison between contextual settings and CCA methods. The criteria applied within this approach included the presence of a well-established adaptation plan, prominent status at the national scale, significant population, and similar climate hazards. Cities with membership of C40 were also prioritised. Furthermore, collaboration with Sweco enabled access to a professional network in several of the European cities, which also informed the refinement of case selection. Communication with Sweco representatives was also used to validate assumptions about specific cities to ensure that case studies aligned with the criteria for selection. The five case cities were finally selected on the basis of these criteria.

Berlin, Copenhagen, London, Rotterdam, Warsaw were compared through the analysis of adaptation implementation projects, and subsequent assessment of the perceived dynamics and critical factors that emerged during CCA implementation.

3.3 Data Collection

The Urban Adaptive Capacity analytical framework (Section 2.6) provided the basis for a semi-structured interview guide. This was used to drive interview discussion, whilst specific interview questions were tailored for each individual in order to optimize insights and relevance. Strategic stakeholder selection, usually governmental stakeholders, expert advisors and civil society actors, was complemented by stakeholder identification via a snowball methodology. Academic and professional expertise was utilized to gain an overview of the contemporary conditions and dynamics within the field of urban climate adaptation. Appendix 1 outlines the respondents interviewed in this research, whilst the interview guide and a selection of interview questions are included in Appendix 2. Appendix 3 outlines the respective policy documents reviewed for each city, although this is not a comprehensive list of all documents reviewed.

Table 8: Chronological research process, from case selection to reporting, towards final success factor identification and recommendation generation

Case Cities	Berlin	Copenhagen	London	Rotterdam	Warsaw
Case Study Selection	Compile C40 target cities				
	Identify city-specific target projects via literature review and expert insight				
Data Collection	Desktop literature review of target case studies and cities				
	Desktop analysis of existing adaptive capacities				
	Semi-structured interviews with relevant stakeholders				
Adaptation Project Analysis	Assess adaptive capacities in CCA implementation				
	Assessment of Interconnections & Actionability of ACF's				
	Evaluate relationality between adaptive capacities & success of CCA implementation				
Overarching Analysis & Reporting	Case Study Reporting	Case Study Reporting	Case Study Reporting	Case Study Reporting	Case Study Reporting
	Comparative Analysis: Synthesising city-specific critical ACF's for adaptation success				
	Interconnection & Actionability Assessments				
	Critical Adaptive Capacity Factor Identification and Recommendation Generation				

Table 8 outlines the stepwise research process utilized, although the linear nature of the table does not reflect the iterative approach to interview formulation and stakeholder investigation. This process helped to feed back into the preceding research steps, via snowball sampling of respondents and the provision of additional municipal documents and reports. Information and case-study specific data utilized in this research primarily took the form of:

- Academic and institutional literature relating to the adaptation planning and implementation systems of each case study city revealed the broader contextual conditions within the CCA field, and the complex social-technical-ecological systems themselves.

- The top-down perspective emerged from official policy documents and strategy plans from across governmental scales. These documents were derived from municipal databases, or via snowball sampling during the interview process.
- Bottom-up perspectives were provided through in-depth interviewing of stakeholders.

The triangulation of methods and data sources provided both case-specific and more generalizable insights. Whilst strategic city selection was aimed at existing frontrunners, there remains an element of contextual variability across case studies, therefore facilitating more transferable insight generation to cities in the design and planning phases of CCA. Internal validity is maintained via the comparative approach, focused on case-specific, in-depth analysis, which aims to reveal specific dynamics of adaptation processes within the complex city systems

3.4 Data Analysis Methods

Data analysis followed a stepwise approach, integrating transcript analysis to inform the Urban Adaptive Capacity analytical framework, accompanied by assessment of factor interconnections, actionability, and result validation, which is further outlined in Figure 4.

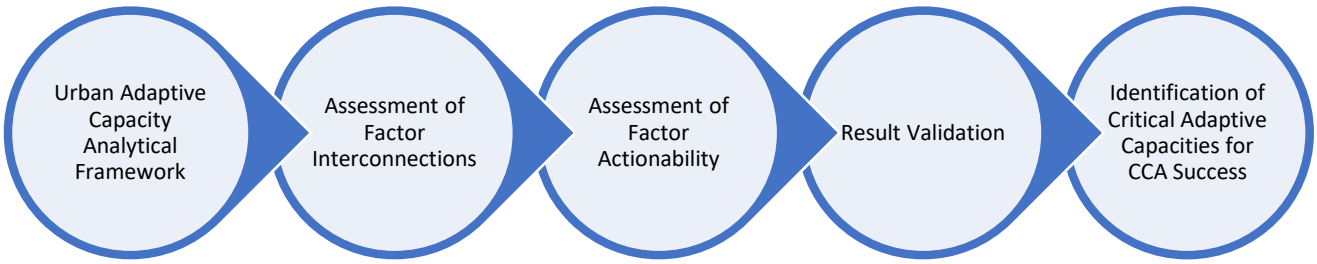


Figure 4: The stepwise methodology to analysis city-specific and inter-city adaptive capacities

Transcription of the 23 stakeholder interviews resulted in analysis using QSR NVivo. This software enables qualitative data analysis via the use of a descriptive coding system and thematic analysis. By creating coding sequences and themes, qualitative information within interview transcripts could be connected to the adaptive capacity indicators, providing justification of the performance of different factors using interviewee insights (Figure 5). The coding sequences utilised are outlined within Appendix 4.

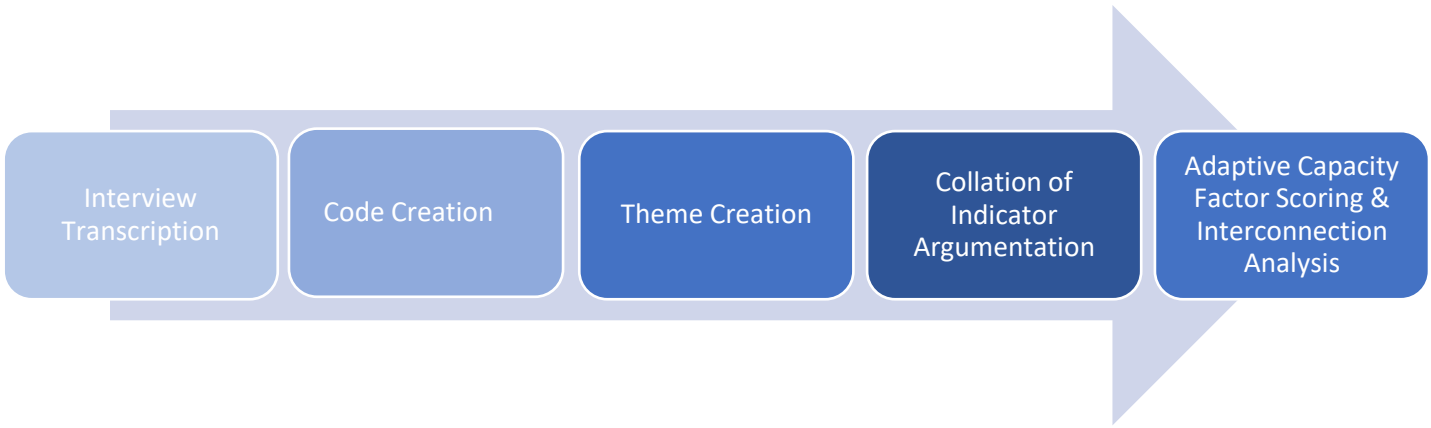


Figure 5: Stepwise analytical methodology combining interviews and transcript analysis

Adaptation policy analysis was undertaken using the analytical framework outlined in sections 2.3 and 2.4. This involved the application of indicator metrics to identify key elements of grey literature. This also aided in connecting respondents to key features of adaptation policies, such as implementation plans or budget allowances.

Indicators for the respective capacity factors provided a means of "measuring" the roles of specific system components in relation to CCA. The rubric for indicator scoring related to several variables, as outlined in Table 9**.** This Likert-style scoring is commonly utilised in qualitative research (Verschuren & Doorewaard, 2010), and aims to reveal the interactions between differing contextual conditions, adaptive capacity scores, and resultant adaptation implementation, thus identifying how different municipalities have integrated capacities towards "best practice". Generally, this research assumes positive or negative linearity between capacity scoring and the subsequent successfulness of an adaptation project.

Assessment Criterion	Very Weak (1)	Weak (2)	Moderate (3)	Strong (4)	Very Strong (5)
Development & Progress	Limited or non-existent efforts to address adaptation	Limited efforts in development	Efforts not fully developed but progress is evident & generally positive	Efforts established or in establishment	Efforts well established with positive influence on adaptation progress
Demonstrable Action	Limited or non-existent efforts to implement adaptation	Limited evidence of adaptation in specific sectors	Developing & emerging efforts to implement adaptation	Ongoing efforts to implement adaptation	Well-established and ongoing efforts to implement adaptation
Risk Management	Negative or negligible impact on climate hazard risk reduction	Tangible impact on risk and vulnerability	Moderate impact on climate hazard risk reduction	Significant impact on climate hazard risk reduction	Very significant impact on climate hazard risk reduction
Transformative Intervention	Limited or non-existent efforts towards transformative intervention	Limited & incremental efforts towards transformation	Developing & positive efforts towards transformative intervention	Ongoing efforts and evidence for transformative intervention	Established efforts and norms towards transformative intervention
Capacity Building	Very weak and constraining contribution to adaptive capacity	Weak & mostly constraining contribution to adaptive capacity	Moderate or developing contribution to adaptive capacity	Strong & mostly enabling contribution to adaptive capacity	Very strong and enabling contribution to adaptive capacity

Table 9: A Likert-style scoring to guide the analysis of urban adaptive capacity factors within case study cities

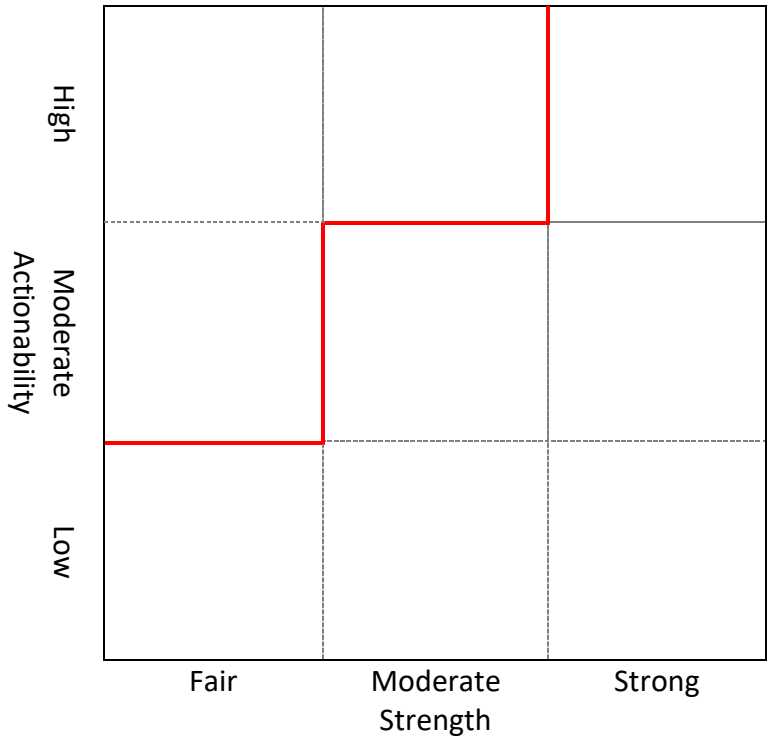
3.5 Interconnectivity & Actionability Assessment

It is important to look at how the adaptive capacities that underpin successful adaptation interrelate and can be actioned, amidst the challenging complexity of urban SET systems.

Thematic analysis allows assessment of factor interconnections. In reality, many adaptive capacity factors are closely inter-linked and an appreciation of the relationships between specific factors could be used to identify respective importance of specific ACF's in driving successful CCA. Interconnections were assessed in terms of implicit factor association with other factor themes, or explicit reference to interconnections or dependencies between factors by practitioners or within policy.

Actionability of adaptive capacity factors refers to the potential for targeting specific factors to increase levels of adaptive capacity in cities. Building upon the "Strength-Actionability" matrix developed by Mees (2010) and the Action Prioritisation Tool from C40 (C40, 2018), this research aims to offer a rapid means to identify and prioritise the adaptive capacity factors with highest potential to accelerate success in CCA.

The matrix displays the relative strength of each factor on the horizontal axis, weighted equally across all cities. The vertical axis displays "actionability", representing the extent to which CCA practitioners can accelerate action on this factor. This was measured using several indicators, with accompanying assumptions (Figure 6).



Indicators
Extent of measures available to enhance the ACF, evidenced from case studies: assuming that diversity oi measures improves potential for enhancement
Extent of opportunities or niches for improvement, evidenced by respondents: assuming that more platforms and niches identified by stakeholders translates to more opportunities for acceleration.
Extent of inclusion of local or municipal-level actors, evidenced by respondent and policy insights: assuming that greater local-level involvement enables enhance local-level implementation
Extent of affordability and feasibility of measures evidenced by respondent and city experiences: assuming that resource-intensive measures may be less likely to be implemented.

Figure 6: An overview of the Strength-Actionability-Matrix, with accompanying indicators for guiding assessment

By combining insights from analysis of city contexts, and estimating actionability potential from literature, it is easier to strategically assess opportunities for rapidly influencing adaptive capacity and CCA implementation in the cities. Further elaboration of the actionability assessment is available in Appendix 5.

3.6 Result Validation

Validation of the results generated via literature analysis and stakeholder interviews was required to confirm the importance of specific factors in practice. The verification by practitioners of initial findings allowed for three main outcomes. Firstly, theoretical assumptions and conclusions could be checked against implementation in reality, improving the evaluation of specific conditions within each city. Furthermore, it allowed for additional suggestions or modifications to specific success factors based on practical experience and reflection, which assisted the creation of recommendations. Lastly, validation offered a means of internal evaluation of the research methodology and its external value as a tool for assessing adaptive capacities.

3.7 Conclusions

The qualitative approach utilised will be further elaborated in terms of city-specific adaptive capacity performance within the five cities. Cities will be scored in terms of the presence and performance of adaptive capacity factors, with subsequent analysis of factor interconnections and actionability. This will result in identification of city-specific critical factors, accompanied by best practice examples.

4. City-Specific Analysis of Urban Adaptive Capacities

In this section, from chapter 5 to 9, the individual city case studies will be explored and the analysis of their ACF's elaborated upon and synthesised to identify critical ACF's for adaptation success in their specific contexts.

5. London

5.1 Introduction & Adaptation Context

The Greater London Area is coordinated by the Greater London Authority (GLA). The GLA operates at the regional scale to coordinate London-wide policies and strategy, whilst local boroughs act at community scales. The devolution of the GLA from national government provides London with greater autonomy in strategisation and decision-making. The London Plan is a statutory regulation of the GLA in guiding development and strategy within the city, and alongside the London Environment Strategy (LES) outlines the nature of climate action at regional and local scale (Rosenzweig *et al*., 2018). London's context is elaborated further in Box 1. The following section will address London's adaptive capacity performance and conclude with city-specific critical factors.

London	**Population: 8.9 million**	**Climate: Temperate Oceanic**	**Key Policy Documents: The London Plan (2016) and London Environmental Strategy (2018)**
Climate Hazard	**Current Risk**	**Future Risk: 2050**	**Adaptation Options**
Pluvial Flooding	High	High: Extreme rainfall will become more intense. Significant risk of sewer overflow and surface flooding.	SUDS measures for stormwater retention and conveyance. Expansion of Blue-Green Infrastructures. Rainwater Management Systems
Fluvial Flooding	Medium	High: Extensive development in Thames floodplain. Sea-level rise and storm surge frequency threaten effectiveness of Thames Barrier	Zoning Regulation for Critical Infrastructure Awareness Building and Preparedness
Drought	Medium	Medium: Up to 47% reduction in summer precipitation. Severity increase when combined with increased average & maximum air temperature Significant potential for groundwater level reduction	Expansion of green spaces Blue-Green Infrastructures Incorporate blue-green solutions into private and public planning Expansion of water-use efficiency measures
Heatwave + UHI Effect	High	Medium: 50% increase in occurrence of hot summers 3.1° C mean summer temperature increase and a 18% reduction in summer precipitation will worsen the UNI UHI effect likely to cause localized heat islands within the city. Biodiversity loss and air quality reduction	Blue-Green Infrastructures Expansion of urban green space across public areas and utilities Incorporate green solutions into private & public planning, including retrofitting.

Box 1: An overview of London's current context in terms of climate hazards and future risks (Greater London Authority, 2018)

5.2 Urban Adaptive Capacity Analysis

Table 10: An overview of London's Urban Adaptive Capacities, scored from 1-5 for each ACF with accompanying argumentation.

	Adaptive Capacity Factor	Score	Reasoning
Legal Capacity	Adaptation Policy Instruments	4	Connectivity between national and local standards for flood management measures via LLFA's/LWMP's, with LA's responsible for regulating CCA implementation. The Flood and Water Management Act and Planning and Compulsory Purchase Act are strongly influential national policy documents. *"We use our Local Plan Policy to require SuDS measures in developments; this is a more stringent policy than that in the London Plan and the requirements set out in national policy."*(Respondent 4, Environmental Policy Planner)
	Policy Cohesion	4	The London Plan and LES generally work synergistically with LA spatial development and climate risk management plans, although ambition for CCA acceleration is variable across city boroughs (Respondent 4). LES identifies synergies and alignment between CCA and multi-sectoral development and is perceived to motivate and facilitate stakeholder action.
	Statutory Compliance	3	The lack of regulatory power afforded to the GLA inhibits compliance towards CCA measures in the private sector, and although LA's have greater flexibility for enforcement of CCA implementation, this is highly dependent on a variety of competing agendas (Respondent 2, LCCP).
	Awareness of Socio-Environmental Equity	4	Policy tools strategically target equity redistribution but there is limited connectivity to implementation in practice, in the form of vulnerability assessing, socio-environmental policy objectives, and urban development plans (LES, 2018; LP, 2016).
	Redistribution of Socio-Environmental Equity	3	Specific redistribution mechanisms exist, such CCA projects specifically implemented in areas of high deprivation, progress lacks urgency (LES, 2018; Respondent 6). *"In terms of coming up with more ambitious plans, they (local authorities) are highly constrained."*(Respondent 1, Professor of Environmental Engineering)
Institutional Capacity	Institutional Leadership for Adaptation	5	Mayor of London places CCA high on agenda. LCCP provides an important guiding role for leaders across sectors in London, raising awareness and coordinating organisation of CCA through stakeholder networks (Respondent 2). From a bottom-up perspective, London has many motivated environment officers and social enterprises at the borough level, connecting leadership across the city.
	Organisation of Adaptation Implementation	4	Institutional fragmentation within the GLA has been significantly reduced in recent years with the growth of the Environment Team, alongside strategic cooperation with DEFRA and EA on larger-scale development projects.
	Vertical Coordination of CCA	3	Some incoherence between policies across scales, slowing local-level implementation of CCA interventions
	Horizontal Coordination of CCA	4	*"We have to collaborate with other organizations that will help us deliver our strategy. So the boroughs or NGO's or academic institutions."* (Respondent 5, GLA)
	Embeddedness of Adaptation Discourse	5	CCA is a high priority across all organisations (5) (Thames Water, 2019; EA, 2016; LBHF, 2018), who re responsible for implementation of measures like SUDS or green roofing, although coordination between the organisations is not explicitly clear within planning and implementation.
	Institutional Responsibility	4	The devolution of significant hazard management responsibilities to local boroughs has ensured a more coherent approach to adaptation across the 33 boroughs, however, there remains significant fragmentation at this smaller scale, especially in relation to adaptation interventions in public spaces (Respondent 2).
	Institutional Transparency	4	Most organisations have responsible adaptation leads. Adaptation lead frequently also has significant other responsibilities, straining resources
	Institutional Accountability	4	Partnership of DrainLondon with academic institutions guarantees more rigorous evaluation and accountability setting
	Ambition and Goal Setting	4	Ambition in the LES and London Plan is generally high and looks to integrate adaptation holistically.
Resource Capacity	Financial Availability	4	Recent creation of new funding for green and adaptive interventions. The London Green Fund also provides an element of public-private funding for the use of green roofing in energy efficiency improvements.
	Willingness to Pay	3	Perception of high costs of maintenance of CCA measures a significant constraining factor at local level. Co-benefits frequently used to motivate CCA implementation. Limited willingness in private sector to integrate CCA into implementation costs. *"We need developers to recognize the benefits and necessity of including well-designed SuDS measures into their developments."* (Respondent 4, LA Environmental Policy Officer).

	Financial Continuity	4	The GLA has identified a funding gap for urban development in London of 3.1 billion GBP per year. As such, borough and GLA officials alike have seen stretched financial resources. The New London Plan specifically target diversification of income streams via taxation and private investment
	Human Manpower	4	*"We need officers with expertise in design and implementation of SuDS projects, as well as planning policy."* (Respondent 4, LA Environmental Policy Officer)
	Adaptation Expertise	4	DrainLondon and the LCCP are responsible for the delivery of generating technical skill and knowledge development via pilot projects and research studies, whilst industry expert bodies, like CIRIA, are critical in determining new standards for innovation and implementation.
	Organisational Resource Flexibility	3	The capabilities of local authorities and EA officials to monitor and evaluate adaptation measures within the array of public and private developments is acutely constrained by low staffing and limited multi-sectoral understanding of regulations (Respondent 3).
	Diversity of Solutions	4	High level of technical expertise and variety of pilot project implementation. Widely established SuDs implementation network and emergent urban greening
	Integrated Adaptive Planning	3	No clear evidence within the LES but EA and Thames Water model longer-term interventions in relation to adaptive planning principles
Social Capacity	Active Network Participation	5	London plays a significant role in C40 network, and the GLA Environment Team has a specified C40 lead. The LCCP also plays a role in connecting London to regional and global networks for climate action
	Integration of Network Knowledge in CCA	4	C40 case studies and methodologies intermittently used in adaptation approaches. Larger-scale adaptation projects, such as Thames Tideway 2100 has utilised best practice from global cases.
	Stakeholder Participation	4	The London Plan integrates specific policy tools to work towards more active participation of stakeholders. Broad array of partnerships and networks (LCCP, Cross River Partnership) connecting and facilitating relevant stakeholder engagement
	Cooperation with the Community	4	Many boroughs actively organise engagement events with communities, via schools, charities or housing organisations. *"Always get your researchers around the table; to get your boroughs around the table; and to get the community organisations; and as far as practicable to get the users involved."* (Respondent 5, GLA)
	Community Adaptation Initiatives	4	*"We need people to see that they can change their local area, so that adaptation is their thing."* (Respondent 2, LCCP). Partnerships such as the LCCP and CRP work to integrate expert institutions into the implementation and monitoring of community-led initiatives.
Learning Capacity	Local Knowledge Integration	4	Role of LLFA's highly influential in understanding local climate hazards. Heat mapping also increasingly important. Borough level projects more effective in integrating local knowledge
	Risk & Vulnerability Assessments	5	UKCIP is established assessment group, alongside EA and LLFA's. Also undertaken by utilities and transport providers.
	Adaptation Policy Assessments	5	Regular policy assessment commonplace across GLA and boroughs. Role of LCCP as independent body enables greater inclusion and transparency in assessment methods. GLA held accountable by GLA Board thus also improving assessment transparency
	Collaborative Learning	5	Extensive networks, partnerships and forums across London for information dissemination and knowledge co-creation. Boroughs have frequently collaborated and pooled knowledge resources to produce strategies and solutions
	Monitoring & Evaluation	2	*"Some planning permissions are granted with conditions set to providing additional information on climate adaptation measures. Other than this element of monitoring, there is little time or resources available to monitor the implementation of measures in new developments."* (Respondent 4, LA Environmental Policy Officer).
	Reporting & Application	4	Reporting of uncertainty and evaluations not statutory although industry standards such as BREEAM and EA regulations are useful tools for reporting CCA performance
Transformative Capacity	Multi-Benefit Interventions	4	*"There is an incentive in terms of provision of integrated, multifunctional SuDS measures that can help make developments more desirable and improve quality of life for occupants."* (Respondent 4, LA Environmental Policy Officer).
	Synergy Optimization	4	Closer alignment of planning and development policies in relation to environmental management has aided CCA implementation. Regulation by the EA and the impending use of the Urban Greening Factor from the GLA will incentivise synergies of intervention
	Innovation & Experimentation	3	Most experimentation lead by knowledge institutes and ambitious stakeholders . LCCP and CRP are important networks for mobilising resources and interest for innovation. Emergence of knowledge sharing platforms from GLA and DrainLondon

5.3 City-Specific Critical Adaptive Capacity Factors

Successful CCA in London is strongly enabled by the institutional, learning and social capacities (Figure 7). Resource and transformative capacity provide opportunities for improvement and acceleration. The devolution of the GLA has enabled London to develop strong ambitions relating to climate adaptation, and it is well integrated as a priority for strategic development across several sectors. Local authorities have often chosen to go beyond minimum standards set within the guiding London Plan and London Environment Strategy. Policy and planning remain strong components within legal and institutional frameworks, although implementation by practitioners is accelerating, especially in relation to stormwater management and urban BGI.

Enabling Factors:

- Inspirational, multi-sectoral leadership: facilitated by devolved legislative power and highly effective expert networks for cooperation and knowledge transfer
- Ambition and Goal Setting: mirrored across institutional scales to accelerate SuDs and urban greening implementation
- Stakeholder Participation: aided by legislative requirements within planning processes, whilst public developments are increasingly concerned with early and transparent participation.
- Multi-Benefit Interventions: there is an expanding movement towards urban greening and small-scale stormwater management practices, with a focus on their co-benefits for socio-economic development and public health.

Factor Interconnections:

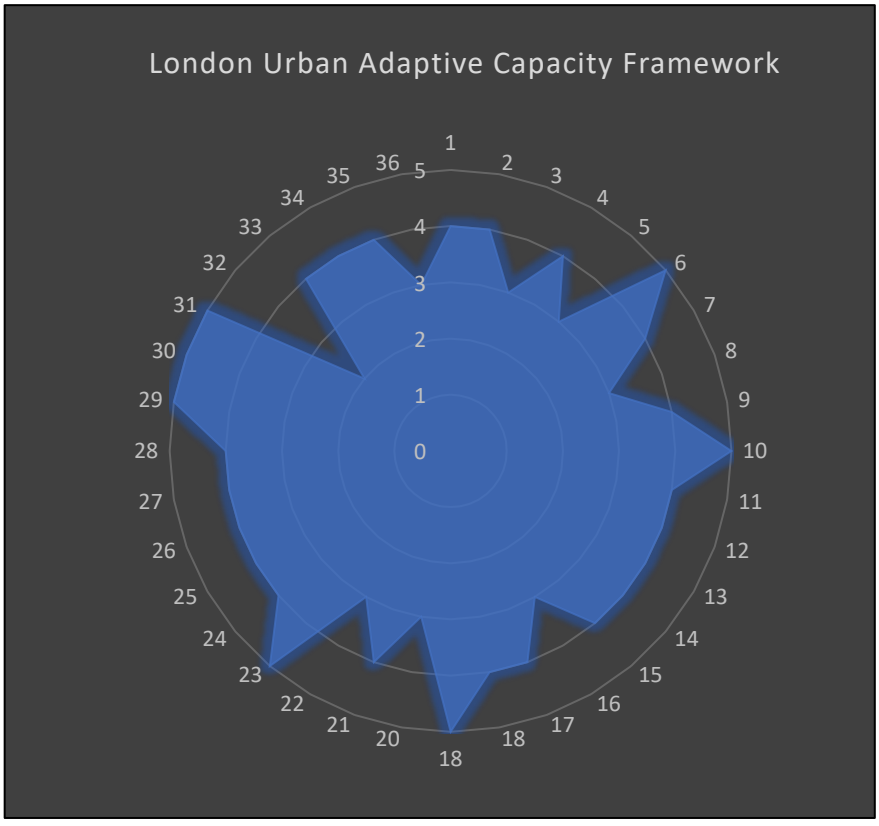
- Horizontal CCA coordination and Collaborative Learning: horizontal coordination of CCA interventions has resulted in innovative organisational arrangements, such as pooling of expertise and resources across borough boundaries.
- CCA Embeddedness: London has worked to tackle challenges of vertical and horizontal coordination via networks and partnerships. This has proved highly effective in maintaining a broad CCA strategy, and embedding learning processes in adaptation planning

Actionable Factors:

- Monitoring & Evaluation: targeting a smarter, integrated city within the New London Plan
- Community Initiatives: targeting private- and community actors to accelerate CCA holistically
- Innovation & Experimentation: targeting resource and expertise synergies across practitioners, particularly for urban development and flood management

Overall, critical factors for successful adaptation in London are therefore:

- Policy Cohesion and Adaptation Embeddedness across policy scales (Legal Capacity & Institutional Capacity)
- Motivational and aspirational leadership across government scales (Institutional Capacity)
- Network Participation: Creation and maintenance of influential partnerships and networks (Institutional, Social & Learning Capacity)
- Integration of CCA interventions as critical for co-benefit generation in broader urban development (Legal, Institutional & Transformative Capacity)
- Community Participation & Collaborative Learning: Formal and informal mechanisms for participation in CCA decision-making and implementation (Social & Learning Capacity)
- Innovation and Experimentation: New forms of resource management for CCA implementation via cross-borough partnerships & public-private partnerships (Resource & Transformative Capacity).



Factor	No	Factor	No
Adaptation Policy Instruments	1	Adaptation Expertise	19
Adaptation Policy Cohesion	2	Organisational Resource Flexibility	20
Statutory Compliance	3	Diversity of Solutions	21
Socio-Environmental Equity Awareness	4	Integrated Adaptive Planning	22
Redistribution of Socio-Environmental Equity	5	Active Network Participation	23
Institutional Adaptation Leadership	6	Integration of Network Knowledge	24
Organisation of Adaptation Implementation	7	Stakeholder Participation	25
Vertical Coordination of CCA	8	Cooperation with the Community	26
Horizontal Coordination of CCA	9	Community Adaptation Initiatives	27
Institutional Responsibility	10	Local Knowledge Integration	28
Institutional Transparency	11	Risk & Vulnerability Assessments	29
Institutional Accountability	12	Adaptation Policy Assessments	30
Adaptation Embeddedness	13	Collaborative Learning	31
Ambition & Goal Setting	14	Monitoring & Evaluation	32
Financial Availability	15	Reporting & Application	33
Willingness to Pay	16	Multi-Benefit Intervention	34
Financial Continuity	17	Synergy Optimization	35
Human Manpower	18	Innovation and Experimentation	36

Figure 7: An overview of London's Urban Adaptive Capacity Factor scoring

6. Copenhagen

6.1 Introduction & Adaptation Context

The Municipality of Copenhagen is large, led by Mayor Frank Jensen heading a 55-strong elected City Council, supported by seven sectoral committees. The Technical and Environment committee and the Centre for Climate Adaptation are primarily responsible for the coordination and implementation of climate adaptation interventions, alongside a partnership with municipal water utility provider, HOFOR. Crucially, Copenhagen has integrated CCA with the emergence of principles of smart city design and carbon neutrality in urban planning in recent years. Box 2 outlines additional contextual information. The following section will address the adaptive capacity performance within Copenhagen and conclude with specific critical factors and best practices.

Copenhagen	**Population: 1.2 million Climate: Oceanic**		**Key Policy: Cloudburst Management Plan (2011) & Climate Adaptation Strategy 2025 (2013)**
Climate Hazard	**Current Risk**	**Future Risk: 2050**	**Adaptation Options**
Pluvial Flooding	High	High: 25% increase in extreme rainfall volumes. 11-40% increase in winter precipitation. Significant damage to assets and disruption to urban functionality	Split sewage system SUDS measures Stormwater Conveyance
Storm Surge	Low	High: 30cm increase in average sea-level. Current 100-year event likely to occur every 20 years. Potential damage of DKK 1.5 billion by 2060.	Building Design Regulations Zoning Regulations
Drought	Low	Low: Higher occurrence of water-borne diseases. Potential groundwater level reduction Biodiversity loss & reduced performance of SUDS	Expansion of green spaces Blue-Green Infrastructures Incorporate blue-green solutions into private and public planning
Heatwave + UHI Effect	Low	Medium: Summer temperature rise of 2-3°C. UHI effect likely to cause localized heat islands within the city with greater public heath challenges. Biodiversity loss, air quality reduction and water quality reduction.	Blue-Green Infrastructures Expansion of urban green space Incorporate green solutions into private & public planning Promote district cooling

Box 2: An overview of Copenhagen's current context in terms of climate hazards and future risks (Municipality of Copenhagen, 2011)

6.2 Urban Adaptive Capacity Analysis

Table 11: Analysis of Copenhagen's Urban Adaptive Capacity, with scoring and argumentation

	Adaptive Capacity Factor	Score	Reasoning
Legal Capacity	Adaptation Policy Instruments	5	Cloudburst Management Plan provides clarity and comprehensive demands for adaptation standards. *"The way we are able to do this (successfully adapt) is that we made it as a comprehensive plan, involving citizens and stakeholders, and made it as a good business case."* Respondent 9 (CCA Implementation Planner)
	Policy Cohesion	4	National level CAP aligns well with municipal planning, particularly in relation to coastal flood adaptation. The CMP has had a transformative effect on policy in Copenhagen, alongside legal obligations enacted by the Ministry for the Environment for municipalities to assess climate risks, in accordance with the EU Floods Directive (EC/60, 2007) and generate climate adaptation action planning (Danish Parliament, 2009).
	Statutory Compliance	4	Whilst the legal basis for municipal funding is unclear, strong compliance to the stringent regulations for flood and storm surge protections laid out within the Adaptation Plan and the Storm Surge Plan developed in 2017 (City of Copenhagen, 2017) is generally evident.
	Awareness of Socio-Environmental Equity	4	Integration of policy instruments for tackling inequality. High awareness for integrated approach, alongside CPH Climate Neutral Plan
	Redistribution of Socio-Environmental Equity	4	Projects such as large-scale regeneration in Nordhavn and the Climate Quarter in Østerbro have placed socio-environmental equity and benefits as key features of their planning and implementation.
Institutional Capacity	Institutional Leadership for Adaptation	5	Strong leadership across poly-centric governance system Committees work to integrate CCA across jurisdictions and avoid political agendas
	Organisation of Adaptation Implementation	4	Relatively hierarchical organisational structure but committees and working groups are present to integrate CCA across institutions and sectors. Distinct authorities leading planning and implementation.
	Vertical Coordination of CCA	3	Strong connectivity to national level targets but some disconnect in implementation. At city level, TEA is dominant and dictates CCA progress with lower levels of coordination and cooperation but politicized nature of CCA means some conflict occurs
	Horizontal Coordination of CCA	5	Strong evidence for the integration of external experts, businesses and utilities. Horizontal coordination utilised as an effective way to accelerate awareness, innovation and diversify investment City-subsidised clusters such as the CleanTech cluster facilitate coordination
	Embeddedness of Adaptation Discourse	5	Adaptation is implemented alongside clear goals towards 2030. The creation of phased adaptation plans links longer-term and short-term agendas. *"We need to look at understanding the implications and cascades of good CCA intervention. We need to look at public land as valuable and a source of profit."* (Respondent 8, CALL Copenhagen).
	Institutional Responsibility	4	TEA and Climate Adaptation Centre are distinctly responsible actors. But emergence of IUR's and HOFOR means that responsibilities are sometime perceived unclear. *"One of our main challenges is not being able to invest in private properties. The planning system allows some forcing of implementation, but we could use insurance companies to force them to protect against basement flooding. We have to prove the value of adaptation, though."* (Respondent 9, CCA Implementation Planner)
	Institutional Transparency	3	High trust in municipal decision-making means that information is not always readily available. Online tools are utilized for citizens/stakeholders who wish to acquire information
	Institutional Accountability	4	Financial accountability plays an important role in Copenhagen. Existence of administrative committees, working groups, and the politicized nature of city organisations means that there are accountability measures embedded in the practice of CCA
	Ambition and Goal Setting	5	Highly ambitious and transformative targets across sectors for CCA and mitigation have made Copenhagen a frontrunner. May benefit from a shift in emphasis when using public investment, namely away from functional success of a project towards value-creation, and monetisation, of the technological and best-practice approaches emerging in the city (Respondent 8).
Resource Capacity	Financial Availability	4	Substantial budget availability towards 2030 for CCA adaptation to flooding and coastal storm surges. Limited by lack of funding support from national government
	Willingness to Pay	4	Stakeholders across departments generally willing to pay due to interconnectivity of CCA across urban development strategy. Co-benefits are generally well utilized to catalyse willingness to pay, although CCA is sometimes still seen as a convenient "add-on" in some larger infrastructure projects
	Financial Continuity	5	Budgeting & stormwater taxation accounts for long-term continuity whilst lack of national support has driven innovation in ensuring diversity of financial support
	Human Manpower	4	High level of manpower availability within the city for planning and implementation but M&E lacks human resource support.

			May need more facilitating actors in implementation phases of projects.
	Adaptation Expertise	5	Most stakeholders are highly skilled and external experts are sought if required. Expertise seen as a value-creation and commercial tool for marketing and commercialisation of CCA. *"HOFOR provide the hydraulic experts, and we provide the landscape architects, planners, and other staff. This is a cost-effective way and thinks about how to integrate adaptation with other projects and city development."* (Respondent 9, CCA Implementation Planner)
	Organisational Resource Flexibility	4	Political nature of organisations constrains optimal flexibility but stakeholders and decision-makers generally effective in resource flexibility, particularly in relation to broader Cloudburst Management Plan targets and IUR zones
	Diversity of Solutions	4	High level of expertise relating to implementation of CCA measures, whilst innovation and experimentation also aids with the generation of diverse solution options. This is important given the influence of private actors on space within the city.
	Integrated Adaptive Planning	4	Dynamic planning, with iterative change of cloudburst management plan seen as effective strategy for dealing with climate change impacts. *"It is about convincing the politicians and citizens about these challenges and uncertainties. If the rain doesn't get worse, then we can build benefits anyway via our approaches.".* (Respondent 9, CCA Implementation Planner)
Social Capacity	Active Network Participation	5	*"We learn a lot by participating in networks, we share our knowledge, and we become aware of what solutions may work in a Copenhagen context, and vice versa."* (Respondent 7, Municipal Planner).
	Integration of Network Knowledge in CCA	4	Evidence for use of network knowledge to inform cloudburst management strategies and tools for CCA solutions. New York and Rotterdam seen as key partners and opportunities for learning.
	Stakeholder Participation	4	High engagement required due to private ownership of urban infrastructure in Copenhagen. Involvement primarily limited to formal planning processes but design and implementation of measures in specific projects worked to involve citizens. This boosted satisfaction and ownership and proved to be an international marketing tool (Respondent 7).
	Cooperation with the Community	4	Danish climate adaptation forum offers open-access information about CCA on a national scale Community participation and initiatives are also stimulated by the Danish Integrated Urban Renewal (IUR) program. IUR's target regeneration in marginalised or less affluent city districts. Participation and community engagement is central to their premise.
	Community Adaptation Initiatives	3	Dominant focus has been upon public sector CCA interventions. Emergence of CALL and Co-Create Copenhagen may connect long-term participation. *"We can showcase solutions by establishing demonstration projects targeting innovative solution providers and help them connect to stakeholders."* (Respondent 8, CALL Copenhagen)
Learning Capacity	Local Knowledge Integration	5	High level of knowledge and simulation across actors, particularly within HOFOR and local knowledge institutes. Knowledge particularly relevant in considering hydraulic interconnections and green corridors across city.
	Risk & Vulnerability Assessments	5	Foundation of climate adaptation planning is Risk & Vulnerability assessing. Increasingly focused towards socio-economic impacts as well as physical impacts. *"We need to look at understanding the implications and cascades of good CCA intervention. We need to look at public land as valuable and a source of profit."* (Respondent 8, CALL Copenhagen).
	Adaptation Policy Assessments	3	Limited evidence of policy assessments due to long-term and holistic nature of Cloudburst Management Plan. Political cyclicity within municipality has led to some changes in policy agendas. Threatened by political agendas currently.
	Collaborative Learning	4	Co-Create Copenhagen is an emerging initiative. Communities and stakeholders seen to be important in local-level planning of adaptation. Creation of Living Lab experiments or visual exhibits used to generate feedback and community-led solutions (Respondent 8)
	Monitoring & Evaluation	3	Lack of formalised M&E frameworks inhibits learning and improvement. M&E not obligatory within private interventions limiting data availability. *"If we frame our CCA investments using data that frame who benefits from intervention, it is about quantifying and providing information for investors and funders."* (Respondent 8, CALL Copenhagen).
	Reporting & Application	3	Challenged by public-private boundaries in Copenhagen. Limited evidence of action to guide changes in practice. Constrained by blurred role of HOFOR in hydraulic implementation and role of municipality at surface level
Transformative Capacity	Multi-Benefit Interventions	4	*"Transformation into something better can take many shapes and forms, it can be about climate sustainability but certainly also about the social sustainability, which is extremely important."* (Respondent 7, Municipal Planner). The CMP and CCAP both include explicit reference to the co-benefits of adaptation interventions, such as green-space connectivity, urban cooling, leisure and recreation (City of Copenhagen, 2011;2015b).
	Synergy Optimization	4	Co-benefit targeting is embedded with the core principles of multiple sectoral policies, whilst adaptation to climate impacts is seen as an effective way to synergize municipal budgeting.
	Innovation & Experimentation	3	Innovation is fostered by a successful Living Lab program. Copenhagen is seen as a playground for experimentation and innovation, in which monitoring and evaluation can be closely controlled and utilized, and where investments can be considered based on analysed performance (Respondent 8).

6.3 City-Specific Critical Adaptive Capacity Factors

Copenhagen exhibits many examples of highly successful CCA to climate hazards. It has achieved significant success via a polycentric governance model that is guided by a comprehensive, ambitious and well-resourced adaptation strategy. In terms of its adaptive capacities, strongly enabling factors are evident within the Institutional, Resource and Transformative capacities (Figure 8).

Enabling Factors:

- Horizontal Coordination of CCA: seen as a core principle of their holistic urban development strategies. This has resulted in the generation of policy strategies towards greater cooperation with utility providers, knowledge institutes and private entrepreneurs (Respondent 8). This has also proven to be an effective means of diversifying resource capacity by generating additional funding pathways and targeting the commercialisation of adaptation interventions.
- Innovation and Experimentation: innovation, particularly in relation to governance practices and technological interventions, is a highly enabling factor. Via experimentation, city stakeholders have more effectively raised awareness for CCA, and mainstreamed the principle across multiple sectors, such as urban regeneration.
- Presence of Policy Instruments: comprehensive planning integrates knowledge co-creation & smart solutions maximise benefits such as greater information availability and generate value for socio-economic development of the city.

Factor Interconnections:

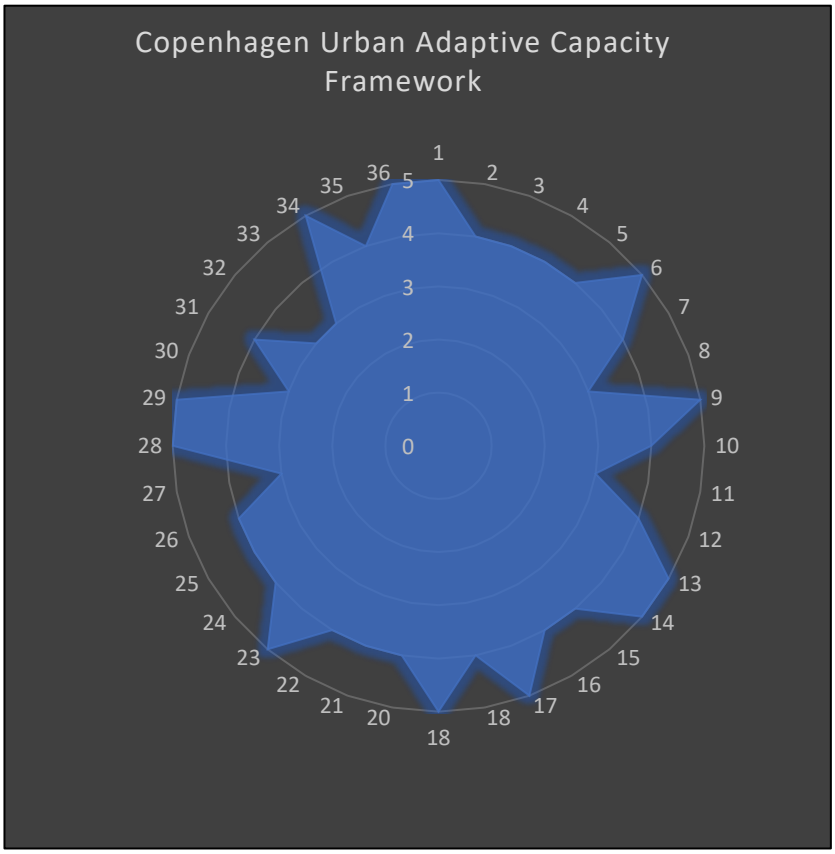
- Risk & Vulnerability Assessments and Financial Availability: providing detailed analysis of the costs & benefits of implementation is a critical driver of political support, financial availability and the generation of longer-term funding.
- Collaborative Learning & Vertical Coordination of CCA: political support across vertical hierarchies is important; *"the biggest challenge we have at the moment is that ministers are far away from implementation, they don't understand it." (Respondent 9)*. Therefore, knowledge generation and vertical coordination are interconnected for fostering momentum and embeddedness across political and social scales.

Actionable Factors:

- Community Initiatives: the emergence of the Co-Create Copenhagen program is a policy lever to stimulate greater stakeholder engagement, and to build local-level monitoring practices for adaptation measures.
- Monitoring & Evaluation: expanding adaptation implementation onto privately-owned land will be critical for longer-term success in Copenhagen, so policy levers that integrate M&E and stakeholder engagement could prove valuable.

Triangulating the insights enables the identification of critical adaptive capacity factors for successful adaptation in Copenhagen:

- Ambitious and binding Adaptation Policy Instruments (Legal Capacity)
- Generation and utilization of Adaptation Expertise via Horizontal Coordination and cooperation (Institutional Capacity & Resource Capacity)
- Synergy Optimization between broader urban development agendas such as SmartCity status and a Climate-Proof City (Institutional, Social & Transformative Capacity)
- Embeddedness of CCA in broader urban development (Legal & Institutional Capacity)
- Identification of Multi-Benefit Interventions and integration into value creation strategies (Resource & Transformative Capacity)
- Innovation and Experimentation utilised as tools for improving awareness and integrating public and private climate change adaptation (Learning & Transformative Capacity)



Factor	No	Factor	No
Adaptation Policy Instruments	1	Adaptation Expertise	19
Adaptation Policy Cohesion	2	Organisational Resource Flexibility	20
Statutory Compliance	3	Diversity of Solutions	21
Socio-Environmental Equity Awareness	4	Integrated Adaptive Planning	22
Redistribution of Socio-Environmental Equity	5	Active Network Participation	23
Institutional Adaptation Leadership	6	Integration of Network Knowledge	24
Organisation of Adaptation Implementation	7	Stakeholder Participation	25
Vertical Coordination of CCA	8	Cooperation with the Community	26
Horizontal Coordination of CCA	9	Community Adaptation Initiatives	27
Institutional Responsibility	10	Local Knowledge Integration	28
Institutional Transparency	11	Risk & Vulnerability Assessments	29
Institutional Accountability	12	Adaptation Policy Assessments	30
Adaptation Embeddedness	13	Collaborative Learning	31
Ambition & Goal Setting	14	Monitoring & Evaluation	32
Financial Availability	15	Reporting & Application	33
Willingness to Pay	16	Multi-Benefit Intervention	34
Financial Continuity	17	Synergy Optimization	35
Human Manpower	18	Innovation and Experimentation	36

Figure 8: An overview of Copenhagen's Urban Adaptive capacity factor scoring, with accompanying descriptions.

7. Rotterdam

7.1 Introduction & Adaptation Context

The Dutch governmental system involves the decentralization of decision-making authority to municipal governments. The municipality of Rotterdam works to implement climate adaptation and resilience measures alongside a highly diverse range of actors. Financing of adaptation predominantly comes from centralised funding pathways, although Rotterdam has also utilised EU funding for blue-green infrastructure projects (Gemeente Rotterdam, 2016). The Rotterdam Resilience Strategy (2016) and the Rotterdam Climate Change Adaptation Strategy (2019) work alongside the national Delta Programme and National Adaptation Strategy. Box 3 outlines additional contextual information. The following section will address Rotterdam's adaptive capacity performance (Figure 9) and conclude with city-specific critical factors.

Rotterdam	**Population: 650,00**	**Climate: Temperate Oceanic**	**Key Policy: Resilience Strategy (2016), Climate Adaptation Strategy (2019)**
Climate Hazard	**Current Risk**	**Future Risk: 2050**	**Adaptation Options**
Pluvial Flooding	High	High: Increase in frequency of high rainfall days, especially during winter. Rainfall intensity also projected to increase significantly, up to 94mm/day. Significant damage to assets and disruption to urban functionality	SUDS measures for stormwater retention and conveyance. Expansion of Blue-Green Infrastructures Zoning regulation for critical infrastructure
Fluvial Flooding	Low	Medium: River Rhine projected for extremely high discharge up to 40times more frequently. Potential increased storm surge frequency and SLR up to 40cm	Compliance with Delta Plan Incorporation of Blue-Green Infrastructure in Dike Management Awareness Building and Preparedness
Drought	Medium	High: Average annual temperature rise of up to 2.5 °C. Decreased annual precipitation (-5%) whilst dry periods will become up to 30% more likely. Significant risk of groundwater reduction and land subsidence. Saline intrusion and water quality degradation also highly likely.	Expansion of green spaces & Blue-Green Infrastructure Incorporate blue-green solutions into private and public planning Deploy systems for irrigation of urban green spaces during drought
Heatwave + UHI Effect	High	Medium: Longer hot periods are projected with heatwaves increasingly frequent and three times more frequent tropical nights. Low summer river discharges, decreased rainy day frequency and average temperature rise exacerbate the UHI effect.	Blue-Green Infrastructures. Expansion of urban green space across public areas and utilities Incorporate green solutions into private & public planning via building design regulation

Box 3: An overview of Rotterdam's current context, in terms of climate hazards and future risks (KNMI, 2014)

7.2 Urban Adaptive Capacity Analysis

Table 12: An analysis of Rotterdam's Urban Adaptive Capacity factors, with scoring and argumentation.

	Adaptive Capacity Factor	Score	Reasoning
Legal Capacity	Adaptation Policy Instruments	4	National level spatial planning and adaptation policies underpin city policies strongly. Regulatory power of municipality constrains value of some instruments, due to lack of enforcement. *"There isn't a way for a city to add anything to building regulations and we don't have any legislative power. We cannot force implementation but perhaps in the end that is where it may lead to."* (Respondent 11, Urban Roof Real-Estate Planner)
	Policy Cohesion	3	Moderate cohesion across multiple sectors due to complexity of actors and agendas. Competing agendas of differing institutions may limit acceleration of adaptation.
	Statutory Compliance	4	Generally strong due to cultural understanding of need for adaptation. Spatial Planning Act and Water Act also strongly influence compliance.
	Awareness of Socio-Environmental Equity	4	High awareness in Rotterdam of need for holistic urban development and mitigation of socio-environmental inequity. Aided by strong local knowledge and risk & vulnerability assessing.
	Redistribution of Socio-Environmental Equity	5	Urban regeneration projects are strategic and mainstream adaptation as a core principle within their implementation. The implementation of socially-oriented projects such as the Benthemplein Watersquare or the Peperklip highlight the legislative directives to integrate socio-environmental challenges within adaptation projects.
Institutional Capacity	Institutional Leadership for Adaptation	5	Chief Resilience Officer and motivated adaptation planners drive action and implementation. Also motivated leaders across scales in civil society, aided by Dutch focus on IWRM.
	Organisation of Adaptation Implementation	4	Generally good coordination and organisation, although some conflict between differing important sectors. Resilience Strategy has proved effective for coordinating planning and implementation.
	Vertical Coordination of CCA	3	Challenging relationships between levels of government as agendas conflict and political decisions inform adaptation processes. Water boards also influential actors, with competing agendas and resources. The Delta Programme is a good example of vertical coordination towards strategic mitigation and adaptation towards flooding. However, the complex interactions between national, regional, municipal, and local authorities mean that smaller-scale projects often suffer from slow decision-making, siloing, and a lack of responsibility and accountability.
	Horizontal Coordination of CCA	4	Generally strong coordination across sectors, aided by working groups and public-private partnerships to drive learning and cooperation. Horizontal coordination seen as culturally important component of CCA implementation in Rotterdam.
	Embeddedness of Adaptation Discourse	5	High ambition and overarching policy/legislation drives embeddedness. Most departments now incorporating CCA into operations. The city has created a common story and vision for a climate-proof future.
	Institutional Responsibility	3	Complex arrangements for responsibilities lead to incoherence and uncertainty. Differing domains of CCA implementation make this challenging. Role of citizens could also complicate it further.
	Institutional Transparency	5	Planning and implementation generally transparent due strong reporting demands and desire to engage citizens
	Institutional Accountability	3	Complex array of actors means that accountability struggles due to internal friction and conflict. Also influenced by experimental mindset in Rotterdam.
	Ambition and Goal Setting	5	Highly ambitious institutional goals help to mainstream and accelerate implementation. Holistic plan places CCA acceleration as a critical component for sustainability and resilience. *"There is no way we can keep single-use surfaces so we have to get smart and multi-functional in that sense."*(Respondent 11, Roof Real Estate Planner)
Resource Capacity	Financial Availability	4	Generally strong, aided by diversification of funding pathways, from EU and national level sources. Aided by autonomous water board funding pathways for grey infrastructure. Resource availability and continuity is high for both public and private led-projects, via mechanisms such as the CityLab010 and Citizen Initiative subsidies
	Willingness to Pay	5	High awareness of co-benefits that investment brings and willingness to invest in the face of higher future costs of inaction
	Financial Continuity	4	Strong continuity, especially from Delta Programme but also from commercialisation of adaptation processes. Water board funding may increase for increased exposure. Global pandemic explicitly influential on city budgeting in longer-term.
	Human Manpower	5	High quantity and quality of human resources in Rotterdam, aided by use of external experts and partners, and the array of organisations working on water and climate management in the city.

	Adaptation Expertise	5	High level and seen as a world-leader in terms of expertise. Aided by high-level partnerships with knowledge institutes, consultancies and water boards. Looking towards inter-disciplinary expertise for future challenges.
	Organisational Resource Flexibility	3	Challenging environment for resource synergy and flexibility due to political and organisational agendas across differing sectors.
	Diversity of Solutions	5	Partnerships and innovation focus means that solution diversity is a highly enabling adaptive capacity factor. Innovation seen as an opportunity to commercialise CCA in Rotterdam so diversity encouraged.
	Integrated Adaptive Planning	4	Strong feature of implementation relates to adaptive planning. Limited to some regard by overarching Delta Programme which dominates spatial planning.
Social Capacity	Active Network Participation	5	World-leader in relation to knowledge sharing. High priority on adaptation agenda and seen to be a tool for generating funding and mainstreaming CCA. *"In the end, cities can work together better than states because they can share more in-depth knowledge transfer on operational and practical levels."* (Respondent 11, Roof Real Estate Planner)
	Integration of Network Knowledge in CCA	3	C40 case studies and methodologies intermittently used in practice. Limited evidence of utilisation of lessons. Evidence of willingness to improve uptake of lessons.
	Stakeholder Participation	4	Participation encouraged but diversity of stakeholders makes involvement challenging logistically.
	Cooperation with the Community	4	Communities seen as important for maximising co-benefits of adaptation. Educational tools are a means for low-cost engagement with society. Particularly relevant in terms of socio-environmental equity redistribution. *"The central theme in designing water squares is that they have to be inclusive of local populations, using feedback from local actors. You need to be sensitive to the locality and to stimulating ownership."* (Respondent 12, Adaptation Planner)
	Community Adaptation Initiatives	4	Subsidies and neighbourhood initiatives utilised to motivate community-led action. Private stakeholder adaptation seen as an important sector for acceleration in Rotterdam – engagement with housing associations highly important to expanding CCA across public-private domain.
Learning Capacity	Local Knowledge Integration	5	Presence of KNMI and Knowledge for Climate enables high understanding of local context. Rijkswaterstaat also highly influential in providing data and information.
	Risk & Vulnerability Assessments	5	R&V assessments are critical in the Netherlands. Expert organisations are well involved in creating such assessments. Measures exist, such as the Climate Effect Atlas, to communicate these to citizens.
	Adaptation Policy Assessments	3	It is relatively unclear whether adaptation policy assessment is undertaken in Rotterdam. The role of multiple stakeholders in assessment is also unclear. Limited reporting linked to forward-facing focus of adaptation strategy.
	Collaborative Learning	4	Expert organisations are embedded in adaptation implementation. Co-production of knowledge is an increasing priority for the municipality, via schemes run by external partners such as DRIFT (Drift, 2020), dealing with citizen science initiatives. Formalised mechanisms for community involvement in adaptation projects, such as CityLab010, are effective in embedding collective learning and reflection within implementation.
	Monitoring & Evaluation	3	Implementation is not naturally accompanied by M&E in Rotterdam. Procedures are not uniformly embedded in planning, whilst pilot projects and experimentation are often prioritised in terms of exposure and action, rather than success or effectiveness. *"M&E is key to drive smart solutions. We want to know more about climate hazards in the city, which is hard without lots of sensors."* (Respondent 12, Adaptation Policy Planner)
	Reporting & Application	3	The Rotterdam Resilience Centre does utilise evaluation and reporting to guide learning across the city. It is less clear however how reporting of evaluation and monitoring is used to drive behavioural change. This appears limited in Rotterdam.
Transformative Capacity	Multi-Benefit Interventions	5	Adaptation is seen as a core tool for generating value across the city, by bringing in investment, raising global profile, and providing socio-cultural benefits. Measures for co-benefit identification are outlined within the Resilience Strategy and Adaptation Plan. *"You don't always need to prove that you got a return on investment, we should also accept that we have in turn created a nicer and better place."* (Respondent 11, Roof Real Estate Planner).
	Synergy Optimization	4	Institutional arrangements with water authorities and national government mean that synergies are modelled or identified within infrastructure projects. Synergies at smaller scales may be missed as formal mechanisms are not well embedded across all departments within the municipality (Respondent 11).
	Innovation & Experimentation	5	Rotterdam is an innovator city. Pilot projects, experiments and "hedging" of interventions are all key features of the adaptation landscape. Subsidies, partnerships, and accelerator hubs are all instruments used to drive experimentation at all scales within Rotterdam Smart instruments for learning and knowledge sharing are an increasing focus as the city looks towards cyber resilience alongside climate-proofing of the urban area (Respondent 11, Real Estate Planner).

7.3 City Specific Critical Adaptive Capacity Factors

Rotterdam has established itself as a global frontrunner when it comes to adaptation, strongly enabled by several critical factors, principally within Institutional, Resource and Transformative capacities.

Enabling Factors:

- Redistribution of Socio-Environmental equity: the city has utilised adaptation goals to tackle socio-environmental equity issues, which has also succeeded in improving the mainstreaming of CCA across multiple sectors.
- Institutional Adaptation Leadership: successful adaptation projects are typically led or catalysed by aspirational leaders and facilitated by experienced actors who work to connect relevant stakeholders horizontally within the city
- Willingness to Pay: CCA is seen as a critical to the vision of socio-economic and environmental sustainability in Rotterdam so financial availability and continuity are robust.
- Integrated Adaptive Planning: this approach enables the inclusion of a variety of stakeholders across governance levels and generates incentives for innovation and flexibility in planning and implementation of CCA.

Factor Interconnections:

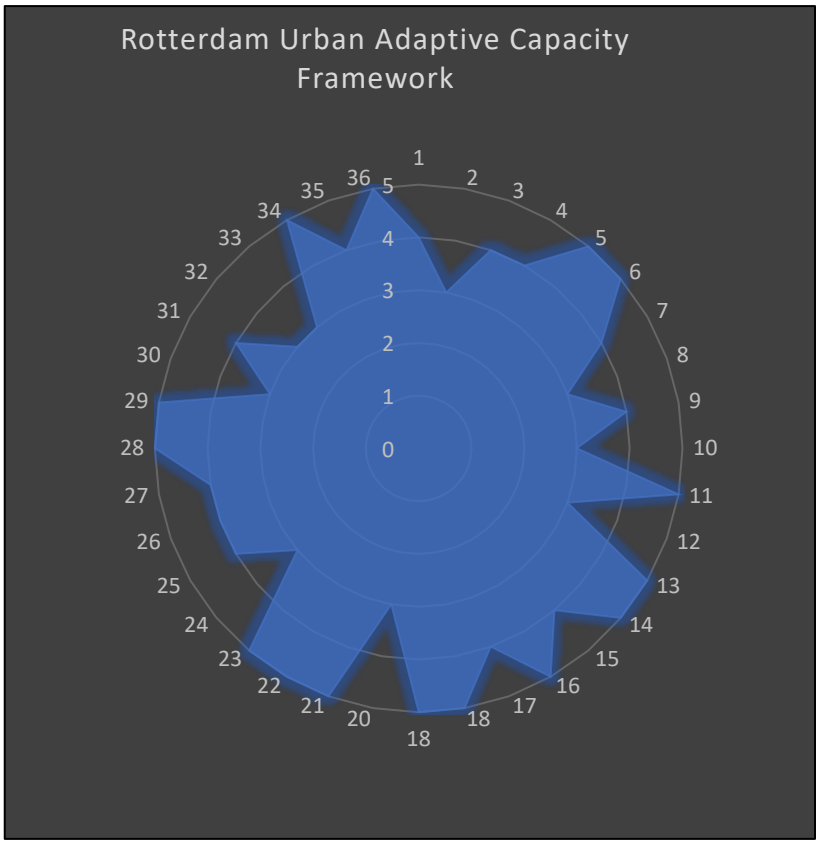
- Community Initiatives & Collaborative Learning: seen to contribute strongly to the pursuit of a climate-proof, resilient city. Building community engagement and participation connects with the generation of improved learning and social capacities and enables the city to generate co-benefits with public-led investment.
- Presence of Policy Instruments & CCA Embeddedness: highly ambitious policy enables the inclusion of a variety of stakeholders across governance levels, but also generates incentive for innovation and flexibility.

Actionable Factors:

- Monitoring & Evaluation: accelerating professional partnerships and innovative smart infrastructure can improve evaluation processes.
- Innovation & Experimentation: Pilot innovations are a branding and marketing tool, generating diverse investment streams and engaging private actors with adaptation implementation. Experimentation generates “no-regret” measures, consolidates partnerships with knowledge institutes and business sectors, and legitimises adaptation interventions.

Therefore, critical factors for success in Rotterdam emerge as:

- Ambitious and holistic Adaptation Policy Instruments (Legal & Institutional Capacity)
- Targeting adaptation as a tool for the Redistribution of Socio-Environmental Equity (Legal & Social Capacity)
- Stimulating implementation via Institutional Leadership for Adaptation (Institutional Capacity)
- Fostering and expanding Adaptation Expertise, across scales of implementation (Resource & Learning Capacity)
- Facilitating and encouraging Community Initiatives to mainstream CCA into urban development (Social & Transformative Capacity)
- Maximise Innovation and Experimentation in pursuit of efficiency and value-creation (Resource & Transformative Capacity)



Factor	No	Factor	No
Adaptation Policy Instruments	1	Adaptation Expertise	19
Adaptation Policy Cohesion	2	Organisational Resource Flexibility	20
Statutory Compliance	3	Diversity of Solutions	21
Socio-Environmental Equity Awareness	4	Integrated Adaptive Planning	22
Redistribution of Socio-Environmental Equity	5	Active Network Participation	23
Institutional Adaptation Leadership	6	Integration of Network Knowledge	24
Organisation of Adaptation Implementation	7	Stakeholder Participation	25
Vertical Coordination of CCA	8	Cooperation with the Community	26
Horizontal Coordination of CCA	9	Community Adaptation Initiatives	27
Institutional Responsibility	10	Local Knowledge Integration	28
Institutional Transparency	11	Risk & Vulnerability Assessments	29
Institutional Accountability	12	Adaptation Policy Assessments	30
Adaptation Embeddedness	13	Collaborative Learning	31
Ambition & Goal Setting	14	Monitoring & Evaluation	32
Financial Availability	15	Reporting & Application	33
Willingness to Pay	16	Multi-Benefit Intervention	34
Financial Continuity	17	Synergy Optimization	35
Human Manpower	18	Innovation and Experimentation	36

Figure 9: An overview of Rotterdam's Urban Adaptive Capacity factor scoring, with accompanying descriptions

8. Berlin

8.1 Introduction and Adaptation Context

Berlin is considered as a federal state in Germany. This gives it significant political autonomy to dictate environmental standards and policies. The Department for Environment, Transport and Climate Protection is responsible for the implementation of climate adaptation measures in Berlin, underlined in the Berlin Energy and Climate Plan 2030 (BEK). The semi-public water utility Berlin Wasserbetriebe (BWB) is responsible for the management and adaptation of physical water-related infrastructure in the city and is given relative autonomy by the Senate Department to pursue adaptation and mitigation strategies. Box 4 outlines additional contextual information. The following section will address Berlin's adaptive capacity performance and conclude with city-specific critical capacity factors.

Berlin	**Population: 3.7 million**	**Climate: Oceanic-Continental**	**Key Policy: BEK 2030, Berlin Climate Neutral 2050**
Climate Hazard	**Current Risk**	**Future Risk: 2050**	**Adaptation Options**
Pluvial Flooding	High	High: 30% increase in frequency of high rainfall days. Rainfall intensity also projected to increase significantly. Ageing drainage infrastructure	SUDS measures for stormwater retention and conveyance Expansion of Blue-Green Infrastructures Rainwater Management Systems
Fluvial Flooding	Medium	Medium: Increase in fluvial flow extremes. Overall rainfall will increase, especially in winter and spring which may combine with upstream snowmelt peaks.	Zoning Regulation for Critical Infrastructure Awareness Building and Preparedness
Drought	Medium	High: Severity increase due to increased average & maximum air temperature, and decreased summer rainfall regularity. Higher occurrence of water-borne diseases.	Expansion of green spaces Blue-Green Infrastructures Incorporate blue-green solutions into private and public planning Deploy systems for irrigation of urban green spaces during drought
Heatwave + UHI Effect	High	High 50% increase in frequency of extremely hot days and tropical nights. 1-2 degree C increase in average air temperature UHI effect likely to cause localized heat islands within the city. Greater public heath challenges. Biodiversity loss and air quality reduction.	Blue-Green Infrastructures Expansion of urban green space across public areas and utilities Incorporate green solutions into private & public planning Building Design regulations

Box 4: An overview of Berlin's current context including climate hazards and future risks (BEK, 2018)

8.2 Urban Adaptive Capacity Analysis

Table 13: An analysis of Berlin's Adaptive Capacity factors, with scoring and argumentation

	Adaptive Capacity Factor	Score	Reasoning
Legal Capacity	Adaptation Policy Instruments	4	National level spatial planning and adaptation policies underpin city policies strongly. Policies also guided by EU legislation, particularly relating to water quality and biodiversity. Strong stormwater management and urban greening policy instruments.
	Policy Cohesion	4	Good cohesion across sectors aided by federal state status. The BEK also integrates holistic elements within its planning. Urban development policies also align with stormwater management.
	Statutory Compliance	3	There remains some scepticism towards the climate plan, despite good cohesion, leading to slightly lower uptake of measures. Commercial uptake is low in terms of CCA measures
	Awareness of Socio-Environmental Equity	3	Limited awareness of the role of adaptation in urban development. Urban greening is however seen as an important feature for urban development, particularly the protection and expansion of greening.
	Redistribution of Socio-Environmental Equity	4	Urban greening measures and instruments play a more significant role that water-focused measures. Stormwater management tariffs do not influence equity and may exacerbate divide if small-scale interventions require capital investment. *"Green Roof Plus is very much in practice. Researchers are working with housing associations to see how they can adopt measures personally."* (Respondent 18, Landscape Architecture Academic)
Institutional Capacity	Institutional Leadership for Adaptation	3	Champions are more broadly seen across the city, rather than within the municipal institution. The KWB has a highly motivated and engaged leader driving horizontal coordination. *"A lot depends on the strength of the network of the adaptation manager into the organisation, but also the civil society."* (Respondent 19, Environmental Consultant)
	Organisation of Adaptation Implementation	4	Generally good coordination and organisation, although some conflict between differing important sectors. The BWB and Municipal Office have a strong relationship with clearly defined methods of cooperation.
	Vertical Coordination of CCA	4	Nature of German environmental systems guarantee strong coordination between scales. German legislation means that practitioners have established norms for coordination.
	Horizontal Coordination of CCA	4	Generally strong coordination across sectors, aided by working groups and public-private partnerships to drive learning and cooperation. The BWB and KWB are influential in also engaging diverse actor groups. *"The BWB, KWB and collaboration between researchers, private agencies and municipal actors influenced policy and action."* (Respondent 18, Landscape Architecture Academic).
	Embeddedness of Adaptation Discourse	4	There is an increasing focus on guiding external stakeholders towards CCA implementation, rather than enforcing it via embeddedness in practices. The BEK 2030 plan is an ambitious comprehensive policy document however, which has helped to drive acceleration from a municipal perspective.
	Institutional Responsibility	3	Some confusion although BWB is a strongly responsible actor for stormwater adaptation. Blurry legislative line in terms of liabilities for CCA performance means responsibilities are less clear.
	Institutional Transparency	3	Planning and implementation generally transparent although the BWB, as formerly private enterprise, still has some challenges.
	Institutional Accountability	4	Accountability norms ensure good performance. The legislative principles of Green Area Ratios mean developers are accountable for performance, whilst stormwater management standards are also in place.
	Ambition and Goal Setting	5	Highly ambitious institutional goals help to mainstream and accelerate implementation. The BEK is a holistic policy approach, with relatively clear time and target indicators.
Resource Capacity	Financial Availability	4	Generally strong, aided by diversification of funding pathways. Split tariff system is hugely effective, alongside other subsidisation schemes and the utilisation of EU-level funding.
	Willingness to Pay	3	Transition towards holistic adaptation has reduced willingness to pay. Focus on cost-effectiveness has reduced willingness to experiment on projects. *"Due to the introduction of the split-tariff, it makes a lot of sense to decentralize your water system, but the commercial sector is still missing from this. It has been a principle agent for change."* (Respondent 18, Academic)
	Financial Continuity	4	Aided by 2030 agenda of the BEK program, and the diversification of income from the BWB. The split-tariff system has proved popular since uptake and continues to generate budget support. Mitigation co-benefits of urban greening align with national-level funding directives.

	Human Manpower	4	High quality and quantity of expertise and human resources, stimulated by the BEK 2030 program and the aspirations of the BWB. The KWB is a primary actor in driving quality and expertise across sectors.
	Adaptation Expertise	4	High level and seen to play an important role in efficiency and effectiveness of adaptation. The BWB provides hydraulic and engineering expertise.
	Organisational Resource Flexibility	3	Challenging environment for resource synergy and flexibility due to political and organisational agendas across differing sectors
	Diversity of Solutions	4	Partnerships and innovation focus means that solution diversity is a highly enabling adaptive capacity factor. Small-scale rainwater harvesting and SUDS measures are popular, whilst natural green space in Berlin is extensive.
	Integrated Adaptive Planning	3	Limited legislative power limits extent of adaptive planning. Historic expansion of drainage systems means that future planning not always compatible with infrastructure.
Social Capacity	Active Network Participation	3	Limited participation in global networks, although German cities have some networking practices.
	Integration of Network Knowledge in CCA	2	C40 case studies and methodologies intermittently used in practice. Limited evidence of utilisation of lessons.
	Stakeholder Participation	4	Participation encouraged and is embedded with a cultural norm for participation. The KWB and BEK advocate for greater stakeholder participation, especially as focus shifts towards CCA on private developments and properties. *"The KWB have recognized that existing structures need decentralisation. In the past, the easy option was always smarter design of new buildings. But without retrofitting you are just tinkering around at the edges. Greening roofs, stormwater harvesting and pervious paving are also ways forward."* (Respondent 18, Stormwater Academic)
	Cooperation with the Community	4	Citizens are well-motivated to act on climate change and thus play an important role in adaptation processes. Communities seen as important for maximising co-benefits of adaptation. Educational tools are a means for low-cost engagement with society. Typically in the form of visual exhibitions, workshops and online information portals.
	Community Adaptation Initiatives	4	Communities have strong self-organisation in terms of adaptation. Small-scale stormwater management is a common feature in Berlin, aided by the split-tariff and subsidy provision. Subsidies and neighbourhood initiatives utilised to motivate community-led action. Split tariffs means that individuals and communities are actively rewarded for initiatives and innovation.
Learning Capacity	Local Knowledge Integration	5	High level of understanding aided by partnership with BWB and local knowledge institutes. Research strongly focusing on stormwater management and wastewater solutions. *"The BWB and KWB has institutionalized academic research in practice via the KWB. The institution is more open to interdisciplinary research."* (Respondent 18, Stormwater Academic)
	Risk & Vulnerability Assessments	4	BWB leads progress on R&V assessments, although strong compliance to the CAP process within Germany has also driven good performance in Berlin
	Adaptation Policy Assessments	2	Expert organisations are embedded in adaptation implementation. The BWB are an important player in co-creating knowledge and expertise
	Collaborative Learning	4	Expert organisations are embedded in adaptation implementation. The BWB are an important player in co-creating knowledge and expertise. The Di-BEK platform fosters community engagement and learning.
	Monitoring & Evaluation	3	M&E is not well established in Berlin. It is challenged by the nature of private implementation measures but also some confusion between the responsibilities of the BWB and the municipality *"With the KWB, they lack the human and technical resources to create an evaluation or monitoring network. They have done some analysis but it is very much more about trying to identify best practices rather than taking a more critical approach."* (Respondent 18, Stormwater Academic)
	Reporting & Application	2	Reporting relating to the BEK is also limited. The agencies lack clarity over responsibilities for reporting. Private-led implementation also restricts reporting.
Transformative Capacity	Multi-Benefit Interventions	4	Multi-benefits are seen as a useful effect of adaptation but not necessarily explicitly targeted and utilized within the BEK program. The 10000 Trees program explicitly combines mitigation and adaptation strategies for co-benefit generation
	Synergy Optimization	4	The role of the BWB in Berlin has enabled strong synergy creation between sectors. The holistic nature of the Department for Environment and Climate Protection has also driven synergy creation.
	Innovation & Experimentation	4	The BWB is leading the way with innovation, but often via financial levers like subsidies, rather than technical interventions. The city itself has not placed innovation at the forefront of their agenda, however, rathe focusing at innovation for mitigation. *"There is always this tension between hard engineering and new technologies, and they think that they can't mess around with the practices for dealing with stormwater."* (Respondent 18, Stormwater Academic)

8.3 City-Specific Critical Adaptive Capacity Factors

Berlin has been an innovator city in terms of urban greening for many decades. However, acceleration of adaptation in recent years has lagged behind other cities. Strong features include the use of innovative financial levers for motivating action at the community or citizen level, whilst inventive cooperation with the BWB has enabled greater synergy and horizontal cooperation across the city (Figure 10).

Enabling Factors:

- Presence of Policy Instruments: the split-tariff system in Berlin has been highly effective in accelerating CCA measures across scales.
- Horizontal Coordination of CCA: effective cooperation with utilities and expert organisations has improved cohesion and accountability for CCA.
- Community Initiatives: small-scale initiatives build learning, awareness and engagement with CCA interventions.

Factor Interconnections

- Horizontal CCA Coordination, Adaptation Expertise & Financial Availability: the public utility BWB operates at the nexus of these three factors, in which strong horizontal coordination of adaptation, predominantly stormwater management, influences the availability of funding and expertise. Innovation and commercialisation of best practices are also interdependent on finance and adaptation expertise, thus accelerating innovative practices for taxation and subsidisation of blue-green approaches

Actionable Factors:

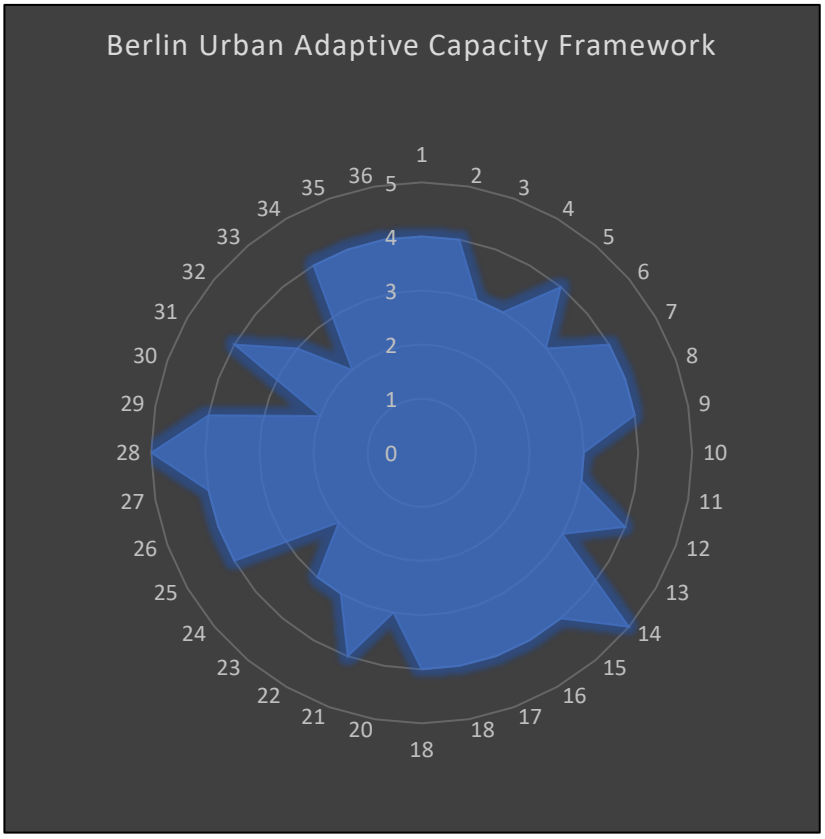
- Adaptation Embeddedness: the BEK2030 program can mainstream and embed climate adaptation across departments and sectors. This could be realised by better connecting adaptation co-benefits alongside the current mitigation focus taken by the city.

- Monitoring & Evaluation: the city lacks formalized M&E practices but research focus at KWB can play an important role in accelerating best practice.

Therefore, critical factors for success in Berlin emerge as:

- Inventive adaptation policy instruments for stormwater management (Legal Capacity)
- Strong financial availability and adaptation expertise, aided by split-tariff system (Resource Capacity)
- Effective horizontal coordination and stakeholder participation in stormwater management (Institutional & Social Capacity)
- Community cooperation and initiatives for rainwater harvesting and attenuation (Social Capacity)

- Diversity of innovative small- and large-scale interventions and measures (Resource & Transformative Capacity)



Factor	No	Factor	No
Adaptation Policy Instruments	1	Adaptation Expertise	19
Adaptation Policy Cohesion	2	Organisational Resource Flexibility	20
Statutory Compliance	3	Diversity of Solutions	21
Socio-Environmental Equity Awareness	4	Integrated Adaptive Planning	22
Redistribution of Socio-Environmental Equity	5	Active Network Participation	23
Institutional Adaptation Leadership	6	Integration of Network Knowledge	24
Organisation of Adaptation Implementation	7	Stakeholder Participation	25
Vertical Coordination of CCA	8	Cooperation with the Community	26
Horizontal Coordination of CCA	9	Community Adaptation Initiatives	27
Institutional Responsibility	10	Local Knowledge Integration	28
Institutional Transparency	11	Risk & Vulnerability Assessments	29
Institutional Accountability	12	Adaptation Policy Assessments	30
Adaptation Embeddedness	13	Collaborative Learning	31
Ambition & Goal Setting	14	Monitoring & Evaluation	32
Financial Availability	15	Reporting & Application	33
Willingness to Pay	16	Multi-Benefit Intervention	34
Financial Continuity	17	Synergy Optimization	35
Human Manpower	18	Innovation and Experimentation	36

Figure 10: An overview of Berlin's Urban Adaptive Capacity factor scoring, with accompanying factor descriptions

9. Warsaw

9.1 Introduction and Adaptation Context

Climate adaptation in Warsaw is led by The Office for Air Protection and Climate Policy, alongside the Environmental Protection Office and Architecture and Spatial Planning Office. They are guided by the 2019 Urban Adaptation Plan (UAP), as well as national-level Adaptation Strategy and the Strategic Adaptation Plan 2020 (2013). Warsaw remains in a transitional phase between planning and implementation but the city is showing motivation for mainstreaming and accelerating CCA. Box 5 outlines additional contextual information. Section 9.2 will elaborate upon Warsaw's performance in terms of adaptive capacity factors in relation to successful project implementation, and conclude with a summary of critical factors.

Warsaw	**Population: 3.1million**	**Climate: Continental**	**Key Policy: Urban Adaptation Plan to 2030 (2019) & Strategic Adaptation Plan (2013)**
Climate Hazard	Current Risk	Future Risk: 2050	Adaptation Options
Pluvial Flooding	High	High: Increase in frequency of high rainfall days. Rainfall intensity also projected to increase significantly. Significant damage to assets and disruption to urban functionality	SUDS measures for stormwater retention and conveyance Expansion of Blue-Green Infrastructures Rainwater Management Systems
Fluvial Flooding	Medium	High :Increase in number of flood events across Vistula and tributaries. Potential for groundwater flooding alongside fluvial floods	Zoning Regulation for Critical Infrastructure Awareness Building and Preparedness
Drought	Medium	Medium: Severity increase due to increased average & maximum air temperature, and decreased summer rainfall regularity. Higher occurrence of water-borne diseases. Potential groundwater level reduction Biodiversity loss & reduced performance of SUDS	Expansion of green spaces Blue-Green Infrastructures Incorporate blue-green solutions into private and public planning Deploy systems for irrigation of urban green spaces during drought
Heatwave + UHI Effect	High	Medium: 50% increase in frequency of extremely hot days and tropical nights. 1-2 degree C increase in average air temperature UHI effect likely to cause localized heat islands Greater public heath challenges. Biodiversity loss and air quality reduction	Blue-Green Infrastructures Expansion of urban green space across public areas and utilities Incorporate green solutions into private & public planning Building Design regulations

Box 5: An overview of Warsaw's current context including climate hazards and future risks (UAP, 2019)

9.2 Urban Adaptive Capacity Analysis

Table 14: Analysis of the Urban Adaptive Capacity factors for Warsaw, including scoring and argumentation

	Adaptive Capacity Factor	Score	Reasoning
Legal Capacity	Adaptation Policy Instruments	3	Poland has national, regional, municipal and local level adaptation policies. These policies generally consist of well-defined legislative targets and standards, although the relevance for implementation is often unclear. Instruments to enforce CCA within spatial planning lacking.
	Policy Cohesion	4	Strong synergy between policies, with holistic action being prioritised across municipal departments. Stronger alignment between physical infrastructure sectors than for social or cultural departments.
	Statutory Compliance	3	Low compliance to policy legislation due to competing agendas and extent of private landowners in the city. *"The city administration lacks the regulatory power to control implementation practices. This slows the rate of successful development."* (Respondent 21, Consultant)
	Awareness of Socio-Environmental Equity	4	Extensive awareness of spatially-dependent inequities. Detailed information relating to different climate hazards and interrelating risks. Used to engage local councils and stakeholders in CCA awareness
	Redistribution of Socio-Environmental Equity	2	Limited evidence of instruments for equity redistribution, despite extensive awareness. Constrained by financial and human resource availability.
Institutional Capacity	Institutional Leadership for Adaptation	5	Climate action is a high priority for Mayor Trzaskowski, alongside motivated leaders within the Department for Air Protection and Climate Policy
	Organisation of Adaptation Implementation	4	Adaptation is relatively well organised within the municipality, aided by clear responsibilities and the existence of inter-departmental working groups
	Vertical Coordination of CCA	4	There is good connectivity between national- and municipal-level priorities on climate adaptation. There remains some conflict due to political nature of governmental administrations
	Horizontal Coordination of CCA	5	The Department for Protection and Climate Policy places high value on horizontal cooperation and partnerships. Participation in working groups, EU-level projects and research projects legitimises and optimizes such relationships. *"Warsaw is well-developed in terms of horizontal and vertical coordination. The EIA and Adaptation plan were developed synergistically, using consultation with other offices and participation processes."* (Respondent 22, Environmental Protection Professor)
	Embeddedness of Adaptation Discourse	3	There is evidence of short-term strategic planning for implementation, with particular progress made towards societal engagement. Many sectors do not have adaptation well embedded in longer-term planning. *"Adaptation is usually facilitated by investment. There is lower general motivation across departments to do CCA without investments."* (Respondent 21, Consultant)
	Institutional Responsibility	4	Clearly distinguishable key actors within municipal departments. Implementation is particularly driven by team in Air Protection and Climate policy department
	Institutional Transparency	3	Participation and transparency are key agendas for this municipal administration. Larger-scale infrastructure projects remain less transparent but local-scale projects display strong measures for maintaining transparency. *"The strategy proposed initially contained sections on implementation. But these were removed before publication."* (Respondent 21, Consultant)
	Institutional Accountability	4	The fragmented nature of city council administration in Warsaw is useful for generating accountability. The national-level emphasis on meeting CAP commitments is also a motivation for generating acceleration and implementation of CCA measures.
	Ambition and Goal Setting	3	The city has good practice in terms of temporal targets but many are ill-defined and lack concrete plans for implementation. There is little clarity on goals for integration of blue-green or adaptive solutions within existing grey infrastructure
Resource Capacity	Financial Availability	4	There is a high dependence on EU-level funding and a strong focus on larger infrastructural projects. Subsidies are now catalysing small-scale interventions. *"Currently, Warsaw offers attractive subsidies for devices used to retain and use rainwater on location, educational activities, programs for schools, and workshops."* (Respondent 20, Municipal Planner)
	Willingness to Pay	3	There is a broad reluctance to pay for adaptation interventions, outside of the Department for Air Protection & Climate Policy, and the Environmental Protection Team. The UAP explicitly mentions co-benefits but there is limited evidence for the utilization in mainstreaming or accelerating action.
	Financial Continuity	3	Governmental funding is highly competitive and thus may constrain adaptation innovation. It is also evident that EU funding pathways reduce diversity of solutions. *"Funding is pre-packaged which limits its flexibility. And it is sometimes easier to implement grey infrastructure that does not explicitly relate to adaptation. Less funding might actually motivate targeting of multiple benefits."* (Respondent 21, Consultant)

	Human Manpower	4	Practitioners feel well supported in terms of human resources, especially with the utilisation of experts from local knowledge institutes. Partnership for Climate also fosters manpower for CCA interventions.
	Adaptation Expertise	4	Institutional actors generally have high skill and knowledge, although CCA is a new topic to differing sectors across the city. Partnerships with PINE and SWPS
	Organisational Resource Flexibility	2	There is limited evidence for resource flexibility in Warsaw. Sectoral departments remain siloed, apart from those explicitly working on climate change or environmental protection.
	Diversity of Solutions	3	There is limited diversity of potential solutions implemented in Warsaw. This may be related to unwillingness to experiment with measures, and also to the availability of funding from the EU for established methodologies.
	Integrated Adaptive Planning	2	Low evidence of adaptive planning principles for planning and implementation. Shorter-term risks are primary focus, despite the awareness of hazards towards 2050. *"There is a lack of longer-term holistic planning. In terms of innovation, financial planning and funding allocation."* (Respondent 21, Consultant)
Social Capacity	Active Network Participation	4	There is a specific working group accountable for maintaining participation in global networks like C40. Focus on funding and investment pathways explicitly links participation to implementation.
	Integration of Network Knowledge in CCA	3	C40 case studies and methodologies intermittently used in practice. The partnerships are primarily utilized to mobilise funding for implementation of adaptation measures, rather than broadly share knowledge and expertise
	Stakeholder Participation	4	A critical feature of the UAP and Warsaw 2030 plan. Implementation of working sessions and collaborative tools seen as a key feature of adaptation implementation. Consensus has lower influence due to municipal leadership on most projects.
	Cooperation with the Community	4	Communities seen as important for maximising co-benefits of adaptation. Educational tools are a means for low-cost engagement with society. Explicit focus in UAP and Warsaw 2030 Plan on improving civic engagement via formal communications strategies or working group
	Community Adaptation Initiatives	3	Subsidies and neighbourhood initiatives utilised to motivate community-led action, particularly for rainwater management and harvesting. Other measures include guided walks through green spaces, creation of educational material for citizens and schools (Respondent 20). *"There is a launch of a new programme for greening roofing and water retention basins to tackle flooding and heat stress. There are education measures for schools and communities too."* (Respondent 21, Consultant)
Learning Capacity	Local Knowledge Integration	5	High cooperation between expert bodies and municipality to deliver knowledge on climate hazards and impacts
	Risk & Vulnerability Assessments	4	Strong risk assessing with detailed information available for all 18 city districts and correlated against uncertainty thresholds. R&V explicitly addressed in UAP and Warsaw 2030.
	Adaptation Policy Assessments	3	Limited evidence of policy assessments for implementation. Reflection on policy levers is limited. There are formalised bi-annual targets for assessing and evaluating adaptation policy performance.
	Collaborative Learning	4	Collaboration and citizen engagement is a high priority. Stakeholders typically responsible for knowledge co-production, whilst experts are responsible for solution generation and implementation. Aided by targets for improving citizen participation and engagement, and for utilizing NGO and corporate skills and resources to drive adaptation (Respondent 20).
	Monitoring & Evaluation	3	M&E is lacking within adaptation in Warsaw. There are formalised frameworks and procedures but they are not readily applied. Data availability on performance of adaptation is limited due to relatively recent introduction of UAP. Monitoring & Evaluation practices are emerging slowly in relation to adaptation. This is potentially linked to the low embeddedness of adaptation in different city departments but also due to the lack of holistic connectivity between adaptation, spatial planning and environmental protection
	Reporting & Application	3	Reporting is constrained by limited M&E processes. Reporting of performance of water management infrastructure has been used to highlight co-benefits of green-blue intervention. *"Sharing knowledge and evaluation are key issues for effective adaptation. These are issues requiring constant reinforcement at the city office."* (Respondent 20, Municipal Planner)
Transformative Capacity	Multi-Benefit Interventions	3	Co-benefits are not explicitly used to drive adaptation in Warsaw. Environmental protection and adaptation are not intuitively linked in practice. Lastly, partnerships with businesses and knowledge institutes primarily relates to knowledge generation. There is limited interconnectivity with these experts and innovators in relation to implementation of CCA measures.
	Synergy Optimization	3	Connectivity between UAP and Warsaw 2030 plan allows for some synergy creation. Project-focused nature of funding acquisition limits research and experimentation with synergy creation. *"Opportunities for retrofitting are often missed. We are lacking a policy for implementation and small scale measures on smaller buildings."*(Respondent 21, Consultant)
	Innovation & Experimentation	3	There are incentives at local/household-scale for experimentation with rainfall harvesting and retention but large scale incentives for experimentation are limited. UAP and Warsaw 2030 Plan mention pursuit of innovation but do not provide concrete methods for implementation of experiments. Limited willingness to experiment with adaptation due to nature of funding acquisition. *"We run the "Partnership for Climate" project, which is a platform for cooperation between organisations. It gives the opportunity to participate in thematic groups, such as sustainable buildings or clean air."*(Respondent 20, Municipal Planner)

9.3 City-Specific Critical Adaptive Capacity Factors

Warsaw lags behind other cities in terms of successful climate adaptation (Figure 11). There are several adaptive capacity factors that have proved valuable for generating success however.

Enabling Factors:

- Awareness of Socio-Environmental Equity: there is good awareness of the public health and economic implications of adaptation inaction in vulnerable city districts, aided by strong risk and vulnerability assessing.
- Horizontal CCA Coordination: this style of governance enables city departments to optimise financial and human resources, and has driven improvements in the technical efficiency of adaptation interventions. It also works to legitimize decision-making and ensure transparency relating to climate action planning.
- Adaptation Expertise: the city has worked to build adaptation expertise within its municipal departments. Where necessary, external partnerships facilitate expertise acquisition.

Factor Interconnections:

- Financial Availability & Solution Diversity: the nature of financial support or availability is both enabling and constraining. The nature of governmental funding cycles in Poland, as well as a reliance on EU centralized funding, means that cities are unwilling to innovate and experiment with measures that do not fit to funding criteria. It also means that the diversity of solutions to climate impacts is fairly homogenous and thus holistic adaptation is very difficult to achieve

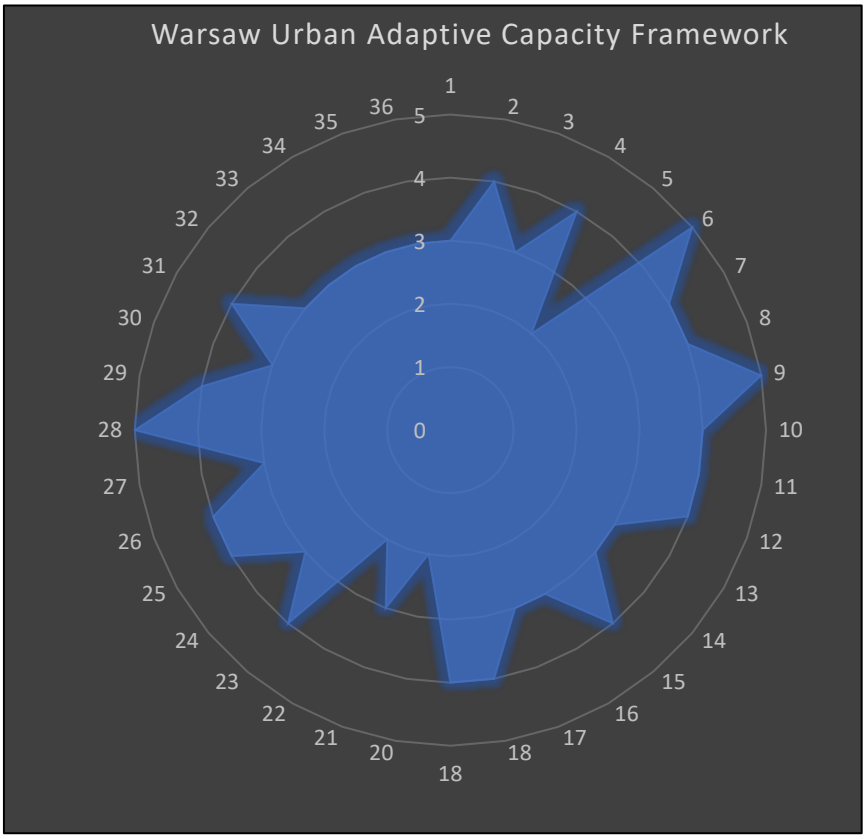
- Multi-Level Interventions: interventions, such as blue-green infrastructures, are not well embedded into spatial planning regulations. Limited embeddedness also constrains related factors such as redistribution of socio-environmental equity and community initiatives.

Actionable Factors:

- Stakeholder Participation: generates momentum towards stakeholder engagement, including academics, business leaders and citizens, particularly for urban blue-greening.
- Policy Cohesion: broader use and enforcement of the UAP can motivate cohesion across policies.

Therefore, critical factors for adaptation success in Warsaw are identified as:

- Awareness of socio-environmental equity challenges relating to CCA implementation (Legal Capacity)
- Horizontal coordination of CCA implementation optimises expertise and works to embed CCA across the city (Institutional Capacity)
- Institutional Responsibility is well-defined in terms of implementing CCA plans
- Financial Availability is maximised via EU funding pathways (Resource Capacity)
- Risk & Vulnerability Assessing is comprehensive across the city for a range of climate hazards (Learning Capacity)



Factor	No	Factor	No
Adaptation Policy Instruments	1	Adaptation Expertise	19
Adaptation Policy Cohesion	2	Organisational Resource Flexibility	20
Statutory Compliance	3	Diversity of Solutions	21
Socio-Environmental Equity Awareness	4	Integrated Adaptive Planning	22
Redistribution of Socio-Environmental Equity	5	Active Network Participation	23
Institutional Adaptation Leadership	6	Integration of Network Knowledge	24
Organisation of Adaptation Implementation	7	Stakeholder Participation	25
Vertical Coordination of CCA	8	Cooperation with the Community	26
Horizontal Coordination of CCA	9	Community Adaptation Initiatives	27
Institutional Responsibility	10	Local Knowledge Integration	28
Institutional Transparency	11	Risk & Vulnerability Assessments	29
Institutional Accountability	12	Adaptation Policy Assessments	30
Adaptation Embeddedness	13	Collaborative Learning	31
Ambition & Goal Setting	14	Monitoring & Evaluation	32
Financial Availability	15	Reporting & Application	33
Willingness to Pay	16	Multi-Benefit Intervention	34
Financial Continuity	17	Synergy Optimization	35
Human Manpower	18	Innovation and Experimentation	36

Figure 11: An overview of Warsaw's Urban Adaptive Capacity factor scoring, with accompanying descriptions

10. Comparative Analysis of Urban Adaptive Capacities

This chapter will compare urban adaptive capacities from across the case studies, explore similarities and differences between adaptive capacity factors and identify significant interconnections between factors. Utilising the Strength-Actionability matrix from Section 2.3, the actionability of specific factors will be assessed, to aid the final identification of critical adaptive capacity factors for successful CCA implementation.

10.1 Comparing Urban Adaptive Capacities across cities

This section will elaborate on the broad trends relating to city-specific adaptive capacity. The five case cities score moderately to strongly in terms of adaptive capacity. Copenhagen and Rotterdam exhibit strongest performance, whilst Berlin and Warsaw perform similarly (Table 15). The positive framing of the Likert-scoring system means that scores exceeding three can be considered to enable adaptation success. Therefore, scores below three are considered to constrain or inhibit success. All cities exhibit adaptive capacity features that stimulate and enable successful adaptation, which is expected given their status as frontrunners.

Table 15: Comparative scoring across sub-capacities and cities

Adaptive Capacity (Average Score per Sub-Capacity)	London	Copenhagen	Rotterdam	Berlin	Warsaw	Inter-City Average per Sub-Capacity
Legal	3.60	4.20	4.00	3.60	3.20	**3.72**
Institutional	4.11	4.22	4.11	3.67	4.00	**4.02**
Resource	3.75	4.25	4.50	3.75	3.12	**3.87**
Social	4.20	4.00	4.00	3.40	3.60	**3.84**
Learning	4.16	3.83	3.83	3.33	3.67	**3.76**
Transformative	3.67	4.67	4.67	4.00	3.00	**4.00**
Total	**3.94**	**4.19**	**4.16**	**3.61**	**3.50**	

Institutional Capacity performs strongly across the cities, as do Resource, Social and Transformative capacities. Legal and Learning capacities score more moderately, with Legal Capacity scoring consistently lower across all cities. Copenhagen, Rotterdam and London exhibit more uniform ACF spider-diagrams. Warsaw and Berlin exhibit poorer ACF performance in relation to Social and Learning capacity, whilst Warsaw exhibits moderate to low Transformative and Resource capacity.

10.2 Analysing Inter-City Urban Adaptive Capacity Factor performances

This section will explore specific sub-capacity trends in terms of ACF performance. Each sub-capacity's similarities and differences will be elaborated, with specific points of interest identified and substantiated.

10.2.1 Legal Capacity

Legal capacity factors are compared in Figure 12. Cities generally cluster towards Adaptation Policy Instruments, Adaptation Policy Cohesion and Socio-Environmental Equity Redistribution as key factors for success.

"The legislation we have now makes it possible to establish WSUD solutions, including green roofs, because we can just enrol climate adaptation as part of the local plans." (Respondent 7, Copenhagen, Municipal Planner).

Local policies are sensitive to the nuances of implementation processes. This enables local authorities and relevant stakeholders to drive more ambitious adaptation practices in some cases. The emergence of policy levers such as London and Copenhagen's "Urban Greening Factor" or Berlin's "Green Area Ratio" are useful tools for embedding socio-environmental equity awareness and redistribution in urban development and adaptation processes.

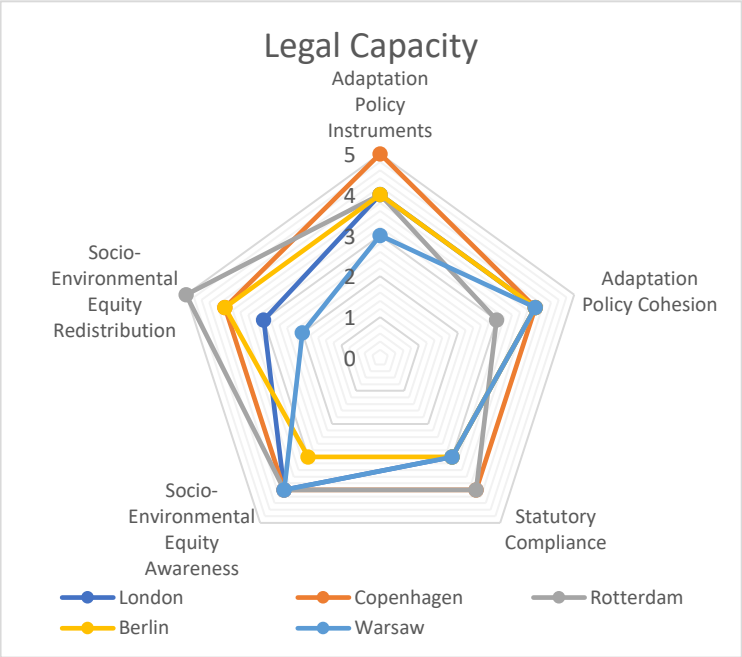
"Generally, the current London Plan is very good in terms of environmental policy approach. The Drainage Hierarchy approach set out in the policy is something we use very frequently in getting improvements made in proposed SuDS schemes." (Respondent 4, London, Local Authority Environmental Policy Officer)

Statutory compliance is a common challenge in all cities, limited by inconsistent application of policy instruments, vague regulatory frameworks and low engagement with CCA by private developers. This factor is highly actionable across all cities. A primary cause of poor compliance remains an embedded focus on finances rather than socio-environmental benefits.

"The London Plan forms the basis of initial planning & design, but the policy doesn't back it up in terms of coordinated enforcement. The bare minimum is being done, especially by property developers." (Respondent 3, London, Environmental Consultant).

Socio-Environmental Equity Redistribution is a critical ACF but requires contextual interpretation. In Copenhagen, Rotterdam and Berlin it is framed as a key outcome of CCA, whilst it is perceived as a useful co-benefit of CCA in London. This is a factor that catalyses improved awareness for CCA measures, offers opportunities for horizontal coordination and stakeholder participation, and is critically focused on transformative generation of co-benefits in urban areas.

"We need to look at understanding the implications and cascades of good CCA intervention. We need to look at public land as valuable and a source of profit." (Respondent 8, CALL Copenhagen).



	London	Copenhagen	Rotterdam	Berlin	Warsaw	Average
Adaptation Policy Instruments	4	5	4	4	3	4
Adaptation Policy Cohesion	4	4	3	4	4	3.8
Statutory Compliance	3	4	4	3	3	3.4
Socio-Environmental Equity Awareness	4	4	4	3	4	3.8
Socio-Environmental Equity Redistribution	3	4	5	4	2	3.6
Average	**3.6**	**4.2**	**4**	**3.6**	**3.2**	

Figure 12: Comparative analysis of Legal Capacity Factors

10.2.2 Institutional Capacity

Comparative analysis revealed that common high-performing ACF's across cities included Adaptation Leadership, Horizontal CCA coordination, Organisation of CCA implementation and Ambition and Goal Setting. Policy champions drive ambition, policy cohesion and CCA embeddedness across cities. Crucially, cities also need multi-scalar champions. This connects the top-down policy direction to grassroots implementation, and improves social and learning practices relating to CCA implementation. Multi-level leadership is also likely to result in effective horizontal coordination of CCA.

"A lot really depends on the mayor and the mayor's advisor. You could get a mayor that is quite strong on the environment, but you also need an advisor with an environment portfolio who really understands these issues as well." (Respondent 5, London GLA)

This interconnectivity extends to adaptation embeddedness. A critical factor, yet it featured differentially across cities. Embeddedness was perceived to mean explicit mention of CCA across organisations in Warsaw, whereas Rotterdam and Copenhagen deemed embeddedness to involve practices of knowledge, resource and attitude sharing towards implementation. This ideological perception actually helped to actively embed CCA across departments.

"The CCA strategy was really something from the city of Rotterdam. It has its own identity, which is really a movement that connects to all stakeholders, requiring us to do it together."
(Respondent 12, Rotterdam, Adaptation Planner)

Horizontal coordination is crucial across all cities. They have identified the necessity of effective cooperation and collaboration in synergizing plans and implementation measures. This is a measure to reduce conflict amongst stakeholders, and is strongly aided by comprehensive adaptation strategies or distinct organisational processes and responsibilities.

"The way we are able to do this (successfully adapt) is that we made it as a comprehensive plan, involving citizens and stakeholders, and made it as a good business case." (Respondent 9, Copenhagen, CCA Implementation Planner)

"Warsaw is well-developed in terms of horizontal and vertical coordination. The EIA and Adaptation plan were developed synergistically, using consultation with other offices and participation processes." (Respondent 22, Environmental Protection Professor)

Institutional Organisation is generally a strong capacity for success. Clear practices, responsibilities and accountabilities help to accelerate and mainstream CCA measures within development. Innovative working groups and expert bodies have been utilised to improve quality and efficiency of CCA interventions.

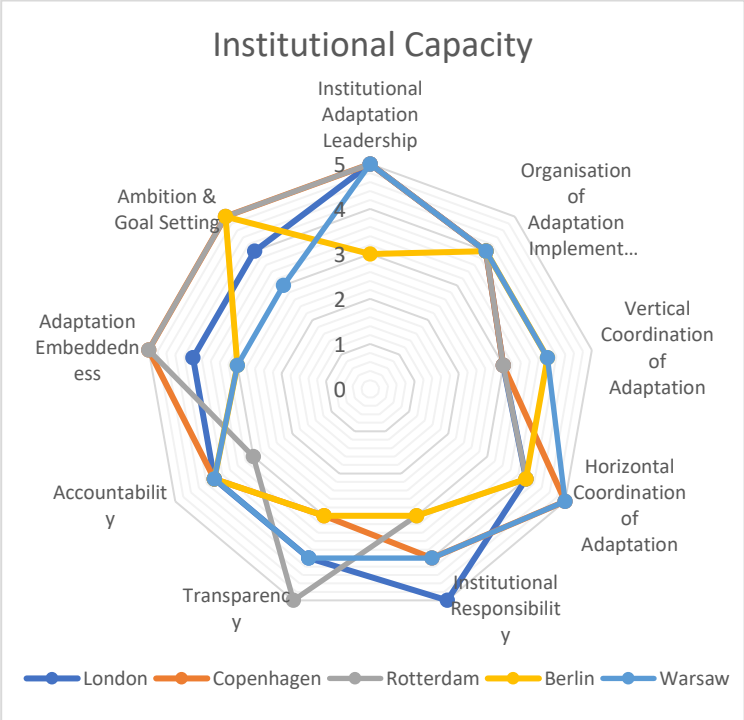
"We get strong support from bodies such as CIRIA and officer groups such as London Drainage Engineer Group." (Respondent 4, London, LA Environmental Policy Officer).

Weaker ACF's include vertical coordination of CCA, and transparency and accountability within CCA implementation processes. In some cities, locally relevant institutions and organisations miss out on involvement in processes, which can reduce local knowledge integration, and also reduce the embeddedness of CCA in communities.

"We help by trying to open up the playing field to enable actors to offer to assist with different parts of the task. Smaller businesses can provide innovative solutions from their local experience, rather than large consultancies dominating." (Respondent 8, CALL Copenhagen).

Ambition is high across all cities. CCA is acknowledged as a key component of future development and is integrated across multiple sectors and policies. Ambition should have clear boundaries and targets, especially relating to urban greening and SUDS implementation, to match the urgency of the climate challenge.

"There is no way we can keep single-use surfaces so we have to get smart and multi-functional in that sense." (Respondent 11, Roof Real Estate Planner).



	London	Copenhagen	Rotterdam	Berlin	Warsaw	Average
Institutional Adaptation Leadership	5	5	5	3	5	**4.6**
Organisation of Adaptation Implementation	4	4	4	4	4	**4.0**
Vertical Coordination of Adaptation	3	3	3	4	4	**3.4**
Horizontal Coordination of Adaptation	4	5	4	4	5	**4.4**
Institutional Responsibility	5	4	3	3	4	**3.8**
Institutional Transparency	4	3	5	3	4	**3.8**
Institutional Accountability	4	4	3	4	4	**3.8**
Adaptation Embeddedness	4	5	5	3	3	**4.0**
Ambition & Goal Setting	4	5	5	5	3	**4.4**
Average	**4.11**	**4.22**	**4.11**	**3.67**	**4**	

Figure 13: Comparative analysis of Institutional Capacity factors

10.2.3 Resource Capacity

Key factors within Resource Capacity include Financial Availability, Adaptation Expertise, and Diversity of Solutions, as seen across several cities.

Financial availability enables ambition, community participation alongside innovation and experimentation. However, as seen in Warsaw, financial availability should be flexible for application of CCA measures across multi-sectoral interventions, in which CCA co-benefits can be targeted and maximised.

"It is about convincing the politicians and citizens about these challenges and uncertainties. If the rain doesn't get worse, then we can build benefits anyway via our approaches."
(Respondent 9, Copenhagen, CCA Implementation Planner)

"Funding is pre-packaged which limits its flexibility. And it is sometimes easier to implement grey infrastructure that does not explicitly relate to adaptation. Less funding might actually motivate targeting of multiple benefits."
(Respondent 21, Warsaw, Environmental Consultant)

The diversity of adaptation expertise and CCA solutions are also strongly enabling factors. Practitioners should be willing to collaborate with utility companies, civil society experts and private sector actors to maximise human, technical and economic resources. A diversity of expertise cascades into experimentation with new solutions and ideas, particularly relevant when looking to connect blue-green and grey infrastructure in cities.

"HOFOR provide the hydraulic experts, and we provide the landscape architects, planners, and other staff. This is a cost-effective way and thinks about how to integrate adaptation with other projects and city development." (Respondent 9, CCA Implementation Planner)

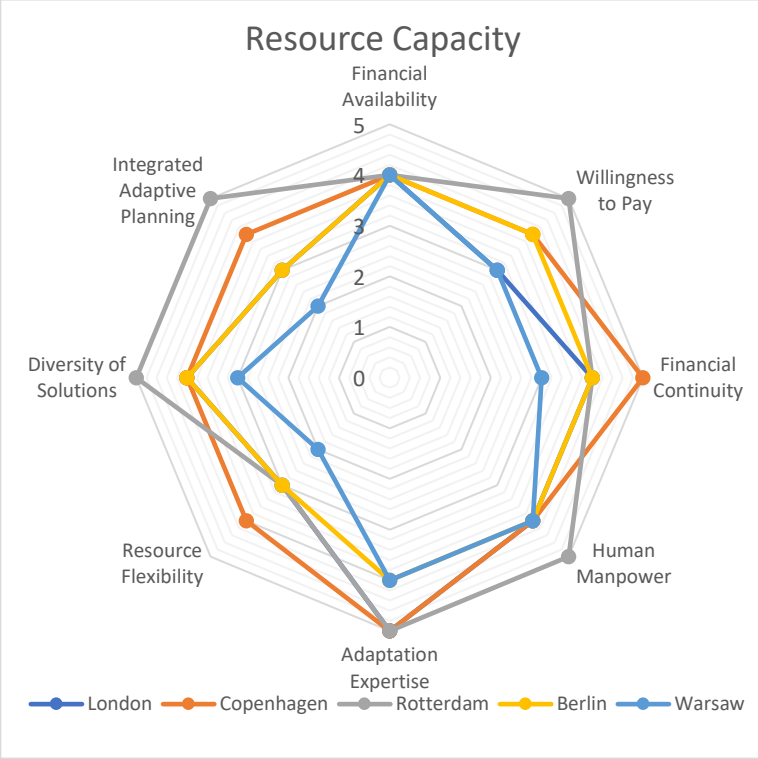
"We need developers to recognize the benefits and necessity of including well-designed SuDS measures into their developments." (Respondent 4, London, LA Environmental Policy Officer).

Cities are looking towards inventive means of resource generation but also expanding willingness to pay and resource flexibility. Copenhagen and Berlin have successfully implemented stormwater tariff systems, which offer financial continuity and place the onus on the citizen or private actor for CCA implementation. Similarly, subsidisation of community initiatives can be another innovative means to maximise resource capacity. Cities are tackling the challenge of extensive privately-owned public space by incentivising private action, which in turn builds awareness, community participation and co-benefit creation.

"Due to the introduction of the split-tariff, it makes a lot of sense to decentralize your water system, but the commercial sector is still missing from this. It has been a principle agent for change." (Respondent 18, Berlin, Stormwater Academic)

Resource Capacity is limited by low resource flexibility and poor adaptive planning. The latter ACF differs in performance across cities, with Rotterdam scoring highly due to the popular nature of dynamic adaptive planning in Dutch environmental management, whilst existing silo thinking and systematic planning processes in other cities mean that practitioners find long-term, dynamic planning challenging to integrate with political and financial cycles.

"Our long-term planning is to 2060. So we need an integrated approach for the next 10 years, understanding where the city is exposed, where opportunities are and where maintenance can be optimized. This allows interconnectivity between problem solutions."
(Respondent 12, Rotterdam, Adaptation Planner)



	London	Copenhagen	Rotterdam	Berlin	Warsaw	Average
Financial Availability	4	5	4	4	4	**4.2**
Willingness to Pay	3	4	5	4	3	**3.8**
Financial Continuity	4	4	4	4	3	**3.8**
Human Manpower	4	4	5	4	4	**4.2**
Adaptation Expertise	5	3	5	4	4	**4.2**
Resource Flexibility	3	4	3	3	2	**3**
Diversity of Solutions	4	4	5	4	3	**4**
Integrated Adaptive Planning	3	4	5	3	2	**3.4**
Average	**3.75**	**4**	**4.5**	**3.75**	**3.12**	

Figure 14: Comparative analysis of Resource Capacity factors

10.2.4 Social Capacity

Social capacity performed consistently across cities. Specific key ACF's did emerge however, specifically relating to Active Network Participation, Stakeholder Participation, and Community Adaptation Initiatives. These factors typically scored higher across high-performing cities, with Copenhagen, Rotterdam and London all citing that Active Network Participation and Community Adaptation Initiatives proved effective mechanisms for building multi-level social capacity.

"The central theme in designing water squares is that they have to be inclusive of local populations, using feedback from local actors. You need to be sensitive to the locality and to stimulating ownership."
(Respondent 12, Rotterdam, Adaptation Planner)

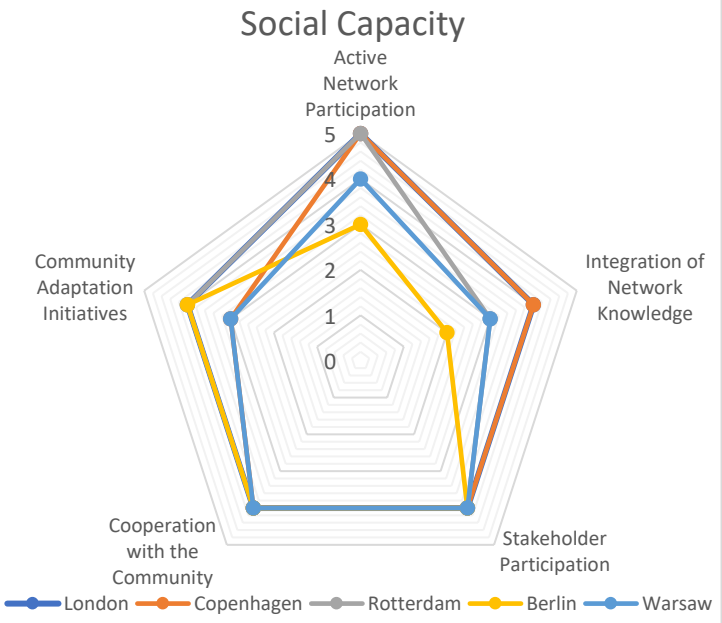
Active Network Participation goes further than transnational municipal networks. Networks and partnerships, such as the KWB (Berlin) and LCCP (London) have proven highly effective in connecting stakeholders, focusing CCA ambitions, and fostering political and public support for accelerating interventions. This operational level of knowledge sharing is highly important for building success.

"In the end, cities can work together better than states because they can share more in-depth knowledge transfer on operational and practical levels."
(Respondent 11, Rotterdam, Roof Real Estate Planner)

Stakeholder participation is an enabling factor but requires careful consideration. Participation should be meaningful and be seen to drive tangible implementation outcomes. Foster ownership and understanding of the benefits of CCA intervention is important. Community initiatives are a critical factor in terms of interconnectedness and actionability. Holistic CCA acceleration require citizen participation, which in turn generates the equity and co-benefits that CCA can provide. Building ownership, engagement, and tangible benefits are key to successful implementation.

"Always get your researchers around the table; to get your boroughs around the table; and to get the community organisations; and as far as practicable to get the users involved." (Respondent 5, GLA)

"We can showcase solutions by establishing demonstration projects targeting innovative solution providers and help them connect to stakeholders."
(Respondent 8, CALL Copenhagen)



	London	Copenhagen	Rotterdam	Berlin	Warsaw	Average
Active Network Participation	5	5	5	3	4	**4.4**
Integration of Network Knowledge	4	4	3	2	3	**3.2**
Stakeholder Participation	4	4	4	4	4	**4**
Cooperation with the Community	4	4	4	4	4	**4**
Community Adaptation Initiatives	4	5	4	4	3	**4**
Average	**4.2**	**4.4**	**4**	**3.4**	**3.6**	

Figure 15: Comparative analysis of Social Capacity factors

10.2.5 Learning Capacity

Cities all perform strongly in terms of local knowledge integration, risk and vulnerability assessing and collaborative learning. The interrelation between the first two factors is important, as scenario generation, spatial modelling, and data communication significantly influences capacity for risk assessing, especially at suitable high-resolution scales for pluvial flood and urban heat assessments.

"If we frame our CCA investments using data that frame who benefits from intervention, it is about quantifying and providing information for investors and funders."
(Respondent 8, CALL Copenhagen).

Collaborative Learning scored strongly across cities. Rotterdam and London are leading the way in terms of multi-level, meaningful collaborations between stakeholders for learning and knowledge generation. This ACF is a strongly interconnecting factor. It relates to social, resource and institutional capacity factors by formalising and legitimising cooperation between stakeholders, and generating accountability in relation to the learning outcomes.

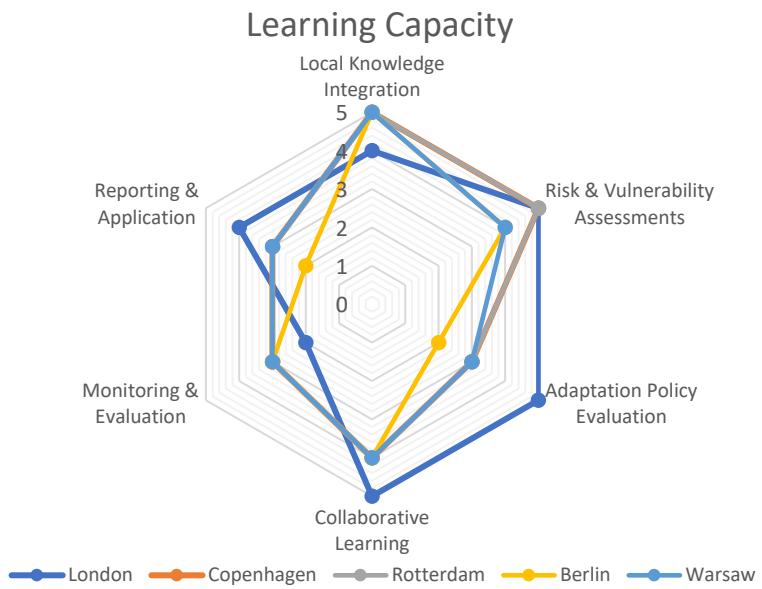
"More inclusion of universities and research institutes to collectivise learning and research is required. It should be improved as it is not perfectly structurally integrated."
(Respondent 11, Rotterdam, Roof Real Estate Planner)

Monitoring & Evaluation and Reporting & Application both score a moderate to poor performance, symptomatic of a focus on implementation with low inclusion post-ante evaluation or monitoring processes. As cities shift towards retrofitting of CCA interventions, new framings such as Living Labs or Integrated Urban Renewal zones could provide momentum for improving M&E. There may be actionable opportunities to more strongly regulate M&E processes within development tenders or planning processes.

"The KWB have recognized that existing structures need decentralisation. In the past, the easy option was always smarter design of new buildings. But without retrofitting you are just tinkering around at the edges. Greening roofs, stormwater harvesting and pervious paving are also ways forward."
(Respondent 18, Berlin, Stormwater Academic)

"There is this whole idea of a Living Lab as a vehicle for solving complex problems. Monitoring and evaluation is critical. We need to build solutions with added value."
(Respondent 8, CALL Copenhagen).

Cities are increasingly looking towards smart, technological development. CCA interventions can complement this transition by integrating M&E practices, generating knowledge and data, and targeting holistic system change. Citizen science, co-creation platforms and large-scale community initiatives may be useful vehicles for embedding M&E within CCA interventions.



	London	Copenhagen	Rotterdam	Berlin	Warsaw	Average
Local Knowledge Integration	4	5	5	5	5	**4.8**
Risk & Vulnerability Assessments	5	5	5	4	4	**4.6**
Adaptation Policy Evaluation	5	4	2	2	3	**3.2**
Collaborative Learning	5	3	4	4	4	**4**
Monitoring & Evaluation	2	3	3	3	3	**2.8**
Reporting & Application	4	5	3	2	3	**3.4**
Average	**4.17**	**4.17**	**3.67**	**3.33**	**3.67**	

Figure 16: Comparative analysis of Learning Capacity factors

10.2.6 Transformative Capacity

Rotterdam and Copenhagen score very strongly in terms of Transformative Capacity. Their international reputations as innovative adapters, combined with a focus on adaptation as a multi-sectoral value creation tool, means they are well-placed in terms of transforming urban systems via adaptation. London and Berlin also score strongly, constrained by lower levels of formalized experimentation. Warsaw differs, with transformative capacity likely constrained by lower financial availability, poorer adaptation embeddedness and an ideological focus on larger-scale adaptation projects.

Multi-benefit interventions are important factors for success. Targeting, quantifying and communication the benefits of CCA intervention, beyond risk and vulnerability reduction, are highly useful for generating support, embedding CCA across sectors, and encouraging innovation and experimentation.

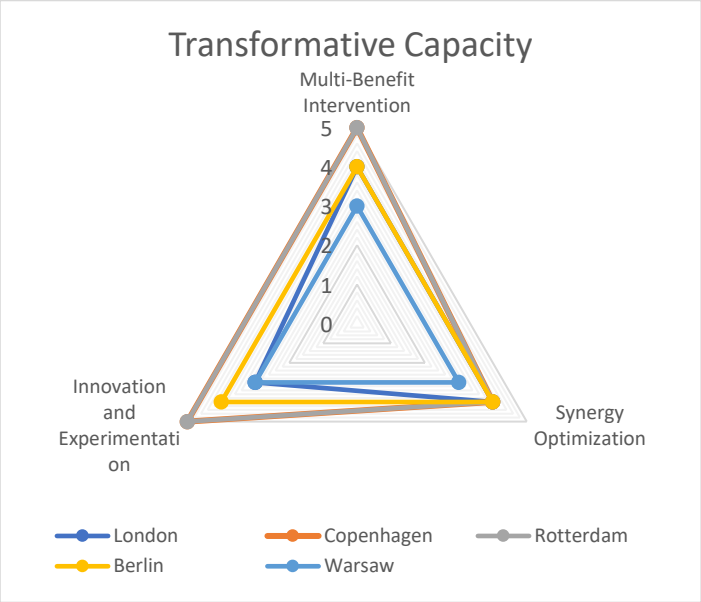
"There is an incentive in terms of provision of integrated, multifunctional SuDS measures that can help make developments more desirable and improve quality of life for occupants." (Respondent 4, London, LA Environmental Policy Officer).

Berlin, Rotterdam, Copenhagen and London have all embedded utility providers within their adaptation programs. This places synergisation opportunities as central to CCA implementation, and enables the identification of optimal opportunities for more transformation change to urban systems.

"Transformation into something better can take many shapes and forms, it can be about climate sustainability but certainly also about the social sustainability, which is extremely important." (Respondent 7, Copenhagen, Municipal Planner).

Innovation and experimentation are core elements of CCA strategies in Rotterdam and Copenhagen. It is the framing of innovation and experimentation that has generating additional value for the city, via SmartCity projects, visible and marketable pilot projects, and the generation of commercial partnerships with research institutes and private entrepreneurs.

"You don't always need to prove that you got a return on investment, we should also accept that we have in turn created a nicer and better place."(Respondent 11, Rotterdam, Roof Real Estate Planner).



	London	Copenhagen	Rotterdam	Berlin	Warsaw	Average
Multi-Benefit Intervention	4	4	5	4	3	**4**
Synergy Optimization	4	5	4	4	3	**4**
Innovation and Experimentation	3	5	5	4	3	**4**
Average	**3.67**	**4.67**	**4.67**	**4**	**3**	

Figure 17: Comparative analysis of Transformative Capacity factors

10.3 Identifying critical adaptive capacity interconnections

10.3.1 Critical Factor Interconnections

Critical interconnections between factors are elaborated below. Via individual and comparative analysis, it was possible to identify ACF's that exhibited clear interconnections. Experiences surrounding adaptation implementation highlight how cascading effects linking to insufficient capacity within a specific domain can inhibit progress. Practitioners should prioritize the improvement of interrelating capacities in order to work to longer-term sustainability and success. These connections will be visualised and briefly elaborated (Table 16 & Figure 18) in order to connect empirical and theoretical findings.

Table 16: An overview of ACF interconnections, accompanied by argumentation and case examples, see further elaboration in Appendix 6

Interconnecting Factors	Argumentation	City Examples
Adaptation Policy Instruments and Institutional Embeddedness of CCA	• Holistic policies can embed CCA across sectors and reduce transaction costs between stakeholders (Kern, 2010). Costs, like negotiating political disagreements or incompatible values and interests, limit the pace and extent of adaptation (Oberlack, 2014). • It is clear that ineffective multi-level policies constrain embeddedness of adaptation across governance sectors and practitioner groups.	Berlin, London and Warsaw all experience challenges in overcoming sectorality but a shifting focus, facilitated by holistic policy instruments, towards new forms of organisation and governance is proving successful.
Policy Cohesion, Responsibility & Horizontal Coordination	• The presence of overarching, multi-sectoral policy levers, specifically the Cloudburst Management Plan, Rotterdam Adaptation Strategy and London Environment Strategy have been used to build policy cohesion. • Building horizontal coordination can involve private or semi-private actors via legislative "nudges", rather than enforcing participation. This is a cost-effective way for municipalities to diversify funding and resource pathway responsibilities, while increasing their influence on privately-owned land.	In the case of the Tåsinge Square and Vesterbro developments (Copenhagen), climate adaptation legislation was used to connect practitioners and stakeholders across governance scales, which had otherwise been limited under normal planning and implementation practices
Financial Availability, Adaptation Expertise, Innovation & Experimentation and Monitoring & Evaluation	• Financial and technical resource availability are especially important for the innovation and M7E component of CCA implementation. • In all cities, financial resources closely accompany technical capacities. Experts are frequently utilized at critical junctures in adaptation planning and implementation, but not necessarily retained for the duration of a project.	In Rotterdam, experimentation and implementation were seen as "no-regret" processes, thus often accompanied by inadequate M&E. In London, lack of expertise inhibited M&E and experimentation processes.
Active Network Participation, Transparency & Accountability	• Municipal networks have generated significant momentum towards climate adaptation (IPCC, 2014; Bellinson & Chu, 2018). They offer formalized structures within which to share best practices and distribute knowledge (Hoffmann, 2011). • Expert-led, semi-public bodies to generate a niche in which they facilitate public and private sector cooperation, and drive good practices of inclusivity, transparency and accountability (Respondent 2 & 17).	In Rotterdam and Copenhagen, network participation facilitated study-trips, international conferences and working sessions, which offered access to expertise, but also proved valuable in generating transparency and accountability within the municipalities themselves (Respondent 2 & 10).

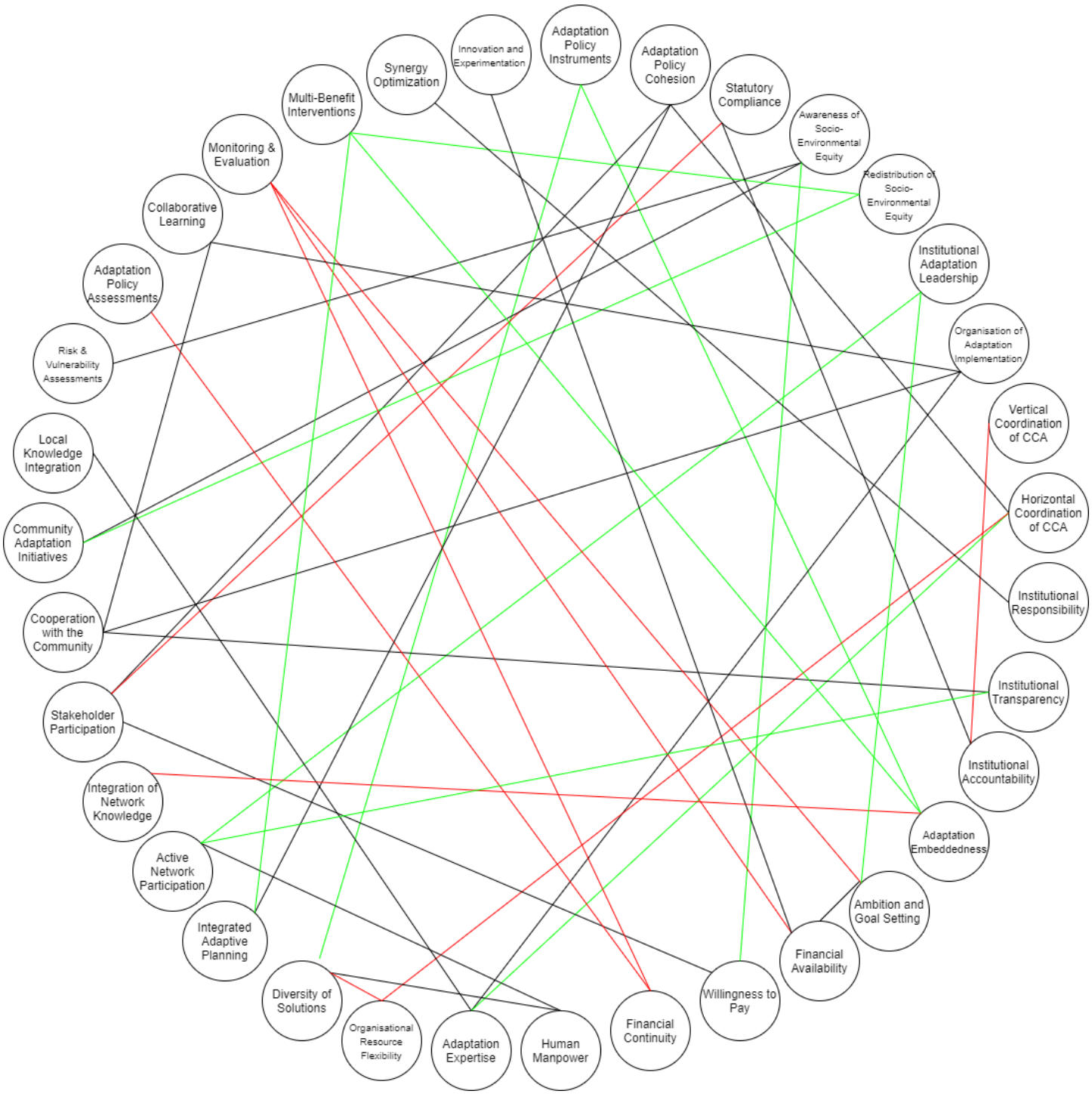


Figure 18: Characterising the interconnections between adaptive capacity factors, where green connectors indicate an enabling connection, red connectors indicate a constraining or poor performing connection, and black connectors highlight moderate connections

10.4 Actionability Assessment

A final methodological step aimed further stratify critical adaptive capacity factors. An actionability analysis helps to reveal where high-performing ACF's may have the potential for further improvement, and which low-performing ACF's might be quickly actionable to accelerate CCA success. The actionability matrix (Figure 19) reveals that several factors provide high potential for improving adaptive capacity for successful adaptation implementation. The identified factors will likely be relevant in the short- to medium-term, although improvement of certain factors may provide longer-term value for the cities (Table 17).

Table 17: An overview of critical actionable factors, and potential approaches for actioning, derived from case city best practices

Actionable Factor	Potential Approach
Monitoring & Evaluation	Procedural demands for M&E and integration with SmartCity concept
Statutory Compliance	Alignment and strengthening of legislative regulations for CCA implementation across multiple sectors
Innovation & Experimentation	Strengthening partnerships and networks with industry, academia and entrepreneurs
Redistribution of Socio-Environmental Equity	Improved data collection and synergisation of urban development agendas, via blue-green infrastructure or urban greening
Solution Diversity	Integration of no-regret ideology into implementation and engagement with small-scale private actors
Organisational & Resource Flexibility	Targeting agile and flexible governance structures alongside innovative resource generation and management
Community Initiatives	Expansion of education and subsidisation schemes to expand private-sector CCA success, and embedding of Living Lab approach into policy & organisations

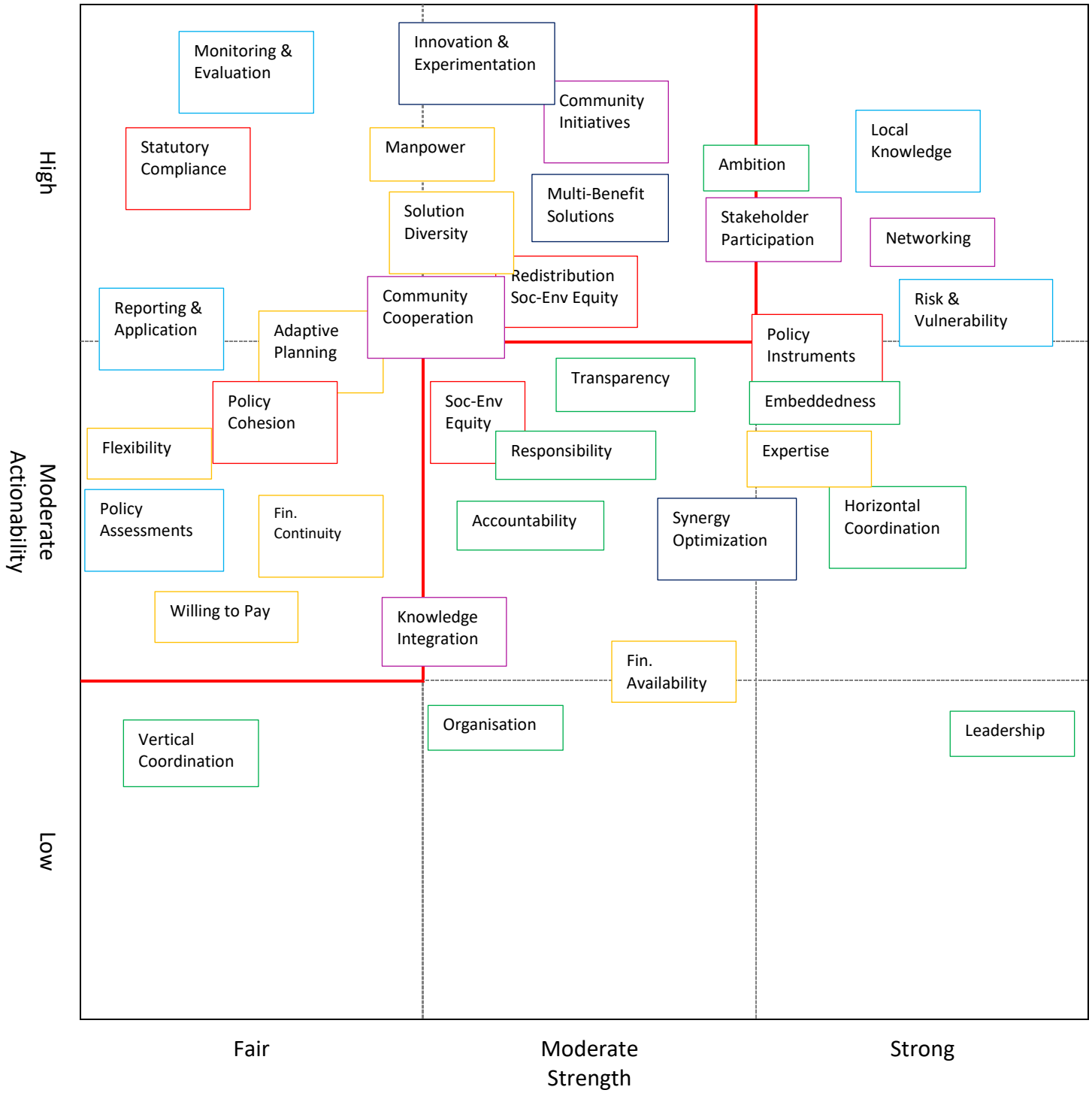


Figure 19: An Strength-Actionability matrix for the Adaptive Capacity Factors from across all 5 cities, with factors in the top-left corner the focus for rapid improvement, and top-central factors enabling further improvement of critical factors.

10.5 Critical Adaptive Capacity Factors

Triangulating city-specific critical factors, ACF interconnections, and actionability assessments provides a means of identifying critical adaptive capacity factors for successful climate change adaptation. Further validation of critical factors by experts has helped to refine their selection. Figure 20 outlines a selection of critical factors for each sub-capacity. These will be further elaborated in section 12.1.

Figure 20: The Urban Adaptive Capacity framework, with critical adaptive capacity factors identified for each sub-capacity.

11. Discussion

11.1 Introduction

In order to address a knowledge gap relating to the role of adaptive capacities in successful implementation of urban climate change adaptation measures to water-related hazards, an analytical framework was created. This framework operationalised influential adaptive capacity conditions, using adaptive capacity factors (ACF), to provide insights into the underlying adaptation processes across five case-cities to allow comparative analysis. This section reflects upon the analytical framework whilst discussing the research findings and methodology.

11.2 Evaluating Urban Adaptive Capacity as an Analytical Tool

This research aimed to identify what conditions and factors influence inter-city commonalities and differences, via comparative analysis of empirical data and theoretical concepts in relation to adaptive capacity for climate change adaptation. It was hypothesised that successful adaptation to water-related hazards would be accompanied by higher adaptive capacity, manifested in the presence of common critical urban adaptive capacity factors. Targeting these critical factors will contribute to higher adaptive capacity and more successful CCA implementation.

The analytical framework proved useful for assessing adaptive capacities for successful urban CCA to water-related hazards. The comprehensive nature of the framework provided detailed and appropriate results for the differing city contexts. Application of the analytical framework incorporated several considerations including clear definition of the urban contexts that underpin the functioning of adaptive capacities, to assess the presence and significance of conditions and factors. Case cities were deliberately selected in terms of minimum difference but careful interpretation of results, sensitive to their contextual framing, was required to ensure the identification of critical adaptive capacity conditions and factors.

Complexity of urban systems challenges successful CCA implementation. The concept of adaptive capacity is a useful tool for negotiating these challenges. Founding the analytical framework upon the holistic and comprehensive framing of adaptive capacity allows for an appreciation of the nuances and interconnections between capacities for success. By fragmenting the framework into conditions and operational factors, a detailed understanding of process dynamics and phenomena can be obtained. This understanding and identification of key factors and processes allows the framework to be utilized to identify the impacts of measures to improve adaptive capacity. Interconnections between conditions and factors can be used to identify strategic interventions that may result in improvement of multiple enabling capacity factors. This could be a tool to improve the efficiency and effectiveness of measures for successful CCA implementation as it is inherently multi-sectoral and integrates principles of dynamic adaptive planning (Haasnoot *et al*., 2015).

Implementation of CCA measures for pluvial flooding or drought is action-focused. Adaptive capacity is similarly implementation focused. As argued by Fazey *et al*. (2018) and city stakeholders (Respondents 8, 10 & 11), greater focus should be placed on "doing" adaptation in order to scale up knowledge generation and seize "no-regret" opportunities. Adaptive capacity conditions and factors integrate analysis of what cities and practitioners both "have", and "are doing", to drive successful CCA. Whilst this framing is open to interpretation by practitioners, by blurring the boundary between the presence of a condition and its practical application, this positivist approach to adaptive capacity is a practical means of improving success. It explicitly highlights best practice rather than a more passive evaluation of the characteristic approaches to CCA in different cities.

11.3 Evaluating the Research Methodology

Factor interconnectedness and actionability were assessed to aid the refinement of critical ACF's. This approach aimed to provide tailored and relevant recommendations for acceleration and mainstreaming of adaptation, which is more robust against the criticisms of poor transferability of case-study specific adaptation evaluations (Bulkeley, 2013).

Factor interconnectedness was founded upon simplistic connectivity between ACF's, based upon practitioner and policy analysis insights. Whilst a suitable method to rapidly identify highly influential factors, it may have been valuable for participants to have identified or weighted factor connections themselves. This could be a valuable addition to the analytical methodology utilised. Actionability assessment was undertaken to guide the identification of short-term opportunities for accelerating adaptation and to synthesise critical adaptive capacity factors. By introducing an actionability assessment, the critical aspects of adaptive capacity from the five cities can be directly utilised to improve adaptation success and mainstream best practices across contexts. In relation to implementation inertia, a simplistic and quick methodology such as the actionability matrix may help to accelerate action. Furthermore, it may enable the selection of actionable factors that can be synergistically improved or enacted. It is important to note that this assessment methodology is inherently subjective. The determination of actionability is dependent on superficial analysis of the aforementioned indicators and fails to capture more detailed constraints to actionability within local authorities.

11.4 Research Limitations

Limitations arose relating to the analytical framework, research methodology and additional ACF assessments. One research limitation was that using pre-defined stakeholders limited data collection. This was done to achieve holistic insights into climate adaptation processes but likely fails to be fully representative of all relevant stakeholders. Particularly, the lack of community-level respondents may limit the analytical value relating to social and learning capacities. Each case city was assessed using at least four respondents, however to improve the external validity of this study, a greater number of interviewees would have been valuable. Whilst the analytical approach utilised includes inherent subjectivity, the simplistic scoring matrix worked to mitigate

this, alongside detailed explanation and interpretation of the respondents insights. It may prove valuable for future studies to allow respondents to add specific weighting to their interpretations of adaptive capacity factors. The weighting is also applicable to the actionability assessment. This component is not academically-robust but rather offers a descriptive means of communicating opportunities for action, allowing a iterative refinement of key recommendations for practitioners and policy-makers.

12. Conclusions & Recommendations

12.1 Introduction

Adaptation to climate change is high-priority within many urban areas. Cities are extensively planning and strategizing for adaptation to urban flooding and drought but concerns still arise around the slow progress made in terms of accelerating implementation. Building capacities for adaptation is hypothesized to bring successful CCA implementation, thus the higher the adaptive capacity of a city, the more successful CCA implementation will be. This research aimed to connect theoretical and empirical insights on specific critical adaptive capacities for accelerating climate change adaptation in cities. The primary research question was therefore:

What are critical factors for successful implementation of urban climate adaptation to flood and drought challenges in European cities?

Chapters 1 and 2 outlined the context and theoretical basis of this research resulting in the creation of an adaptive capacity analytical framework, which was framed alongside the research methodology in Chapter 3. Chapters 4 to 9 applied the analytical framework to the five city case studies of London, Copenhagen, Rotterdam, Berlin and Warsaw to yield their respective adaptive capacity performances (SQ2). Chapter 10 identified critical similarities and differences across the cases via comparative analysis of conditions and factors of adaptive capacities (SQ3). Chapters 11 & 12 provides conclusions and discussion points relating to the critical adaptive capacity factors, their actionability and interconnections, and key recommendations for policy and implementation (SQ4 & SQ5).

12.2 Critical Adaptive Capacities for Successful Climate Change Adaptation

This study investigated the adaptive capacities of five European cities in terms of their abilities to deliver and accelerate successful CCA to water-related hazards. The presence of urban adaptive capacities varies across case cities. All cities score moderately to strongly in terms of adaptive capacity for climate change adaptation success. Institutional and Resource capacities are generally strong, whilst weaker performances can be seen for Social and Learning capacities. Transformative capacities vary significantly across city contexts, but this sub-capacity may prove less descriptive due to the smaller number of indicators and the relative infancy of transformational change as a concept within urban climate adaptation. Applying actionability and translation assessments to city-specific adaptive capacity results generated several critical adaptive capacities, which were common across cities and actionable within existing resource and policy scenarios.

Legal Capacity

Critical factors relating to legal capacity were identified as:

Table 18: Critical Adaptive Capacity factors for Legal Capacity

Critical Factor	Impact	Best Practice
Presence of Adaptation Policy Instruments	Accelerate action in public & private sectors	Urban Greening Factors (London, Copenhagen, Berlin)
Policy Cohesion	Catalyse improved inter-sectoral cooperation & city-scale consistency	Cloudburst Management Plan (Copenhagen)
Redistribution of Socio-Environmental Equity	Policy lever to broaden impact of CCA. Motivate CCA as more than an "add-on"	Business Improvement Districts & Integrated Urban Renewal Zones (London, Copenhagen, Rotterdam)

Policy instruments are essential for adaptation. More progressive instruments are naturally accompanied by improved mainstreaming and acceleration of CCA. In order to capture the diversity of opportunities for CCA, instruments also require diversity. Success is enabled by the presence of strong instruments from ambitious policy, zoning regulation, building certification requirements or subsidy incentives.

Policy cohesion facilitates the transition of policy instruments into action. In Rotterdam and Copenhagen, specific consideration of cohesion between instruments and practice were used to optimize processes and costs. This factor also proved effective in raising the profile of CCA for multi-sectoral mainstreaming. The presence of policy documents such as the CMP or Rotterdam Resilience Strategy connect adaptation to principle features of valuable, growing and liveable cities.

Strategic redistribution of socio-environmental equity related to climate change impacts takes place via programs like BID and IUR's. Framed within broader development, they facilitate the mainstreaming and acceleration of CCA as a key measure in cities. Copenhagen, London and Rotterdam have embedded such mechanisms in broader urban development.

Institutional Capacity

The critical factors for institutional capacity are identified as:

Table 19: Critical Adaptive Capacity factors for Institutional Capacity

Critical Factor	Impact	Best Practice
Institutional Leadership for Adaptation	Leadership across scales to overcome inertia and drive progressive CCA action. Can build organisational flexibility and embed CCA in practice	Chief Resilience Officers (London, Rotterdam), Expert Network Facilitators (Copenhagen, London)
Horizontal Coordination of CCA	Drives action and cooperation at the local implementation scale and catalyses multi-sectoral engagement	Multi-Sectoral Working Groups (Resilience Strategy Team, Rotterdam; GLA Water Advisory Group & LCCP, London; BRW, Berlin)
Adaptation Embeddedness	Improve knowledge sharing and cohesion across municipal actors. Improve resource flexibility.	Holistic Urban Development Planning (London Plan; Rotterdam Resilience Strategy, Berlin Environmental Program).
Institutional Responsibility	Generates continuity and transparency around CCA implementation	Dedicated CCA institutional actors (GLA Environment Team, London; Climate Protection Team, Warsaw)
Ambition & Goal Setting	Aspirational goal setting can act to accelerate action. Also relevant to mainstream ambition across private sector actors	10000 Trees Project (Berlin), Copenhagen Zero-Carbon City

Institutional Leadership for Adaptation is flexible. Mayoral drive was actually cited as less important than strategic leaders across institutional scales. Semi-political actors such as Chief Resilience Officers, or high-level, experienced networkers within professional partnerships, were seen as most important for generating acceleration and mainstreaming of CCA. They also played an influential role in horizontal coordination.

Horizontal coordination of CCA is important in influencing diverse public and private sector actors. Whilst this takes the form of engagement with housing corporations in Rotterdam and Copenhagen, London and Berlin have accelerated partnerships with municipal utility providers and knowledge institutions to drive progress and development of successful CCA measures.

Institutional Responsibility for CCA implementation was seen as important enabling factors if managed carefully. This is highly relevant for maintenance and monitoring of CCA measures, such as the creation of distinct partnerships with utility providers.

Ambition & Goal setting was important for generating vision and mainstreaming of CCA across institutions and actors. It can be a critical feature for leveraging financing and motivating innovation and experimentation with CCA measures, such as smart green roofs or multi-functional water squares as seen in Rotterdam.

Resource Capacity

Critical factors relating to resource capacity were identified as:

Table 20: Critical Adaptive Capacity factors for Resource Capacity

Critical Factor	Impact	Best Practice
Financial Availability	Adaptation planning and implementation can account for experimentation and adaptivity with long-term budget availability	44MPA Program (Warsaw), Copenhagen Cloudburst Management Plan, Split-Tariff Systems (Berlin, Copenhagen)
Adaptation Expertise	Multi-sectoral expertise builds best practice and works to accelerate sustainable measures and avoid maladaptation	Semi-Public Expert Institutions (KWB, Berlin; CALL, Copenhagen; GCA, Rotterdam)
Organisational Flexibility	Innovative modes of cooperation and resource utilization have streamlined costs and created new modes of adaptation practice	Inter-borough partnerships (London), Integrated Urban Renewal Zones (Copenhagen).
Integrated Adaptive Planning	Framing of adaptation as open to learning, experimentation and hedging of investment and intervention avoids lock-in and maladaptation.	Adaptive Planning tools (Rotterdam, London); Investment in no-regret measures (Warsaw, Berlin, Rotterdam)

Financial availability is critical for the holistic processes of CCA planning, implementation and evaluation & maintenance. Investment requirements for adaptation will continue to rise in our cities, whilst trade-offs in the face of longer-term sustainability will also be required.

Adaptation Expertise is a key target for many public and private stakeholders. Whilst expertise is predominantly perceived to mean technical expertise, many cities are also investing in expert participation facilitators, communicators and networkers in order to tackle the socio-cultural challenges that accompany urban system transformation.

Organisational flexibility, in terms of resource mobilization and optimization, is emerging as a highly enabling factor as cities face shrinking adaptation budgets. They offer new means of cost optimization and also inadvertently drive improved horizontal coordination and accountability.

Integrated Adaptive Planning encourages action, flexibility and experimentation. Tackling flooding and extreme heat requires measures that can deal with uncertainty, whilst implementation processes also benefit from reduced silo thinking and innovative action pathways.

Social Capacity

Critical factors relating to social capacity were identified as:

Table 21: Critical Adaptive Capacity factors for Social Capacity

Critical Factor	Impact	Best Practice
Active Network Participation	Generate learning and knowledge sharing, and foster horizontal cooperation	LCCP (London), Partnership for Climate (Warsaw)
Stakeholder Participation	Improve ownership and understanding of CCA measures, and mobilise new stakeholders in CCA mainstreaming	Spatial planning regulations for stakeholder participation (Copenhagen, London)
Community (Local-Level) Initiatives	Ensure community-level engagement to generate socio-cultural norms relating to CCA implementation urgency	Social Blue-Greening Initiatives (Groundwork London, Flussbad Berlin)

Active Network Participation, alongside partnerships, drives awareness, learning and best practice acquisition. However, city respondents often believed that participation in networks and partnerships at the national or municipal level drove greater acceleration and mainstreaming. Transnational municipal network participation was, however, influential in generating publicity, financing and momentum for CCA implementation, particularly in Warsaw and Rotterdam.

Stakeholder participation involves generating engagement, ownership and understanding of CCA implementation, proving an effective tool for improving cooperation and reducing conflict. In Copenhagen, strong cultural norms for civic participation drove best practice, whilst niche stakeholders, such as commune networks, were influential participants in driving sewer system disconnection measures in Berlin.

Community initiatives are important tools for generating ownership and highlighting the co-benefits of adaptation. London, Berlin and Rotterdam are particular front-runners in this domain, facilitated by existing cultural norms of community participation and also an emphasis on the role of the "citizen actor" within municipal adaptation policies.

Learning Capacity

Critical factors for learning capacity were identified as:

Table 22: Critical Adaptive Capacity factors for Learning Capacity

Critical Factor	Impact	Best Practice
Risk & Vulnerability Assessments	Robust quantitative appreciation of risks guides adaptive planning and informs robust decision-making	C40 Rapid Climate Risk Assessing (all cities)
Collaborative Learning	Generate broader learning and evaluation across sectors and stakeholders. Tool for generating mainstreaming of CCA awareness	Copenhagen Adaptation Living Labs (Copenhagen); DrainLondon (London)
Monitoring & Evaluation	Drive learning and improvement in project delivery. Tool for aligning utility and infrastructure performance monitoring	SMARTCity Project (Copenhagen); MetroPolder(Rotterdam)

Risk & Vulnerability Assessments are critical for embedding detailed and robust information in decision-making. Cities should prioritize the generation of such data to guide multi-sectoral decision making, and develop adaptation strategies that are resilient in the face of future climatic and socio-economic perturbations.

Collaborative Learning is important for social engagement and CCA embeddedness. The creation of Living Labs, social engagement initiatives, and knowledge institution partnerships can drive collaborative learning and evaluation of CCA implementation. This has been particularly successful in London, with the DrainLondon project providing visible experimentation and innovation across boroughs to cope with river and rainfall flooding via SUDS implementation.

Monitoring and Evaluation is perceived to be a crucially enabling factor for success. Opportunities to evaluate and reflect on adaptation implementation are frequently missed in cities, whilst robust M&E practices offer means to integrate smart solutions and iterative transformation of city infrastructures in the future. Blue-Green Infrastructure particularly benefits from M&E practices that help to motivate uptake and integration with existing grey infrastructure.

Transformative Capacity

Critical factors for transformative capacity were identified as:

Table 23: Critical Adaptive Capacity factors for Transformative Capacity

Critical Factor	Impact	Best Practice
Multi-Benefit Interventions	Systematic improvement to urban environments via adaptation. Re-framing of importance and urgency of CCA	Multi-benefit calculation tools (Rotterdam, London); BIDs and IUR zones (Copenhagen, London, Berlin)
Synergy Optimization	Targeting synergies between sectoral interventions to optimize benefits	Utility Partnerships (Berlin, Copenhagen), Flagship Projects (Thames 2100, London;
Innovation & Experimentation	Willingness to innovate and experiment brings no-regret benefits and drives interest and mainstreaming of CCA	CALL (Copenhagen); MetroPolder (Rotterdam)

Multi-Benefit Interventions are important for catalysing funding availability and willingness to pay and for maximising the efficiency and effectiveness of interventions. Calculation tools can help developers and planners quantify the co-benefits of CCA integration into urban development.

Synergy Optimization will become more crucial in dense, dynamic cities. Resource partnerships, innovative city mapping and novel funding mechanisms are all means for maximising synergies between sectors. In the face of transformative change, synergies will require integration into planning and implementation processes across multiple sectors, thus is highly actionable in terms of leveraging success.

Innovation and Experimentation is perhaps most critical in leveraging interest and understanding of CCA measures, but also in terms of generating private engagement and investment, and commercializing CCA measures to acceleration across the entire urban domain, rather than just public sector space. Private actors will become increasingly important in cities thus diversification of CCA solutions for pluvial flooding, urban heat or drought via experimentation can motivate greater participation and successful implementation across scales.

12.3 Recommendations

By integrating the critical factors for accelerating and mainstreaming climate change adaptation, it was possible to generate several recommendations for adaptation practitioners. These are elaborated below:

- *Embed inspirational leaders across the city:* successful implementation of CCA requires drivers and momentum at all scales, especially in local-level institutions.
- *Foster multi-level governance*: use national and international legislation to inform progressive and ambitious policy and governance at the city scale. Create guidelines, policies and standards for partnerships, horizontal coordination and policy cohesions.
- *Experiment with policy instruments*: by innovating subsidy schemes, sewage levies or funding pathways, adaptation can be mainstreamed across society, and diversify public and private action. Target measures that build funding continuity for urban transitions, motivate solutions that yield net benefits, rather than cost-effectiveness, and frame CCA interventions as "low-hanging" fruit for sustainable, healthy urban systems.
- *Sustain expertise*: by supporting networks and partnerships, integrating experts from planning to evaluation, and building understanding and expertise at a grassroots-level. Innovate with citizen science and community education programs to build resilience and knowledge, and maximise partnerships with interdisciplinary expert institutions to incorporate expertise from planning to implementation to maintenance.
- *Look towards SMART synergies*: integrate smart solutions into implementation and M&E, to maximise efficiency, highlight value creation, and synergize with sectoral actors. Target windows of opportunity for systemic change, build finance and expertise synergies, and use technologies to identify operations and maintenance needs of new CCA interventions.
- *Communicate Experimentation and Innovation:* by providing examples of successful implementation measures, facilitating participation, and building cities as Living Labs. Use these measures to convince stakeholders and citizens that CCA measures are as, or more, robust than existing infrastructures, and create socio-economic and ecological value for cities and their inhabitants.
- *Monitor, Evaluate and Report:* pursue improvements in efficiency and effectiveness of adaptation measures, build transparency and accountability, and facilitate learning and experience sharing.

12.4 Future Research

This research has outlined the role of adaptive capacity in climate adaptation success. Several recommendations have arisen for future research in this field.

- Grassroots, informal adaptation practices are emerging within urban communities, particularly relating to stormwater harvesting, urban greening and heat stress management. The role of adaptive capacity at the individual- or community-scale in accelerating adaptation could provide insight into opportunities for modifying the communication, type, or scale of adaptation measures.
- Moving further into the domain of private-led adaptation, questions arise as to how critical adaptive capacity factors could guide action in the private sector. Operating with different modes of governance, responsibility, resource mobilization and procedural norms may require a modified array of indicators for adaptive capacity. These should take account of interrelationality and co-dependency between private and public actors, yet appreciate more flexible and dynamic natures of private stakeholders.
- There is a need for prioritization of actions and the targeting of levers that facilitate maximum impact. This relates to intervention points for transformation (Meadows, 1999). Using adaptive capacity assessing it may be possible to identify entry points for the leveraging of more accelerated or transformative adaptation. The question therefore arises as to whether adaptive capacities offer a means of targeting and accelerating interventions for significant transformation within urban socio-ecological-technical systems.
- Cities utilise adaptive capacity to inform their climate risk assessments. Operationalising this academic framework to incorporate quantitative indicators could improve its value as a tool for global cities.

13. References

1. Abson, D.J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., Von Wehrden, H., Abernethy, P., Ives, C.D., Jager, N.W. and Lang, D.J. (2017). Leverage points for sustainability transformation. *Ambio*, *46*(1), pp.30-39.
2. Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global environmental change*, *15*(2), 77-86.
3. Adger, W. N., & Barnett, J. (2009). Four reasons for concern about adaptation to climate change. *Environment and Planning A*, *41*(12), 2800-2805.
4. Adger, W. N., Lorenzoni, I., & O'Brien, K. L. (Eds.). (2009). *Adapting to climate change: Thresholds, values, governance*. Cambridge University Press.
5. Anguelovski, I., & Carmin, J. (2011). Something borrowed, everything new: innovation and institutionalization in urban climate governance. *Current opinion in environmental sustainability*, *3*(3), 169-175.
6. Bai, X., McAllister, R. R., Beaty, R. M., & Taylor, B. (2010). Urban policy and governance in a global environment: complex systems, scale mismatches and public participation. *Current Opinion in Environmental Sustainability*, *2*(3), 129-135.
7. Bauer, A., Feichtinger, J., & Steurer, R. (2012). The governance of climate change adaptation in 10 OECD countries: challenges and approaches. *Journal of Environmental Policy & Planning*, *14*(3), 279-304.
8. Bellinson, R., & Chu, E. (2018). Learning pathways and the politics of governing innovations in urban climate change adaptation. *Journal of Environmental Policy and Planning*.
9. Berkes, F. (2009). Evolution of co-management: role of knowledge generation, bridging organizations and social learning. *Journal of environmental management*, *90*(5), 1692-1702.
10. Berrang-Ford, L., Ford, J. D., & Paterson, J. (2011). Are we adapting to climate change?. *Global Environmental Change*, *21*(1), 25-33.
11. Biermann, F. (2007). 'Earth system governance'as a crosscutting theme of global change research. *Global environmental change*, *17*(3-4), 326-337.
12. Biermann, F., Betsill, M.M., Gupta, J., Kanie, N., Lebel, L., Liverman, D., Schroeder, H., Siebenhüner, B. and Zondervan, R. (2010). Earth system governance: a research framework. *International environmental agreements: politics, law and economics*, *10*(4), pp.277-298.
13. Biermann, F., Abbott, K., Andresen, S., Bäckstrand, K., Bernstein, S., Betsill, M.M., Bulkeley, H., Cashore, B., Clapp, J., Folke, C. and Gupta, A., (2012). Transforming governance and institutions for global sustainability: key insights from the Earth System Governance Project. *Current Opinion in Environmental Sustainability*, *4*(1), pp.51-60.
14. Biesbroek, G. R., Termeer, C. J. A. M., Kabat, P., & Klostermann, J. E. M. (2009). Institutional governance barriers for the development and implementation of climate adaptation strategies.

15. Biesbroek, G. R., Klostermann, J. E., Termeer, C. J., & Kabat, P. (2013). On the nature of barriers to climate change adaptation. *Regional Environmental Change*, *13*(5), 1119-1129.
16. Bovens, M., Schillemans, T., & Hart, P. T. (2008). Does public accountability work? An assessment tool. *Public administration*, *86*(1), 225-242.
17. *Browder, G., Ozment, S., Rehberger Bescos, I., Gartner, T., Lange, G-M., (2019). Integrating Green and Gray : Creating Next Generation Infrastructure. World Bank and World Resources Institute. Washington, DC*
18. Bulkeley, H. (2010). Cities and the governing of climate change. *Annual review of Environment and Resources*, *35*.
19. Bulkeley, H. (2013). *Cities and climate change*. Routledge.
20. Bulkeley, H., Castán Broto, V. (2013). Government by experiment? Global cities and the governing of climate change. *Transactions of the institute of British geographers*, *38*(3), 361-375.
21. C40. (2016). LSE Cities: Co-Benefits of Climate Action: A framework for cities. Last accessed online 10/02/20, from https://www.c40.org/researches/c40-lse-cobenefits
22. C40. (2018). Climate Action Planning Framework. Last accessed online 10/02/20, from https://cdn.locomotive.works/sites/5ab410c8a2f42204838f797e/pages/5ae2f92374c4837e195d0e00/files/CAP_Framework_20180608.pdf?1580490089
23. C40. (2019). Urban Climate Action Impacts Framework. Last accessed online 10/02/20, from https://c40-production-images.s3.amazonaws.com/other_uploads/images/1670_C40_UCAIF_report_26_Feb_2.original.pdf?1521042661
24. Carmin, J., & Dodman, D. (2013). Engaging science and managing scientific uncertainty in urban climate adaptation planning. *Successful adaptation to climate change: Linking science and policy in a rapidly changing world*, 220-234.
25. Carmin, J., Dodman, D., & Chu, E. (2013). Urban climate adaptation and leadership: From conceptual understanding to practical action.
26. Chu, E., Anguelovski, I., & Roberts, D. (2017). Climate adaptation as strategic urbanism: assessing opportunities and uncertainties for equity and inclusive development in cities. *Cities*, *60*, 378-387.
27. Cinner, J.E., Adger, W.N., Allison, E.H., Barnes, M.L., Brown, K., Cohen, P.J., Gelcich, S., Hicks, C.C., Hughes, T.P., Lau, J. and Marshall, N.A., (2018). Building adaptive capacity to climate change in tropical coastal communities. *Nature Climate Change*, *8*(2), pp.117-123.
28. CIRIA. (2015). The SuDS Manual. Last accessed online 23/6/20, https://www.ciria.org/Memberships/The_SuDs_Manual_C753_Chapters.aspx
29. City of Copenhagen. (2011). Climate Adaptation Plan. Last accessed online 22/6/2020, from https://en.klimatilpasning.dk/media/568851/copenhagen_adaption_plan.pdf
30. City of Copenhagen. (2012). Cloudburst Management Plan. Last accessed online 22/6/2020, from https://en.klimatilpasning.dk/media/665626/cph_-_cloudburst_management_plan.pdf
31. City of Copenhagen. (2012). Copenhagen: Solutions for Sustainable Cities. Last accessed online 22/6/2020, from

https://www.arup.com/perspectives/publications/research/section/copenhagen--solutions-for-sustainable-cities
32. Committee on Climate Change (2016). UK Climate Change Risk Assessment 2017. Last accessed online 22/6/2020, from https://www.theccc.org.uk/publication/uk-climate-change-risk-assessment-2017/#:~:text=The%20UK%20Climate%20Change%20Risk,Infrastructure
33. Craig, R. K. (2010). Stationarity is dead-long live transformation: five principles for climate change adaptation law. *Harv. Envtl. L. Rev.*, *34*, 9.
34. Creutzig, F., Lohrey, S., Bai, X., Baklanov, A., Dawson, R., Dhakal, S., Lamb, W.F., McPhearson, T., Minx, J., Munoz, E. and Walsh, B. (2019). Upscaling urban data science for global climate solutions. *Global Sustainability*, *2*.
35. Dai, L., Wörner, R., & van Rijswick, H. F. (2018). Rainproof cities in the Netherlands: Approaches in Dutch water governance to climate-adaptive urban planning. *International Journal of Water Resources Development*, *34*(4), 652-674.
36. Danish Government. (2008). Danish strategy for adaptation to a changing climate. Last accessed online 22/6/2020, from https://www.klimatilpasning.dk/media/5322/klimatilpasningsstrategi_uk_web.pdf
37. Danish Nature Agency. (2012). Mapping climate change – barriers and opportunities for action. Last accessed online 22/6/2020, from https://en.klimatilpasning.dk/media/600858/130206_mapping_climate_change_final.pdf
38. Dannevig, H., Rauken, T., & Hovelsrud, G. (2012). Implementing adaptation to climate change at the local level. *Local Environment*, *17*(6-7), 597-611.
39. de Bruin, K., Dellink, R.B., Ruijs, A., Bolwidt, L., van Buuren, A., Graveland, J., De Groot, R.S., Kuikman, P.J., Reinhard, S., Roetter, R.P. and Tassone, V.C., (2009). Adapting to climate change in The Netherlands: an inventory of climate adaptation options and ranking of alternatives. *Climatic change*, *95*(1-2), pp.23-45.
40. Dinshaw, A., Fisher, S., McGray, H., Rai, N., & Schaar, J. (2014). Monitoring and evaluation of climate change adaptation: methodological approaches.
41. Dodds, F., & Bartram, J. (Eds.). (2016). *The water, food, energy and climate Nexus: Challenges and an agenda for action*. Routledge.
42. Dovers, S. R., & Hezri, A. A. (2010). Institutions and policy processes: the means to the ends of adaptation. *Wiley Interdisciplinary Reviews: Climate Change*, *1*(2), 212-231.
43. Dowd, A. M., Marshall, N., Fleming, A., Jakku, E., Gaillard, E., & Howden, M. (2014). The role of networks in transforming Australian agriculture. *Nature Climate Change*, *4*(7), 558-563.
44. Elmqvist, T., Cornell, S., Öhman, M.C., Daw, T., Moberg, F., Norström, A., Persson, Å., Peterson, G., Rockström, J., Schultz, M. and Török, E.H. (2014). *Global Sustainability & Human Prosperity:–contribution to the Post-2015 agenda and the development of Sustainable Development Goals*. Nordic Council of Ministers.
45. Eisenack, K., Moser, S.C., Hoffmann, E., Klein, R.J., Oberlack, C., Pechan, A., Rotter, M. and Termeer, C.J. (2014). Explaining and overcoming barriers to climate change adaptation. *Nature Climate Change*, *4*(10), 867-872.

46. Engle, N. L. (2011). Adaptive capacity and its assessment. *Global environmental change*, *21*(2), 647-656.
47. Environment Agency. (2018), Climate Change Impacts and Adaptation. Last accessed online 22/6/2020, from https://www.gov.uk/government/publications/climate-change-impacts-and-adaptation
48. Ernstson, H., Van der Leeuw, S. E., Redman, C. L., Meffert, D. J., Davis, G., Alfsen, C., & Elmqvist, T. (2010). Urban transitions: on urban resilience and human-dominated ecosystems. *Ambio*, *39*(8), 531-545.
49. European Commission. (2013). An EU Strategy on Adaptation to Climate Change. Last accessed online 10/02/2020, from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0216&from=EN
50. European Commission. (2018a). Climate Adaptation Action Plan. Last accessed online 10/02/2020, from https://ec.europa.eu/futurium/en/climate-adaptation/climate-adaptation-final-action-plan-0
51. European Commission. (2019). The European Green Deal. Last accessed online 10/02/2020, from https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1576150542719&uri=COM%3A2019%3A640%3AFIN
52. European Environment Agency. (2015). The Adaptation Support Tool. Last accessed online 23/6/2020, from https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool/step-2-4
53. Evans, B., Chen, A.S., Prior, A., Djordjevic, S., Savic, D.A., Butler, D., Goodey, P., Stevens, J.R. and Colclough, G., (2018). Mapping urban infrastructure interdependencies and fuzzy risks. *Procedia engineering*, *212*, pp.816-823.
54. Few, R., Brown, K., & Tompkins, E. L. (2007). Public participation and climate change adaptation: avoiding the illusion of inclusion. *Climate policy*, *7*(1), 46-59.
55. Fazey, I., Moug, P., Allen, S., Beckmann, K., Blackwood, D., Bonaventura, M., Burnett, K., Danson, M., Falconer, R., Gagnon, A.S. and Harkness, R., (2018). Transformation in a changing climate: a research agenda. *Climate and Development*, *10*(3), pp.197-217.
56. Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annu. Rev. Environ. Resour.*, *30*, 441-473.
57. Fünfgeld, H. (2015). Facilitating local climate change adaptation through transnational municipal networks. *Current Opinion in Environmental Sustainability*, *12*, 67-73.
58. Füssel, H. M. (2007). Adaptation planning for climate change: concepts, assessment approaches, and key lessons. *Sustainability science*, *2*(2), 265-275.
59. Gawlik, B.M., Easton, P., Koop, S., Van Leeuwen, K., Elelman, R., (eds.), (2017). Urban Water Atlas for Europe. European Commission, Publications Office of the European Union, Luxembourg. 160 pp.
60. Geels, F. W. (2019). Socio-technical transitions to sustainability: a review of criticisms and elaborations of the Multi-Level Perspective. *Current Opinion in Environmental Sustainability*, *39*, 187-201.
61. Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research policy*, *36*(3), 399-417.

62. Gemeente Rotterdam. (2013). Rotterdam Climate Adaptation Strategy. Last accessed online 22/6/2020, from http://www.urbanisten.nl/wp/wp-content/uploads/UB_RAS_EN_lr.pdf
63. Gemeente Rotterdam. (2016). Rotterdam Resilience Strategy. Last accessed online 22/6/2020, from https://www.resilientrotterdam.nl/en/download
64. Gemeente Rotterdam. (2019). Rotterdam WeatherWise Urgency Document. Last accessed online 22/6/2020, from https://www.rotterdam.nl/wonen-leven/rotterdams-weerwoord/Urgentiedocument-2020_EN.pdf
65. German Government. (2008). German National Adaptation Strategy. Last accessed online 22/6/2020, from https://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/das_gesamt_bf.pdf
66. German Government. (2015). Second German National Adaptation Plan. Last accessed 22/6/2020, from https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klimawandel_das_fortschrittsbericht_bf.pdf
67. Greater London Authority. (2016). London Sustainable Drainage Action Plan. Last accessed online, 22/6/2020, from https://www.london.gov.uk/what-we-do/environment/climate-change/surface-water/london-sustainable-drainage-action-plan
68. Greater London Authority. (2016). The London Plan. Last accessed online 23/6/2020, from https://www.london.gov.uk/what-we-do/planning/london-plan/current-london-plan
69. Greater London Authority (2018). London Environmental Strategy. Last accessed online 23/6/2020, from https://www.london.gov.uk/what-we-do/environment/london-environment-strategy
70. Greater London Authority. (2019). The New London Plan. Last accessed online 23/6/2020, from https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan/intend-publish-london-plan-2019
71. Grotholt, M. (2017). Spatial planning responses to climate change. Evaluating and comparing the planning capacity of the spatial planning sector to mainstream climate change adaptation into spatial planning in Gothenburg, Poznan and Utrecht. Last accessed online 10/02/2020, from https://dspace.library.uu.nl/handle/1874/356839
72. Gupta, J., Termeer, C., Klostermann, J., Meijerink, S., van den Brink, M., Jong, P., Noteboom, S., & Bergsma, E. (2010). The adaptive capacity wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. *Environmental Science & Policy*, *13*(6), 459-471.
73. Gupta, J., Bergsma, E., Termeer, C.J.A.M., Biesbroek, G.R., van den Brink, M., Jong, P., Klostermann, J.E.M., Meijerink, S. and Nooteboom, S. (2016). The adaptive capacity of institutions in the spatial planning, water, agriculture and nature sectors in the Netherlands. *Mitigation and adaptation strategies for global change*, *21*(6), pp.883-903.
74. Haasnoot, M., Schellekens, J., Beersma, J. J., Middelkoop, H., & Kwadijk, J. C. J. (2015). Transient scenarios for robust climate change adaptation illustrated for water management in The Netherlands. *Environmental Research Letters*, *10*(10), 105008.
75. Hallegatte, S., Hourcade, J. C., & Ambrosi, P. (2007). Using climate analogues for assessing climate change economic impacts in urban areas. *Climatic change*, *82*(1-2), 47-60.

76. Hegger, D., Lamers, M., Van Zeijl-Rozema, A., & Dieperink, C. (2012). Conceptualising joint knowledge production in regional climate change adaptation projects: success conditions and levers for action. *Environmental science & policy*, *18*, 52-65.
77. Hegger, D. L., Mees, H. L., Driessen, P. P., & Runhaar, H. A. (2017). The Roles of Residents in Climate Adaptation: A systematic review in the case of the Netherlands. *Environmental Policy and Governance*, *27*(4), 336-350.
78. HM Government: Department for Environment, Food and Rural Affairs. (2018). The National Adaptation Programme. Last accessed online 22/6/2020, from https://www.gov.uk/government/publications/climate-change-second-national-adaptation-programme-2018-to-2023
79. Hoffmann, M. J. (2011). *Climate governance at the crossroads: experimenting with a global response after Kyoto.* Oxford University Press.
80. Hoppe, T., van den Berg, M. M., & Coenen, F. H. (2014). Reflections on the uptake of climate change policies by local governments: facing the challenges of mitigation and adaptation. *Energy, sustainability and society*, *4*(1), 8.
81. Hupe, P., & Hill, M. (Eds.). (2015). *Understanding street-level bureaucracy*. Policy Press.
82. Ison, R. (2010). *Systems practice: how to act in a climate change world*. Springer Science & Business Media.
83. IPCC. (2014a). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
84. IPCC. (2014b). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.
85. Karvonen, A., & Van Heur, B. (2014). Urban laboratories: Experiments in reworking cities. *International Journal of Urban and Regional Research*, *38*(2), 379-392.
86. Kates, R. W., Travis, W. R., & Wilbanks, T. J. (2012). Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences*, *109*(19), 7156-7161.
87. Kern, K. (2010, June). Climate governance in the EU multi-level system: The role of cities. In *Fifth Pan-European Conference on EU Politics, Porto, Portugal*.
88. Kern, K., & Alber, G. (2008). Governing climate change in cities: modes of urban climate governance in multi-level systems.
89. Kern, K., & Bulkeley, H. (2009). Cities, Europeanization and multi-level governance: governing climate change through transnational municipal networks. *JCMS: Journal of Common Market Studies*, *47*(2), 309-332.
90. Keskitalo, E. C. H. (2010). Climate change, vulnerability and adaptive capacity in a multi-use forest municipality in Northern Sweden. In *Community adaptation and vulnerability in Arctic regions* (pp. 285-311). Springer, Dordrecht.

91. KNMI. (2014). KNMI'14: Climate Change scenarios for the 21st Century – A Netherlands perspective. Last accessed online 22/6/2020, from http://www.climatescenarios.nl/images/KNMI_WR_2014-01_version26May2014.pdf
92. Koop, S. H., & van Leeuwen, C. J. (2015). Application of the improved city blueprint framework in 45 municipalities and regions. *Water Resources Management*, *29*(13), 4629-4647.
93. Koop, S.H.A., Koetsier, L., Doornhof, A., Reinstra, O., Van Leeuwen, C.J., Brouwer, S., Dieperink, C. and Driessen, P.P.J. (2017). Assessing the governance capacity of cities to address challenges of water, waste, and climate change. *Water Resources Management*, *31*(11), 3427-3443.
94. Koop, S., Monteiro Gomes, F., Schoot, L., Dieperink, C., Driessen, P., & Van Leeuwen, K. (2018). Assessing the capacity to govern flood risk in cities and the role of contextual factors. *Sustainability*, *10*(8), 2869.
95. Lamhauge, N., E. Lanzi and S. Agrawala (2012), "Monitoring and Evaluation for Adaptation: Lessons from Development Co-operation Agencies", *OECD Environment Working Papers*, No. 38, OECD Publishing, Paris, https://doi.org/10.1787/5kg20mj6c2bw-en.
96. Leck, H., & Roberts, D. (2015). What lies beneath: understanding the invisible aspects of municipal climate change governance. *Current Opinion in Environmental Sustainability*, *13*, 61-67.
97. London Borough of Hammersmith and Fulham. (2015). London Borough of Hammersmith and Fulham Updated Surface Water Management Plan. Last accessed online 22/6/2020, from https://www.lbhf.gov.uk/emergencies-and-safety/surface-water-management-plan
98. London Climate Change Partnership. (2014). Adapting dwellings to climate change: Retrofit Advice Tool. Last accessed online 22/6/2020, from http://climatelondon.org/publications/adapting-dwellings-to-climate-change-retrofit-advice-tool/
99. Long, R., & Chaves, M. R. (2018). Bridging the Ocean, Water and Climate Action Goals under the 2030 Agenda on Sustainable Development. In *The Marine Environment and United Nations Sustainable Development Goal 14* (pp. 83-110). Brill Nijhoff.
100. Loorbach, D., & Rotmans, J. (2010). The practice of transition management: Examples and lessons from four distinct cases. *Futures*, *42*(3), 237-246.
101. Marvin, S., Bulkeley, H., Mai, L., McCormick, K., & Palgan, Y. V. (Eds.). (2018). *Urban living labs: Experimenting with city futures*. Routledge.
102. McKinsey and Company. (2020). Climate Risk and Response. Physical Hazards and Socioeconomic Impacts. Last accessed online 23/6/2020, from https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts
103. Measham, T. G., Preston, B. L., Smith, T. F., Brooke, C., Gorddard, R., Withycombe, G., & Morrison, C. (2011). Adapting to climate change through local municipal planning: barriers and challenges. *Mitigation and adaptation strategies for global change*, *16*(8), 889-909.

104. Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and urban planning*, *147*, 38-49.
105. Meerow, S., Newell, J. P. (2019). Urban resilience for whom, what, when, where, and why?. *Urban Geography*, *40*(3), 309-329.
106. Mees, H. L. P. (2010). *Climate Greening London, Rotterdam and Toronto A comparative analysis of the governance capacity of adaptation to climate change in urban areas* (Master's thesis). Last accessed online 23/6/2020, from https://dspace.library.uu.nl/handle/1874/43635
107. Mees, H. L., Dijk, J., van Soest, D., Driessen, P. P., van Rijswick, M. H., & Runhaar, H. (2014). A method for the deliberate and deliberative selection of policy instrument mixes for climate change adaptation. *Ecology and Society*, *19*(2).
108. Mees, H., Crabbé, A., & Driessen, P. P. (2017). Conditions for citizen co-production in a resilient, efficient and legitimate flood risk governance arrangement. A tentative framework. *Journal of Environmental Policy & Planning*, *19*(6), 827-842.
109. UK Ministry of Justice. (2020). A Climate Change Adaptation Strategy. Last accessed online 22/6/2020, from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/885242/moj-climate-change-adaptation.pdf
110. Ministry of Infrastructure & Water Management. (2015). Adaptation to climate change in the Netherlands – studying related risks and opportunities. Last accessed online 22/6/2020, from https://www.pbl.nl/en/publications/adaptation-to-climate-change-in-the-netherlands
111. Ministry of Infrastructure & Water Management. (2018). National Adaptation Strategy Implementation Plan. Last accessed online 22/6/2020, from https://ruimtelijkeadaptatie.nl/publish/pages/125102/nas_implementation_programme.pdf
112. Ministry of Infrastructure & Water Management. (2019). National Delta Programme 2020. Last accessed online 22/6/2020, from https://english.deltacommissaris.nl/documents/publications/2019/09/17/dp2020-en-printversie
113. Mortreux, C., Barnett, J. (2017). Adaptive capacity: Exploring the research frontier. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(4), e467.
114. Moser, S. C., Boykoff, M. T. (Eds.). (2013). *Successful adaptation to climate change: Linking science and policy in a rapidly changing world*. Routledge.
115. Moser, S. C., Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the national academy of sciences*, *107*(51), 22026-22031.
116. Nooteboom, S. G. (2006). *Adaptive networks: the governance for sustainable development*. Eburon Uitgeverij BV.
117. Moser, S. C., & Pike, C. (2015). Community engagement on adaptation: Meeting a growing capacity need. *Urban Climate*, *14*, 111-115.
118. Nowotny, H. (2003). Democratising expertise and socially robust knowledge. *Science and public policy*, *30*(3), 151-156.

119. Oberlack, C. (2014). *Institutional diagnostics of climate adaptation* (No. 01-2014). The Constitutional Economics Network Working Papers.
120. Ostrom, E. (2005). Self-governance and forest resources. *Terracotta reader: A market approach to the environment*, *12*.
121. Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global environmental change*, *19*(3), 354-365.
122. Pelling, M. (2010). *Adaptation to climate change: from resilience to transformation*. Routledge.
123. Pelling, M., & High, C. (2005). Understanding adaptation: what can social capital offer assessments of adaptive capacity?. *Global environmental change*, *15*(4), 308-319.
124. Pelling, M., & Schipper, L. (2009). Climate Adaptation as Risk Manage-ment: Limits and Lessons from Disas-ter Risk Reduction. *IHDP Update*, *2*, 29-35.
125. Pickett, S. T., Cadenasso, M. L., & McGrath, B. (Eds.). (2013). *Resilience in ecology and urban design: linking theory and practice for sustainable cities* (Vol. 3). Springer Science & Business Media.
126. Polish Government. (2013). Polish National Adaptation Strategy. Last accessed online 22/6/2020, from https://klimada.mos.gov.pl/wp-content/uploads/2014/12/ENG_SPA2020_final.pdf
127. Polish Government. (2018). 44MPA Climate Change Adaptation Plans in 44 Polish Cities. Last accessed 22/6/2020, from http://44mpa.pl/wp-content/uploads/2018/12/MPA_NET-ENG-20-12.pdf
128. Ramboll. (2016). Making cities liveable. Blue-Green Infrastructure and its impact on society. Last accessed online 22/6/2020, from https://ramboll.com/-/media/4bbe54dd43b64f1bab07358f8568cfdd.pdf
129. Rauken, T., Mydske, P. K., & Winsvold, M. (2015). Mainstreaming climate change adaptation at the local level. *Local Environment*, *20*(4), 408-423.
130. Raymond, C.M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M.R., Geneletti, D. and Calfapietra, C., (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environmental Science & Policy*, *77*, pp.15-24.
131. Rihoux, B., & Ragin, C. C. (2008). *Configurational comparative methods: Qualitative comparative analysis (QCA) and related techniques* (Vol. 51). Sage Publications.
132. Romero-Lankao, P., & Gnatz, D. M. (2013). Exploring urban transformations in Latin America. *Current Opinion in Environmental Sustainability*, *5*(3-4), 358-367.
133. Rosenzweig, C., Solecki, W. D., Romero-Lankao, P., Mehrotra, S., Dhakal, S., & Ibrahim, S. A. (Eds.). (2018). *Climate change and cities: Second assessment report of the urban climate change research network*. Cambridge University Press.
134. Samaddar, S., Chatterjee, R., Misra, B., & Tatano, H. (2014). Outcome-expectancy and self-efficacy: reasons or results of flood preparedness intention?. *International journal of disaster risk reduction*, *8*, 91-99.
135. Senate Department for Urban Development and the Environment. (2016). Adapting to the Impacts of Climate Change in Berlin. Last accessed online, from

https://www.berlin.de/sen/uvk/_assets/klimaschutz/publikationen/adapting_to_the_impacts_of_climate_change_in_berlin.pdf

136. Senate Department for Urban Development and the Environment. (2016) Climate Neutral Berlin 2050. Last accessed online 22/6/2020, from https://www.berlin.de/sen/uvk/_assets/klimaschutz/publikationen/broschuere_bek_en.pdf

137. Senate Department for Urban Development and the Environment. (2018). Berlin Energy and Climate Protection Program 2030. Last accessed online 22/6/2020, from https://www.berlin.de/sen/uvk/en/climate-protection/berlin-energy-and-climate-protection-programme-2030-bek-2030/#:~:text=The%20Berlin%20Energy%20and%20Climate,Representatives%20on%2025%20January%202018.&text=The%20BEK%202030%20advances%20Berlin's,%E2%80%9Croadmap%E2%80%9D%20towards%20climate%20neutrality.

138. Sherman, M., Ford, J., Llanos-Cuentas, A., Valdivia, M. J., & Bussalleu, A. (2015). Vulnerability and adaptive capacity of community food systems in the Peruvian Amazon: a case study from Panaillo. *Natural Hazards*, *77*(3), 2049-2079.

139. Solecki, W., Seto, K.C., Balk, D., Bigio, A., Boone, C.G., Creutzig, F., Fragkias, M., Lwasa, S., Marcotullio, P., Romero-Lankao, P. and Zwickel, T. (2015). A conceptual framework for an urban areas typology to integrate climate change mitigation and adaptation. *Urban Climate*, *14*, 116-137.

140. State of Green. (2016). White Paper: Urban Innovation for Liveable Cities. Last accessed online 22/6/2020, from https://stateofgreen.com/en/uploads/2016/09/Urban-Innovation-for-Liveable-Cities.pdf

141. Sussman, E., Major, D. C., Deming, R., & Esterman, P. R. (2010). Climate change adaptation: fostering progress through law and regulation. *NYU Envtl. LJ*, *18*, 55.

142. Suckall, N., Tompkins, E.L., Nicholls, R.J., Kebede, A.S., Lázár, A.N., Hutton, C., Vincent, K., Allan, A., Chapman, A., Rahman, R. and Ghosh, T. (2018). A framework for identifying and selecting long term adaptation policy directions for deltas. *Science of the total environment*, *633*, 946-957.

143. Tanner, T., Mitchell, T., Polack, E., & Guenther, B. (2009). Urban governance for adaptation: assessing climate change resilience in ten Asian cities. *IDS Working Papers*, *2009*(315), 01-47.

144. Termeer, C. J., Dewulf, A., & Biesbroek, G. R. (2017). Transformational change: governance interventions for climate change adaptation from a continuous change perspective. *Journal of Environmental Planning and Management*, *60*(4), 558-576.

145. Thames Water. (2019). Building a better future. Enhancing Thames Water's business plan for 2020 to 2025. Last accessed online 22/6/2020, from https://corporate.thameswater.co.uk/-/media/Site-Content/Thames-Water/Corporate/AboutUs/Our-strategies-and-plans/PR19-April/Building-a-Better-Future---April-2019.pdf

146. Tschakert, P., & Dietrich, K. A. (2010). Anticipatory learning for climate change adaptation and resilience. *Ecology and society*, *15*(2).

147. Uittenbroek, C. J., Janssen-Jansen, L. B., & Runhaar, H. A. (2013). Mainstreaming climate adaptation into urban planning: overcoming barriers, seizing opportunities and

evaluating the results in two Dutch case studies. *Regional environmental change*, *13*(2), 399-411.

148. United Nations Department for Economic & Social Affairs. (2018). World Urbanization Prospects Report (Revision). Last accessed online 10/02/2020, from https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html
149. United Nations Framework Convention on Climate Change. (2015). Paris Agreement. Last accessed online 10/02/2020, from https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf
150. Van Aalst, M. K., Cannon, T., & Burton, I. (2008). Community level adaptation to climate change: the potential role of participatory community risk assessment. *Global environmental change*, *18*(1), 165-179.
151. van Ginkel, K.C., Botzen, W.W., Haasnoot, M., Bachner, G., Steininger, K.W., Hinkel, J., Watkiss, P., Boere, E., Jeuken, A., de Murieta, E.S. and Bosello, F. (2020). Climate change induced socio-economic tipping points: review and stakeholder consultation for policy relevant research. *Environmental Research Letters*, *15*(2), p.023001.
152. Van Rijswick, M., Edelenbos, J., Hellegers, P., Kok, M., & Kuks, S. (2014). Ten building blocks for sustainable water governance: an integrated method to assess the governance of water. *Water international*, *39*(5), 725-742.
153. van Valkengoed, A. M., & Steg, L. (2019). Meta-analyses of factors motivating climate change adaptation behaviour. *Nature Climate Change*, *9*(2), 158-163.
154. Verschuren, P., Doorewaard, H., & Mellion, M. (2010). *Designing a research project* (Vol. 2). The Hague: Eleven International Publishing.
155. Vogel, B., & Henstra, D. (2015). Studying local climate adaptation: A heuristic research framework for comparative policy analysis. *Global Environmental Change*, *31*, 110-120.
156. Von Wirth, T., Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Impacts of urban living labs on sustainability transitions: Mechanisms and strategies for systemic change through experimentation. *European Planning Studies*, *27*(2), 229-257.
157. Wardekker, J. A. (2018). Resilience principles as a tool for exploring options for urban resilience. *Solutions*, *9*(1).
158. Warsaw Municipality & European Commission. (2011). Polish River Basin Management Plan – Warsaw. Last accessed online 22/6/2020, from https://www.warszawa.rzgw.gov.pl/
159. Warsaw Municipality. (2011). Warsaw Sustainable Energy Action Plan. Last accessed online 22/6/2020, from https://infrastruktura.um.warszawa.pl/sites/infrastruktura.um.warszawa.pl/files/broszura_angielska.pdf
160. Warsaw Office for Air Quality and Climate Protection. (2018). Warsaw Urban Adaptation Plan. Last accessed online 22/6/2020, from http://zielona.um.warszawa.pl/sites/all/files/strategia_2030_EN.pdf

161. Webb, R., Rissik, D., Petheram, L., Beh, J. L., & Smith, M. S. (2019). Co-designing adaptation decision support: meeting common and differentiated needs. *Climatic Change*, *153*(4), 569-585.
162. Weiss, T. G. (2012). Governance, good governance, and global governance: conceptual and actual challenges 2000. In *Thinking about Global Governance* (pp. 179-200). Routledge.
163. Wise, R. M., Fazey, I., Smith, M. S., Park, S. E., Eakin, H. C., Van Garderen, E. A., & Campbell, B. (2014). Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environmental Change*, *28*, 325-336.
164. Wolfram, M. (2016). Conceptualizing urban transformative capacity: A framework for research and policy. *Cities*, *51*, 121-130.
165. World Bank. (2011). Guide to Climate Change Adaptation in Cities. *Washington, DC: World Bank*. Last accessed online, 20/02/2020, from http://documents.worldbank.org/curated/en/211791468323118474/Guide-to-climate-change-adaptation-in-cities-executive-summary
166. World Resources Institute. (2009). The National Adaptive Capacity Framework. Last accessed online 23/6/2020, from http://pdf.wri.org/working_papers/NAC_framework_2009-12.pdf
167. Young, O. R., Gasser, L. (2002). *The institutional dimensions of environmental change: fit, interplay, and scale*. MIT press.

14. Appendices

Appendix 1: Table of Respondents

Respondent	Role	City
1.	Professor of Environmental Engineering	London
2.	London Climate Change Partnership	London
3.	Environmental Consultant, Climate Change & Infrastructure	London
4.	Local Authority Environmental Policy & Planner Officer	London
5.	GLA Environment Team	London
6.	Urban Planner	London
7.	Municipality of Copenhagen, Adaptation Policy Planner	Copenhagen
8.	CALL Copenhagen	Copenhagen
9.	Adaptation Implementation Planner, Municipality of Copenhagen	Copenhagen
10.	Professor of Landscape Architecture & Planning	Copenhagen
11.	Municipality of Rotterdam, Green Real Estate	Rotterdam
12.	Municipality of Rotterdam, Urban Heat & Drought Advisor	Rotterdam
13.	Municipality of Rotterdam, Climate Adaptation Policy Planner	Rotterdam
14.	Urban Development & Environmental Planner	Rotterdam
15.	Environmental Consultant, Climate Adaptation & Urban Transitions	Rotterdam
16.	Municipality of Berlin, Climate Adaptation Policy Planner	Berlin
17.	Senior Researcher, stormwater Management	Berlin
18.	EU Green Roofs Network Coordinator	Berlin
19.	Environmental Consultant, GreenAdapt Solutions	Berlin
20.	Municipality of Warsaw, Climate Adaptation Policy Planner	Warsaw
21.	Climate Adaptation & Environmental Management Consultant	Warsaw
22.	Professor of Environmental Protection Policy	Warsaw

23.	Municipal Committee Member for Environmental Protection	Warsaw

Appendix 2: Interview Guide

Evaluating conditions for climate adaptation in European cities: Interview Guide

Dear Participant,
This guide is designed to introduce the context of our research and provide some initial concepts that may (and also may not) relate to your role within the city.
Below the following questions there is a Likert scale in which differing adaptive capacities (the conditions and factors that influence the ability to adapt) can be scored. The research questions are designed to guide you into a evaluative score of each capacity in relation to adaptation planning and implementation in your city.

General

1. What is your job role?
2. What form does climate adaptation, particularly relating to water-related hazards (pluvial floods/drought), usually take in your city?
3. In your professional opinion, what is successful climate adaptation?
4. In your professional opinion, what are the key challenges and barriers to successful climate adaptation (water-sensitive urban design/green roofing)?
5. In your professional opinion, what are the critical factors/conditions for ensuring successful climate adaptation?

Capacity Specific

6. Do any legal requirements/formalized responsibilities guide how you design and implement climate adaptation projects? E.g. national/city level requirements
7. Who is primarily responsible for climate change adaptation in your city? How does this stakeholder(s) typically interact and collaborate with other institutional, private or societal stakeholders?
8. What role do networks (e.g. knowledge networks, contact networks) play, in your role, and within broader adaptation implementation?
9. How are resources important in planning and implementing climate adaptation measures, and what affects their availability/your ability to mobilize them? What kinds of resources are primarily prioritized?
10. How do you consider system interrelationships in your role? (E.g. co-benefits, cost/benefits of different actions, feedbacks). How are these communicated & mobilized in planning and adaptation?
11. What role does learning play in climate adaptation in your city – both formally and informally? (E.g. monitoring past projects, data and knowledge sharing, education and training).
12. How do you collaborate/engage with people (citizens, professionals in other fields, government) to plan and implement adaptation measures for extreme weather events/flooding?
13. What are current incentives for stakeholders (private and public) to develop & implement climate adaptation measures (water-sensitive urban design/green roofing)?

14. What role do innovative or experimental methods of planning, designing, or implementation for climate adaptation play in your city? What are the characteristics of such methods? And do you have any examples?
15. What role does transformative adaptation, that is adaptation that initiates broader structural or social change, have to play in the longer-term sustainability of your city?
16. Anything else you would like to add about this topic that we have not covered?

Capacity Scoring

Capacity	Poor	Fair	Moderate	Good	Excellent
Legal					
Institutional					
Resource					
Social					
Learning					
Transformative					
Poor: Significantly constraining adaptation; Fair: Mostly constraining but some good/enabling features; Moderate: Some constraining and enabling features/conditions; Good: Mostly enabling/good features; Excellent: Significantly enabling adaptation measures					

Legal Capacity: Legal and policy instruments enable climate adaptation, and facilitate flexibility and innovation.
Institutional Capacity: Institutions are flexible, coordinated and efficient in (planning &) implementing climate change adaptation, with CCA integrated into policy, organization structure and long-term strategisation.
Resource Capacity: Adequate and appropriate economic, technical and human resources are available, whilst synergies and transformative resource utilization are prioritized during implementation.
Social Capacity: Stakeholders and Communities are integrated in planning and implementation processes, with knowledge and decisions generated equitably. Engagement is proactive, with adequate transparency and accountability amongst key stakeholders.
Learning Capacity: Learning, knowledge sharing, and monitoring and evaluation are holistically integrated into climate adaptation processes. Practices and tools exist to integrate multi-disciplinary stakeholders in learning processes.
Transformative Capacity: Climate adaptation is targeted as an opportunity for transformational change to infrastructural, social and cultural systems. Adaptive planning, robustness and multi-benefit measures are prioritized within a coordinated network of stakeholders.

Appendix 3: List of Policy Documents

Document Name	Author
General	
Urban Water Atlas for Europe (2018)	Joint Research Centre European Commission
SUDS Manual (2015)	CIRIA
C40 Urban Climate Impacts Framework (2018)	C40 & Ramboll
London	
The London Plan (2016)	Greater London Authority
The New London Plan (2019)	Greater London Authority
London Environment Strategy (2018)	Greater London Authority
UK National Adaptation Programme (2018)	HM Government
Preparing for Climate Change: A Climate Change Adaptation Strategy (2020)	Ministry of Justice & DEFRA
UK Climate Change Risk Assessment (2016)	Climate Change Committee
Climate Change Impacts and Adaptation (2016)	Environment Agency
London Sustainable Drainage Action Plan (2016)	Greater London Authority
Thames Water 5 Year Plan (2019)	Thames Water
Hammersmith & Fulham Surface Water Management Plan (2016)	London Borough of Hammersmith & Fulham
Retrofitting London – Guidance for Social Housing Projects (2014)	London Climate Change Partnership
Copenhagen	
Cloudburst Management Plan (2012)	Municipality of Copenhagen
Climate Adaptation Plan (2011)	Municipality of Copenhagen
National Adaptation Strategy (2008)	The Danish Government
Mapping climate change – barriers and opportunities for action (2012)	Danish Nature Agency: Task Force on Climate Change Adaptation
Urban Innovation for Liveable Cities (2016)	State of Green Copenhagen
Copenhagen: Solutions for Sustainable Cities (2012)	Municipality of Copenhagen
Rotterdam	
National Delta Programme (2018)	Ministry of Infrastructure & Water Management
National Adaptation Strategy Implementation Program (2018)	Ministry of Infrastructure & Water Management
Adaptation to climate change in the Netherlands – studying related risks and opportunities (2015)	Ministry of Infrastructure & Water Management
Rotterdam Resilience Strategy (2016)	Gemeente Rotterdam
Rotterdam Climate Adaptation Strategy (2019)	Gemeente Rotterdam
Berlin	
Berlin Energy & Climate Protection Program (2018)	Senate Department for Urban Development and the Environment
Adapting to the Impacts of Climate Change in Berlin (2016)	Senate Department for Urban Development and the Environment
Climate Neutral Berlin 2050 (2016)	Senate Department for Urban Development and the Environment
German National Adaptation Strategy (2008)	German Government
German National Adaptation Plan (2015)	German Government
Warsaw	
Polish National Adaptation Strategy (2013)	Polish Government
Warsaw Urban Adaptation Plan (2018)	Office for Air Quality and Climate Protection
Warsaw Sustainable Energy Action Plan (2016)	Municipality of Warsaw
44MPA Urban Adaptation Plans (2018)	Ministry of the Environment
Polish River Basin Management Plan (2011)	European Commission & Municipality of Warsaw

Appendix 4: Coding Scheme

Code	Argumentation
Legal Capacity	
Strong legislation	Policies enables successful CCA implementation
Connected legislation	Policies across sectors connect to CCA
Conflicting legislation	Policies negatively influence CCA implementation
Inventive policy instruments	New instruments have positive effect on CCA
Clear standards and guidelines	Guidelines for planning and implementation improve efficiency and legitimacy
Unclear standards and guidelines	Lack of guidelines creates confusion and poor implementation
Strong enforcement	CCA implementation is monitored and regulated well
Weak enforcement	CCA implementation is monitored and regulated poorly
Aware of social inequalities	CCA measures are seen to connect to inequality
Ways to tackle inequalities	CCA measures are used to connect to inequality
Improve legislation	CCA policies are inadequate or need to improve for long-term success
Institutional Capacity	
Inspirational leadership	Policy entrepreneurs who motivate action
Local leaders	Local scale practitioners who motivate action
Good coordination	Connection between organisations or departments on CCA implementation
Poor coordination	Low connection between organisations or departments on CCA implementation
Fragmented departments	Departments are not aware of connectivity of CCA implementation
Connected departments	Departments are aware of opportunities to connect to CCA
Flexible departments	Departments can adopt CCA measures or modify plans & resources
Partnerships and networks	Internal and external networks exist to implement CCA measures
Clearly responsible	Individuals or departments are responsible for CCA implementation
Clearly accountable	Individuals or departments are accountable for CCA implementation
High ambitions	CCA is placed high on the agenda within institutions
Connected ambitions	CCA is seen to connect to multiple urban development goals
Resource Capacity	
Budget availability	There are financial resources available for CCA implementation
Limited budget availability	There are inadequate financial resources available for CCA measures
Different funding options	Funding can be acquired from various sources for CCA measures
Knowledge availability	Practitioners have good knowledge and expertise on CCA measures
Cooperation with partners	External experts are involved in planning and implementation
Variety of solutions	Solutions are available for a variety of hazards and contexts
Planning and implementation skills	Experts are available at all levels of implementation
Community funding	There is funding for community and individual initiatives
New funding tools	There are new measures of funding that offer more funding
Social Capacity	

Networking	Cities are connecting to share CCA practices
Learning from other cities	Lessons from other cities are being implemented in practice
Learning with communities	Communities are involved in CCA learning processes
Lessons for our city	Lessons are translated to relevant city contexts
Involve stakeholders	Stakeholders are engaged in planning and implementation processes
Engage citizens	Citizens are engaged in planning and implementation processes
Engage communities	Communities are engaged in planning and implementation processes
Citizen actions	Citizens are able to implement CCA measures themselves
Incentives for citizens	Citizens are motivated to implement CCA measures themselves
Learning Capacity	
Understanding risks	Risk and vulnerability to hazards is understood and mapped
Understanding future scenarios	Future hazards and risks are built into planning of CCA measures
Trying new things	New approaches to implementation or organisation are in place
Learning with others	External stakeholders are included and utilised in learning processes
Formal experimentation	Formal measures exist to experiment with learning processes
Tools for monitoring and evaluation	Tools exist to monitor and evaluate the performance of CCA measures
Resources for monitoring and evaluation	There are adequate resources to do monitoring and evaluation
Learning from mistakes	Lessons are reported and implemented into future CCA implementation
Transformative Capacity	
Multi-benefits	The multiple benefits of CCA implementation are identified and targeted
Social benefits	The social connections to CCA implementation are targeted
Connecting infrastructure	CCA interventions are connected to other infrastructural changes
Saving costs	CCA interventions are seen to bring efficiency and cost reductions
New approaches	Innovative CCA measures are used in the city
Experimenting with measures	Measures are tested and experimented with to improve them

Appendix 5: Actionability Assessment

Capacity & Capacity Factor	Actionability Score
Legal Capacity: Policy Cohesion Extent of measures available to enhance the ACF: presence of national and international CAP and CCA policy, HIGH Extent of opportunities or niches for improvement: alignment using Green Recovery Fund or EU Green Deal, MED Extent of inclusion of local or municipal-level actors: possible but likely slow, MED Extent of affordability and feasibility of measures: difficult to rapidly modify policies, LOW	MEDIUM
Legal Capacity: Statutory Compliance Extent of measures available to enhance the ACF: presence of stronger regulatory policies & standards, HIGH Extent of opportunities or niches for improvement: possibility for integration into multi-sectoral regulations, MED Extent of inclusion of local or municipal-level actors: depends on higher enforcement and binding regulations, MED Extent of affordability and feasibility of measures: low cost and reasonable feasibility using policy, HIGH	HIGH
Legal Capacity: Redistribution of Socio-Environmental Equity Extent of measures available to enhance the ACF: use of BID's, IUR's, community initiatives, HIGH Extent of opportunities or niches for improvement: potential for alignment with public health policy, HIGH Extent of inclusion of local or municipal-level actors: dependent on local level actors and momentum, HIGH Extent of affordability and feasibility of measures: high costs and challenge of silo thinking, LOW	HIGH
Institutional Capacity: Embeddedness of CCA Extent of measures available to enhance the ACF: networks, partnerships and holistic policy, HIGH Extent of opportunities or niches for improvement: good, given focus on urban sustainable development, MED Extent of inclusion of local or municipal-level actors: high involvement, requires careful management, MED Extent of affordability and feasibility of measures: low cost but friction likely, MED	MEDIUM
Institutional Capacity: Institutional Transparency Extent of measures available to enhance the ACF: working groups, Living Labs, community participation, HIGH Extent of opportunities or niches for improvement: measures need better operationalisation, LOW Extent of inclusion of local or municipal-level actors: highly dependent on practitioners, HIGH Extent of affordability and feasibility of measures: need change of approach and extra budgeting, MED	MEDIUM
Resource Capacity: Diversity of Solutions Extent of measures available to enhance the ACF: extensive range of options, need actioning, HIGH Extent of opportunities or niches for improvement: functional in all scales and sectors, HIGH Extent of inclusion of local or municipal-level actors: dependent on local practitioners, likely face friction, MED Extent of affordability and feasibility of measures: high capital cost of expansion but feasible on public land, MED	HIGH
Resource Capacity: Integrated Adaptative Planning Extent of measures available to enhance the ACF: measures available but poorly implemented, LOW Extent of opportunities or niches for improvement: strong opportunities for holistic usage, HIGH Extent of inclusion of local or municipal-level actors: requires expertise so challenging on local level, MED Extent of affordability and feasibility of measures: some cost and time considerations, MED	MEDIUM
Resource Capacity: Human Manpower Extent of measures available to enhance the ACF: extensive networks & partnerships, training and education, HIGH Extent of opportunities or niches for improvement: idem, HIGH Extent of inclusion of local or municipal-level actors: completely locally dependent, HIGH Extent of affordability and feasibility of measures: likely expensive but quick to mobilise, MED	HIGH
Social Capacity: Community Initiatives Extent of measures available to enhance the ACF: many possible activities and measures, HIGH Extent of opportunities or niches for improvement: networks, social housing partnerships, etc, HIGH Extent of inclusion of local or municipal-level actors: complete involvement, some friction possible, HIGH Extent of affordability and feasibility of measures: some expenses and time needed to mobilise, MED	HIGH
Learning Capacity: Monitoring & Evaluation Extent of measures available to enhance the ACF: extensive measures, processes already exist, HIGH	HIGH

Extent of opportunities or niches for improvement: relevant across all sectors and scales, HIGH Extent of inclusion of local or municipal-level actors: necessary local involvement, engagement needed, HIGH Extent of affordability and feasibility of measures: costly and likely friction with private sector, LOW	
Learning Capacity: Reporting & Evaluation Extent of measures available to enhance the ACF: commonplace measures, some lack of expertise, MED Extent of opportunities or niches for improvement: local-level relevance but likely friction, MED Extent of inclusion of local or municipal-level actors: necessary local engagement, some national level though, MED Extent of affordability and feasibility of measures: time-consuming and a change in norms required, MED	MEDIUM
Transformative Capacity: Multi-Benefit Interventions Extent of measures available to enhance the ACF: diversity of measures, e.g. BGI, BIDs & IUR's, HIGH Extent of opportunities or niches for improvement: relevant across all sectors and in policy, HIGH Extent of inclusion of local or municipal-level actors: mostly local level, some national cohesion required, MED Extent of affordability and feasibility of measures: costs are manageable but feasibility challenged by silos, MED	HIGH
Transformative Capacity: Innovation & Experimentation Extent of measures available to enhance the ACF: high, wide range of opportunities and platforms, HIGH Extent of opportunities or niches for improvement: relevant across all sectors and in policy, HIGH Extent of inclusion of local or municipal-level actors: requires cohesion between actors, MED Extent of affordability and feasibility of measures: highly feasible and diversifies funding, HIGH	HIGH

Appendix 6: Factor Interconnectivity Assessment

	Adaptive Capacity Factor	Interconnections
Legal Capacity	Adaptation Policy Instruments	Statutory Compliance; Horizontal Coordination of CCA; Ambition & Goal Setting; Innovation & Experimentation
	Policy Cohesion	CCA Embeddedness; Institutional Responsibility; Multi-Benefit Interventions; Adaptation Expertise
	Statutory Compliance	Institutional Accountability; CCA Embeddedness; Financial Availability; Willingness to Pay
	Awareness of Socio-Environmental Equity	CCA Embeddedness; Integrated Adaptive Planning; Community Cooperation; Community Initiatives; Multi-Benefit Interventions
	Redistribution of Socio-Environmental Equity	Multi-Benefit Interventions; Community Initiatives; Willingness to Pay
Institutional Capacity	Institutional Leadership for Adaptation	Vertical and Horizontal CCA Coordination; CCA Embeddedness; Innovation & Experimentation
	Organisation of Adaptation Implementation	Organisational Resource Flexibility; CCA Embeddedness, Institutional Responsibility; Active Network Participation
	Vertical Coordination of CCA	Active Network Participation; Policy Cohesion
	Horizontal Coordination of CCA	Statutory Compliance; CCA Embeddedness; Diversity of Solutions; Adaptation Expertise
	Embeddedness of Adaptation Discourse	Redistribution of Socio-Environmental Equity; Willingness to Pay; Stakeholder Participation; Collaborative Learning
	Institutional Responsibility	Adaptation Policy Instruments; Horizontal CCA Coordination; Financial Continuity
	Institutional Transparency	Policy Cohesion; Statutory Compliance, Stakeholder Participation; Synergy Optimization
	Institutional Accountability	Statutory Compliance; Monitoring & Evaluation
	Ambition and Goal Setting	Adaptation Policy Instruments, Innovation & Experimentation; Institutional Leadership
Resource Capacity	Financial Availability	Adaptation Policy Instruments; Institutional Leadership; Stakeholder Participation; Innovation and Experimentation
	Willingness to Pay	Redistribution of Socio-Environmental Equity; CCA Embeddedness; Multi-Benefit Interventions
	Financial Continuity	Policy Cohesion; Integrated Adaptive Planning; Risk & Vulnerability Assessments
	Human Manpower	Horizontal CCA Coordination; Active Network Participation
	Adaptation Expertise	CCA Organisation; Horizontal CCA Coordination; Financial Availability; Monitoring & Evaluation; Innovation & Experimentation
	Organisational Resource Flexibility	CCA Organisation; Policy Cohesion
	Diversity of Solutions	Financial Availability, Adaptation Expertise; Innovation & Experimentation; Community Initiatives
	Integrated Adaptive Planning	Policy Cohesion; CCA Embeddedness; Ambition & Goal Setting; Collaborative Learning; Monitoring & Evaluation
Social Capacity	Active Network Participation	Institutional Leadership; Stakeholder Participation; Synergy Optimization
	Integration of Network Knowledge in CCA	Collaborative Learning; Institutional Transparency

	Stakeholder Participation	Adaptation Policy Instruments; Horizontal CCA Coordination; Multi-Benefit Interventions
	Cooperation with the Community	Collaborative Learning; Redistribution of Socio-Environmental Equity; Horizontal CCA Coordination
	Community Adaptation Initiatives	Adaptation Expertise; Financial Availability; Innovation & Experimentation
Learning Capacity	Local Knowledge Integration	Financial Availability; Adaptation Expertise; Monitoring & Evaluation
	Risk & Vulnerability Assessments	Awareness of Socio-Environmental Equity; Integrated Adaptive Planning; Community Initiatives
	Adaptation Policy Assessments	Institutional Transparency & Accountability; Collaborative Learning
	Collaborative Learning	Adaptation Policy Assessments, Cooperation with the Community; Monitoring & Evaluation; Adaptation Expertise
	Monitoring & Evaluation	Local Knowledge Integration; Collaborative Learning; Innovation & Experimentation; CCA Embeddedness
	Reporting & Application	Institutional Transparency & accountability; Active Network Participation
Transformative	Multi-Benefit Interventions	Adaptation Policy Instruments; Redistribution of Socio-environmental equity; Willingness to Pay; Innovation & Experimentation
	Synergy Optimization	Stakeholder Participation; Policy Cohesion; Financial Availability; Adaptation Expertise
	Innovation & Experimentation	Embeddedness of CCA; Collaborative Learning; Community Initiatives; Monitoring & Evaluation