TOWARDS WATER-WISE CITIES

Towards water-wise cities:
Global assessment of water management and governance capacities

Op weg naar waterwijze steden:
Wereldwijde analyses van waterbeheer en bestuurlijk vermogen

Steven Hendrik Andreas Koop

Thesis designed by Dana Dijkgraaf Design

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Op weg naar waterwijze steden:
Wereldwijde analyses van waterbeheer
en bestuurlijk vermogen
(met een samenvatting in het Nederlands)

Proefschrift

ter verkrijging van de graad van doctor aan de Universiteit Utrecht
op gezag van rector magnificus, prof.dr. H.R.B.M. Kummeling,
ingevolge het besluit van het college voor promoties
in het openbaar te verdedigen op
maandag 25 maart 2019 des middags te 4.15 uur

door

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geboren op 12 augustus 1990 te Wageningen

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Funding has been received from KWR Watercycle Research Institute and the European Commission through the H2020 BlueSCities project (No. 642354) and the POWER project (No. 687809).

ACKNOWLEDGEMENTS

First, my thanks goes to my daily supervisors Kees van Leeuwen, Carel Dieperink and Peter Driessen. Kees, your enthusiasm, experience and helpfulness has been of great value during the entire research process. Your positive mind-set of seizing opportunities and your capacity to overcome seemingly large limitations made working with you a truly inspiring experience, both professionally and in terms of personal growth. Carel and Peter, I am very grateful for all your efforts, guidance and direction, that strongly contributed to the quality of my research. You both had the great ability to structure my thoughts that pulled me forwards. Besides, on a more personal level, you have been great motivators.

There have been many things that made this PhD process very exciting: the societal relevance, the writing process, the international context, but above all, working with the many smart, hardworking and creative students. In fact, I do consider my dissertation as a team process and result. Laurence, Alisa, Eric, Petra, Martien, Daniel, Marketa, Suzanne, Noyara, Laura, Fabian, Chakira and Romy, you all have motivated me to push my ambition, you have opened my eyes sometimes, and above all, you have made my everyday work much more interesting and exciting. Laurence, I have very much enjoyed our discussions about the local decision-making process and levels of governance capacity, sometimes until late in the evening. Your work has been of great value. Alisa, you have surprised me many times with your ability to speak to important people. I am surprised about your ability to arrange a meeting with the CEO of Waternet based on one informal coffee talk! Eric, I admire how you have managed to learn Spanish, did the interviews in Spanish, and managed to write everything down, in such a short time! Petra, your Australian lover turned out to be very beneficial for both our research and your plans to live in Australia. Your organizational planning and social skills have impressed me! Martien, you have analysed an Indian city, and despite chaotic fieldwork conditions and a very long review process, you have been able to produce a very interesting article. Marketa, your study of the capacity to govern non-potable water-reuse in Sabadell (Spain) was impressive and I have enjoyed working with such a motivated and intelligent student. Suzanne, your hard work, intelligence and people skills have made the governance capacity analysis in Taipei (Taiwan) a great success. Noyara, your openness, intelligence and research output are very much appreciated. You have assessed many Asian cities including Bandung (Indonesia), leading to two publications and it greatly supported this dissertation. Laura, your preciseness, dedication and sincerity in the study of flood risk governance in Leicester (UK) is much appreciated and I have very much enjoyed working and travelling with you. Fabian, as one of my last students you also had one of the most challenging and important tasks which you accomplished

exceptionally well. Your intelligence, persistence in the gloomy city of Milton Keynes (UK), and your often expressed gratitude was heart-warming. Romy, after all the international studies, your analyses of Utrecht - the city I love and spent my student years – was of particular interest to me. You took great initiative in finding the right persons to be interviewed and your hard work and writing skills have been exceptional. Chakira, your analysis of Jerusalem's governance capacity to conserve water had many social-political but also practical barriers to overcome. You did this with verve, showing great capacity and talent as an in-dependent researcher and person. Boipelo and Kirsty, I consider your work in Cape Town as one of the most pleasant professional cooperation's I have experienced. Johan thank you for all your efforts and enthusiasm. Thanks to your Wetskills network, the research activities were greatly supported. I would like to thank my colleagues, in particular my team members at KWR, and other colleagues including Farhad, Dries and Richard. You have provided me with both intellectual and mental support for which I am very grateful.

My project manager Gerard deserves a special word of thanks. Without his support and flexibility this dissertation would not have been possible. I would like to thank the current and previous managers of KWR (Jos, Stefan, Marielle, Wim, Idsart, and Dragan) for their continuous (financial) support for this new research at KWR Watercycle Research Institute.

My gratitude also goes to all the individuals in each city that decided to participate in the voluntary assessment research. Without your support, efforts and frankness, this empirically-focused dissertation would not have been possible. In particular, I acknowledge Waternet for being the first test case of the in-depth governance capacity analyses. With special thanks to Otto Reinstra. Also a word of thanks to all collaborating partners within the Watershare community. In particular, to our colleagues in Seoul. Jeryang, Jaewoo, Hyowon, Seockheon and Young June, collaborating with you was a delight! I acknowledge the European Commission for funding part of this research trough the project BlueSCities No. 642354 and POWER No. 687809. I would like to express my greatest gratitude to Dana Dijkgraaf for her creativity, accuracy and design of this beautiful dissertation.

In my personal live I would first of all like to thank the love of my life, Eline. Her patience and support throughout this process meant the world for me. My gratitude also goes to my parents and sister for helping me to get my mind off the dissertation and to relax. My thought are with my grandmother who would be very proud to see this work accomplished. Finally, I would like to dedicate this dissertation to my grandfather: André Engelmann, who passed away in December 2017. His expression of interest in this work was unlimited and I know that he would be very proud of me for completing this PhD trajectory.

CONTENTS

1 INTRODUCTION

1.1 URBAN CHALLENGES OF WATER, WASTE AND CLIMATE CHANGE

IT HAPPENS IN CITIES

Over half of the world's 7.2 billion people live in cities. In the coming 40 years urbanization is projected to increase with an unprecedented 2.7 billion people, meaning that two thirds of the projected 9.7 billion world citizens will live in cities by 2050 (UN DESA 2009). Because by far most resources are consumed here, the current and future challenges to achieve human well-being, sustainable use of natural resources and economic growth are especially great in urban areas (UNEP 2013). Approximately 80% of the world's GDP is produced in cities, and 75% of the global energy and material flows are also consumed here (UNEP 2013). The pressure exerted on cities but also their innovative potential are likely to increase (e.g. Meijer and Bolıvar 2016) due to vast urbanization, rapidly developing infrastructues (Monstadt 2009) and the increasing urban sensitivity to challenges of water, waste and climate change.

THE IMPORTANCE OF URBAN WATER, WASTE AND CLIMATE CHANGE CHALLENGES

The issue of water in a world of rising population, increasing economic activity and a changing climate is increasingly recognized as a priority. As such, the World Economic Forum's (2016) ranking of the largest global risk for the next 10 years is almost entirely water-related: 1. water crisis, 2. failure of climate-change mitigation and adaptation, 3. extreme weather events, and 4. food crisis, which is strongly related to water scarcity (Hoekstra et al. 2012). Moreover, the Paris Climate Conference in December 2015 has made an historical and ambitious agreement to limit global warming to 2.7°C above pre-industrial levels by 2100 (UNFCCC 2015). It has also been recognized that, as a consequence, it is impossible to live in a world without climate change adaptation. By 2030, the world will experience an estimated 40% freshwater shortage (WRG 2009). Urban residents will become increasingly vulnerable to extreme heat that is amplified by both climate change and the urban warmth absorbing environment. Sea level rise and the increase in extreme river discharges already pose a projected 15% of the global population to be at flood risk. This is mainly in urbanities including almost all the world's mega-cities (Ligtvoet et al. 2014). Cities also generate vast amounts of solid waste which releases hazardous substances; in particular plastics that pollute surface water, rivers and ocean ecosystems (Zarfl et al. 2011; McFedries 2012). Furthermore, untreated sewerage discharge, combined sewer overflow and polluted stormwater runoff will increasingly lead to water pollution. In fact, the nutrient emissions in Asia and Africa are projected to double or triple within 40 years leading to eutrophication, biodiversity loss, threatening drinking water, fisheries, aquaculture and tourism (Ligtvoet et al. 2014). Finally, the recovery and reuse of energy and materials from waste water and solid waste are important elements in reducing resource dependency and alleviating the city's environmental impact on ecosystems (EC 2014). Hence, the urban water cycle has an essential role in the process of urban development. Overall, some examples of applied knowledge, experiences and good practices to address water challenges are available and being applied, but they are scattered, lacking ways of learning between science, policy and citizens, between decision-makers across scales and across municipal boundaries (Brown 2008; Borowski and Hare 2007). Therefore, the challenges of water, waste and climate change in cities call for good water management and governance capacity to learn and improve.

URBAN WATER MANAGEMENT ON THE INTERNATIONAL POLITICAL AGENDA

Recently, a variety of major societal initiatives have focused on the challenges of water, waste and climate change in cities[1]. The magnitude of water-related challenges has been recognized as a central theme within the United Nations Development Programmes (UNDP). A clear ideal type of urban water management is propagated by all 17 Sustainable Development Goals (SDGs) and in particular by SDG 6 *Ensure access to water and sanitation for all*, and by SDG 11 *Making cities inclusive, safe, resilient and sustainable* (UN SDGs 2017; UN-Water 2017; UN Habitat III). In accordance, specific targets have been formulated such as reducing water pollution, reducing waste dumping to alleviate

1. Examples of societal initiative to address the challenges of water, waste and climate change: C40, 100 resilient cities, Europe's covenant of major adapts and IWA's water-wise cities (C40 cities 2017; Rockefeller Foundation 2017; Covenant of majors adapt 2017; IWA 2017).

marine pollution, halving the proportion of untreated wastewater, substantially increasing recycling and safe water reuse, increasing water use efficiency across all sectors, increasing resource efficiency, ensuring sustainable freshwater withdrawals, reducing the number of people suffering from water scarcity, mitigating and adapting to climate change, and reducing disaster risks including the risk of water-related disasters. Importantly, the SDGs also specify how these goals have to be achieved. Namely, through the implementation of Integrated Water Resources Management (IWRM) which is inter-sectorial, participatory and inclusive with an important role for multi-stakeholder cooperation between public and private actors to share knowledge, expertise, technology and financial resources at all levels (Rahaman et al. 2005). The focus is on implementing integrated policies and plans towards, inclusion, resource efficiency and mitigation and adaptation to climate change[2]. The role of capacity development is considered as pivotal (Engle and Lemos 2010; Van der Zaag 2005).

At the European level, the Covenant of Mayors for Climate and Energy is the most relevant water-related initiative by the European Commission on the city scale. The initiative helps cities to coordinate the integration between climate mitigation and adaptation action. The aim is to multiply the benefits and synergies, and reduce overall city spending on climate mitigation and adaptation. The aligning of policy processes between sectors of transport, spatial planning, water management, construction sector and others is enhanced through the development of integrated urban adaptation strategies (CovenantofMayors.eu 2017).

These international programmes, although different in aim and scope, address similar water-related issues and suggest corresponding strategies. First, the urban response to challenges of water, climate change and resource recovery are perceived as indispensable for long-term urban development (Fünfgeld 2015; Hakelberg 2014). Second, the integration within and between sectors is considered imperative for cities to govern

2. Sustainable Development Goal 11 *Make cities inclusive, safe, resilient and sustainable: http://www.un.org/sustainabledevelopment/cities/*

overarching water-related challenges (Kern and Bulkeley 2009). Third, a participatory policy process that includes public and private stakeholders is regarded as a precondition to adapt to and anticipate emerging and long-term water-related urban challenges (Toly 2008). This rationale, which these leading international organisations and programmes propagate, strives for an optimalisaton of water management in recognition that governance capacity is pivotal.

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1.2 CHANGING PERSPECTIVES ON WATER GOVERNANCE

In order to addres urban challenges of water, waste and climate change through a widely propagated participatory and intersectorial scope, we first need to understand the scientific debate on water governance throughout the past decades. Starting with the paradigm of traditional water governance, the major shift from government to governance that is taking place is discussed. Second, the emergence of Integrated Water Resources Management and Adaptive Management is discussed, because they are leading approaches for the global efforts to address water-related challenges.

TRADITIONAL WATER GOVERNANCE

Traditional water governance is characterized by an expert culture based on technological solutions for narrowly defined problems (Brown et al. 2009). This traditional approach has resulted in a limited comprehensive understanding of the multiple aspects of the water system (Pahl-Wostl 2002, 2009; Philip et al. 2011). Existing institutional arrangements, technologies, people's expertise and sunk infrastructure investments typically create a *path dependency* that is difficult to overcome (Brown et al. 2011). The tight and well-organized institutional interdependencies amplify existing routines and rules that foster more efficient interactions. As a consequence, existing practices become increasingly faster, more reliable, at decreased time and costs, and with fewer errors (Geels 2006). Hence, there are little stimuli to switch to alternative learning-paths. In other words, the path of the least resistance is naturally preferred over new more risky trajectories (Brown et al. 2011; Hammond et al. 1998). However, the initial gain in efficiency is often offset by limited scope and inflexible structures preventing learning, adaptation and anticipation to changing circumstances. A combination of fragmentation, technological lock-in, institutional inertia and the challenge of reorienting professional and organizational expertise all form barriers that inhibit the adequate governance to address long-term overarching water challenges (Brown and Farrelly 2009; Sydow et al. 2009). It also leads to limited institutional embedment, low awareness and ill-defined water issues that lack cohesion between short and long-term goals, as well as between sectors and policies (OECD 2015b). A fascinating example is the construction of the Thames Tideway Tunnel and Desalination Plant that together exceed a cost of US$5 billion and represent the largest capital investment in urban water infrastructure in the northern hemisphere. The Thames Tideway Tunnel is 36 km long, 7.2 in diameter and is designed to reduce combined sewer overflows. The Desalination Plant is able to produce 140 million litres of drinking water per day to address the diminishing freshwater resources (Brown et al. 2011). Amongst other things, water management fragmentation, sunk expertise and technical lock-in might have led to the inability to address both issues in an integrated way by decoupling the stormwater during the necessary sewer refurbishments and using this water as a freshwater resource for drinking water or secondary purposes and thereby reducing substantial costs and (fossil) energy use. Moreover, reducing London's drinking water consumption was also poorly considered, and opportunities were missed to efficiently recover warmth, renewable energy and valuable nutrients from a decoupled, more concentrated sewage water. Overall, traditional water governance is typically fragmented and inflexible with a limited stakeholder involvement, all leading to narrow scopes and reactive behaviour (Pahl-Wostl 2002; Segrave et al. 2016). Hence, there have been strong incentives to better integrate sectors, interests and institutional arrangements in the field of water governance.

FROM A FRAGMENTED APPROACH TOWARDS INTEGRATED WATER GOVERNANCE

There has been a major shift away from traditional water governance and towards diverse governance modes with more sharing of responsibilities between different public and private actors across multiple-governance levels (OECD 2015b; Palaniappan et al. 2007; Mees 2016; Toonen 2011). It reflects a growing awareness that governments are no longer the only relevant actors when it comes to the management of societal issues (Lange et al. 2013). The shift from 'government' to 'governance' is one of the more profound developments within contemporary social science (Kettl 2000; Stoker 2000; Swyngedouw 2006). It marks the shift from hierarchical to more horizontal network-based types of decision-making, where boundaries between public and private actors become blurred and many different interests need to be integrated into policy and implementation (Mees 2014). Both Integrated Water Resources Management (IWRM) and adaptive management apply this major shift from government to governance in the field of water governance.

INTEGRATED WATER RESOURCES MANAGEMENT

One of the most profound and proliferate approaches that pursue integration has been that of IWRM. The approach aims to integrate the management of water, land and related resources in order to maximize the resultant economic and social welfare without degrading vital ecosystems (UNEP-DHI 2009). IWRM considers water as a major unit for the integration of critical functionalities such as health, environment, transportation, energy, spatial planning and poverty alleviation (OECD 2015b; Grigg 2008). IWRM emphasizes the need to reshape institutional structures and sectorial organizations along hydrological boundaries, and enhances the authentic participation of all stakeholders (Saravanan et al. 2009). The concept of IWRM has led to major policy initiatives in many countries and is widely acclaimed by international organizations such as the International Water Management Institute (IWMI), the Food and Agriculture Organization (FAO), the World Bank and various regional authorities. However, IWRM has also been criticized for being too all-encompassing which results in difficulty in providing tangible implementation steps that can be evaluated in order to falsify or approve its basic assumptions (Medema et al. 2008; Ramahan and Varis 2005). IWRM aims for radical institutional changes that often include large (financial) risks (Jeffrey and Gearey 2006; Horlemann and Dombrowsky 2012). Others argue that the appeal of enhancing the authentic participation of all stakeholders as a means of integrating different social, political and environmental interests is an over-simplified representation of reality. They emphasize the importance of power dynamics, culture, the role of context and therefore plead for the analysis of how integration takes place in real world situations (Saravanan et al. 2009; Medema et al. 2008; Jeffrey and Gearey 2006; Tropp 2007).

ADAPTIVE MANAGEMENT

Another approach that enhances integration in the field of water governance is the concept of adaptive management. Contrary to the traditional technocratic assumptions that ecosystem management is linear, predictable and controllable, adaptive management embraces the fact that natural-resources managers have to make decisions while facing inevitable uncertainties, complexities and risks (e.g. Gunderson and Holling 2002; Folke et al. 2002; Berkes 2009). Adaptive management focusses on changing the way responsible authorities perceive and act, by emphasizing the role of experimentation and the value of learning and evaluation in order to adapt to coping with unexpected and complicated circumstances (Den Uyl 2014). Adaptive management aims to accomplish a better fit between ecosystem dynamics and governance processes (Medema et al. 2008; Folke et al. 2005; Olsson et al. 2010). Adaptive management focusses on enhancing the capacity of an ecological system to recover after major events, to cope with stress and to reduce its vulnerability to collapse (Folke et al. 2002). Although many definitions exist, adaptive governance is generally referred to as a governance system or process that is able to adequately address uncertain, complex and sometimes unknown challenges by means of experimentation and continuous social learning within transdisciplinary teams of managers, stakeholders and scientists (Nyberg 2009). Adaptive management has been shown to be a very promising and much needed approach with great but largely undiscovered potential to facilitate water governance in urban regions (e.g. Folke et al. 2005).

1.3 CITIES AS FOCAL AREA OF INTEGRATED WATER GOVERNANCE

The increased recognition of water as a key element of integrated management of uncertain, complex and value-laden challenges where responsibilities are increasingly shared with private stakeholders marks a major change in the way we need to perceive and understand water governance. In this context, cities emerge as a focal area of integration. In addition, the challenges of water, waste and climate change will particularly affect the rapidly growing urban population.

CITIES AS MAJOR PLATFORM FOR INTEGRATED WATER GOVERNANCE

The scientific literature on the governance of transformation tend to focus on social-ecological systems in general (e.g. Olsson et al. 2004, 2010; Folke et al. 2005; Pahl-Wostl 2007; Pahl-Wostl et al. 2007, 2010) or bioregions and common pool resources such as forestry, fishery, watersheds, river basins, wildlife, wetlands, or protected areas (Plummer et al. 2012; Huitema et al. 2009; Mitchell 1990). However, adaptive management also needs to be integrated into prevailing management paradigms and existing institutions (Halbe et al. 2013; Galaz et al. 2008) which often requires thorough institutional changes with large associated risks, high investments and inefficiencies (Jeffrey and Gearey 2006; Horlemann and Dombrowsky 2012; Galaz et al. 2008). It is clear that the city is not a bioregion. However, cities are important and well-established institutional entities where integration of water with different sectors, objectives and interests is perhaps most prevalent and concrete. In fact, the direct interaction between citizens, governments, and smaller and larger private stakeholders may be most widespread in cities (Haus et al. 2005; Yang and Callahan 2014). Hence, one of the main challenges is to develop an integrated understanding of how urban areas are in different levels of urban development towards becoming water-wise. In this way, we can understand how cities may develop themselves away from fragmented traditional water governance, towards a more integrated governance type that is able to address the profound challenges of water, waste and climate change that cities face across the globe.

PROGRESS IN THE URBAN WATER CYCLE: A BRIEF OVERVIEW OF EMPIRICAL RESEARCH

Major social and environmental trends inevitably lead to gradual shifts and shock events that induce individual cities to address water challenges under various circumstances in different world regions. In fact, cities all over the world are developing, being at different stages of preparedness and possessing valuable lessons, experiences and knowledge that can provide stepping stones for other cities to enhance their capacity to manage and govern these unprecedented challenges of water, waste and climate change. However, the question of how the processes of urban development towards improved water cycle management are taking place, remains largely unanswered (McCormick et al. 2013). One exquisite exception is the urban water management transitions framework developed by Brown et al. (2009) for Australian cities. The framework has been developed based on three research phases: 1) an extensive historical analysis; 2) the identification of current institutional drivers and barriers, and; 3) the exploration of future socio-technical factors that will need to underpin the institutional practice of sustainable urban water management (Brown et al. 2009). The framework presents a typology of six different, yet cumulative stages that cities transition through when pursuing more sustainable futures. The six consecutive stages are: the *water supply city*, the *sewered city*, the *drained city*, the *waterways city*, the *water cycle city*, and the *water sensitive city*. Furthermore, hydro-social contracts (Lundqvist et al. 2001; Brown et al. 2009) have been identified that describe the pervading values reflected in implicit agreements amongst communities, governments and business on how water should be managed. Despite its unique insights, the urban water management framework is largely embedded in the Australian context, with a valuable but also a somewhat unilateral contribution to the understanding of urban development towards improved water management on a global scale.

1.4 TOWARDS WATER-WISE CITIES, A KNOWLEDGE GAP

Overarching rationales – that are propagated by leading international organisations and programmes – may include elements of adaptive management, IWRM and traditional management. For cities in particular, IWA's principles of water-wise cities and water sensitive cities provide a prototype of long-term integrated and inclusive urban water management. However, beyond water-wise principles and a national context of water sensitive cities, an empirical understanding of how water management can be optimised and which steps cities across the globe may take to achieve this, largely remains to be explored. Such an optimised management of the urban water cycle is framed as *water-wise management*. How water-wise management can be defined, operationalized and empirically analysed will be investigated in this dissertation. In order to do so, water-wise management will be operationalized into two measurable indicator frameworks. One to analyse water management performances, and the other to analyse the governance conditions that determine the capacity to improve water management performances. Such an exercise aims to address three important knowledge gaps that exist in the literature on environmental governance.

IMPROVING URBAN WATER MANAGEMENT: A LACK OF EMPIRICALLY-BASED UNDERSTANDING

Despite the huge challenges of managing and governing the world's urban water challenges, there is still little empirically-based understanding of concrete steps that can be observed in the development of cities towards *water-wise* management (e.g. Brown and Farrelly 2009; Bos and Brown 2011; McCormick et al. 2013). Moreover, across disciplines, theories are mainly built on studies within Europe and North America. It is assumed that this also applies in developing countries, whereas there is no proper understanding of the development pathways that these cities may have (e.g. Brown 2011; Brown et al. 2012; Ziervogel et al. 2010). Hence, there is a need for a global perspective on the urban development towards water-wise urban management.
The urban water cycle includes many different elements; amongst others, water infrastructure to secure basic water services of drinking water and sanitation, wastewater treatment

for water pollution control and resource recovery, and blue-green infrastructure and drainage systems to alleviate flood risk and heatwaves. There might be an important role for indicators to integrate these various components because indicators are able to point to, provide information about, and describe the current state, with a significance that extends beyond what is directly associated with the parameter value (OECD 2003). However, existing water indicators are often part of a more generic set of national indicators[3]. There are also frameworks at the level of cities that include water-related indicators[4] but these are often limited to service delivery of almost exclusively drinking water and sanitation (e.g. IBNET 2015). Despite valuable explorations (e.g. Van der Steen 2011; Lundin and Morrison 2002; Brown et al. 2009), we lack an indicator assessment method that analyses urban water cycle management in such a holistic way and is able to consistently compare the different cities across world regions. Such an indicator assessment allows for the continuous build-up of empirical knowledge, which can provide "iterative updates" to improve our understanding of the different levels of urban development towards improved water cycle management across the globe. These phases can provide a basis for meaningful exchange of experiences, knowledge and mutual learning between cities.

IDENTIFYING GOVERNANCE BARRIERS AND WINDOWS OF OPPORTUNITY: A LACK OF COHERENCE

Each improvement step may have specific governance barriers and windows of opportunities that provide valuable insights to enable cities to improve their governance capacity to better address existing challenges of water, waste and climate change. In order to understand these key governance conditions at various levels towards improved water cycle management, a coherent diagnostic governance capacity analysis is required. In environmental governance literature, a plethora of social

3. Examples of national indicator sets that include water: sustainable society index, Notre Dame global adaptation index, water footprint, environmental performance index, OECD environmental indicators and the UN set of water indicators (SDS 2014; ND-GAIN 2013; Hoekstra et al. 2009; Yale university 2014; OECD 2013; UN-Water 2014).

4. Examples of city level indicators frameworks that include water: ISO37120 urban sustainability indicators, European green cities, the Dutch municipal sustainability index, innovation cities index and European smart cities (ISO 2014; Siemens 2015; Vienna University 2014).

factors and conditions have been identified that impede or enhance our ability to adapt and respond proactively to current and future challenges of water, waste and climate change (Biesbroek et al. 2013; Plummer et al. 2012; Eisenack et al. 2014; Van Rijswick et al. 2014). However, despite this rich and emerging literature, a comprehensive understanding of the underlying processes that enhance or limit the development towards water-wise management in cities has not been fully explored through empirical research. First, most identified conditions are based on theoretical and conceptual considerations that often lack empirical validation (Biesbroek et al. 2013; Kersberger and Waarden 2004; Pahl-Wostl 2009; Van Rijswick et al. 2014). Second, existing empirical studies are generally descriptive and focus on specific case studies which limit their usefulness and learning value beyond the individual context or scientific discipline (Measham et al. 2011). Third, concepts, definitions, measurements and methodologies are often inconsistent, not specific and partly overlapping (Eisenack et al. 2014; Plummer et al. 2012). For example, developing adaptive capacity is one of the most cited outcomes. However, what adaptive capacity entails, how it is operationalized or how it can be measured, is often ill-defined (Smit and Wandell 2006; Füssel 2007a). If findings are not organized in a common framework, isolated knowledge will not accumulate (Ostrom 2009). Hence, a diagnostic framework is required that integrates existing knowledge in order to facilitate the accumulation of coherent and empirical knowledge that could enable comparison among cases, improve the understanding of the effects of contextual attributes, and provide conceptual clarity and coherence (Plummer et al. 2012). Hence, the accumulation of a large database consisting of comparative case studies may allow us to obtain a more profound understanding of how cities can govern their water cycle and enables us to identify transferable lessons for cities in different contexts, regions and at different stages of development.

IMPROVE THE SCIENCE POLICY INTERFACE: A NEED FOR AN EMPIRICALLY-BASED NARRATIVE

Successful decision-making requires meaningful communication between scientific research communities, policymakers and stakeholders (Cash et al. 2006; Jones et al. 1999; Hanger et al. 2013). At present, different city-platforms apply indicators to measure progress. However, these types of indicator systems may be non-specific with respect to the water cycle (e.g. City Resilience Index 2018) or are largely black boxes, since they provide little transparency regarding the input data, calculation method and rationale of the indicators in question (e.g. Arcadis 2016). At the other end, in the scientific literature, the role of scientific validity is emphasized, assuming that this alone is sufficient for feeding information into the policy process (Holman 2009). Both extremes are of limited usefulness for practitioners. In order to be useful, an open-source knowledge base needs to be designed and applied with the aim of enhancing network integration between policymakers, departments and stakeholders both across spatial scales and policy sectors (Reed et al. 2005, 2006; Fraser et al. 2006; Holman 2009). By developing an empirically-based understanding of what water-wise cities are and by identifying levels of urban development that cities may go through, practitioners may be better enabled to direct their ambitions, aims and policies. It also enables cities to share knowledge, experiences and learning practices with one another in a meaningful and concrete fashion. Besides envisioning this "physical" development, a coherent understanding of the main governance barriers and stimuli to realise water-wise management can provide cities with tangible knowledge derived from scientific literature that helps them to build the necessary capacity to address their water challenges. This shared knowledge frame can function as a portal that opens up avenues of dialogue between tiers of governance to broaden existing networks and emphasize the importance of long-term planning and integration (Astleithner et al. 2004; Holman 2009). This shared knowledge frame needs to be salient, credible and appeal to multiple audiences with varying backgrounds in order to enhance them to co-produce knowledge (Cash et al. 2006; Hegger et al. 2012; Mostert and Raadgever 2008). Such an empirically-based frame of reference or narrative is largely lacking at the moment, which leads to a poor science-policy interface that, in turn, hampers water-wise management of the urban water cycle.

1.5 RELEVANCE, OBJECTIVE AND RESEARCH QUESTIONS

In the previous sections we have argued that:

- The challenges of water, waste and climate change are great and urges cities to step beyond practices of traditional water management of sectorial fragmentation and incremental action;
- International organisations such as the UNDP, OECD and EU Mayors Adapt initiative propagate an urban development towards intra-sectorial integration through a participatory public-private policy process in order to achieve full adaptation and anticipation of the challenges of water, waste and climate change. This rationale can be framed as *water-wisdom*;
- The prevailing water governance systems are often still rooted in inflexible, fragmented and short-term traditional approaches. However, the development from 'government' to 'governance' marks a profound change towards more horizontal intra-sectorial decision-making that deliberately includes private actors. This development also relates to the emergence of two key approaches: 1. Integrated Water Resource Management which recognizes water as a key element of integration, 2. Adaptive Management which embraces the inherent uncertainty, complexity and risk involved in environmental governance. In this context cities emerge as focal areas of integration;
- We lack a clear understanding of how urban water management is actually evolving and therefore are in need of an empirical assessment that can identify levels of development towards water-wise practice in cities across the globe;
- It is necessary to understand how cities can develop capacity to better govern their water challenges. For this purpose, it is necessary to integrate the incoherent, often overly conceptual and case study-oriented literature regarding key social factors that form barriers or enable adaptive governance;
- The build-up of a large database of integrated empirical knowledge regarding enabling governance conditions may facilitate meaningful science-policy interaction. This is done by providing insight into how cities can improve their capacity to manage and govern integrated challenges of water, waste and climate change and understand how they can become water-wise.

Therefore, the research aim of this dissertation is:

Increasing our understanding of what water-wisdom is and which governance conditions cities require to achieve it, by consistently analysing the water management performance and governance capacity of cities across the globe.

By pursuing this aim this dissertation intends to contribute to the scientific literature on urban water management, water governance and environmental governance by providing an empirically-based integrated understanding of the development towards water-wisdom in cities across the globe. There is little empirically-based generic knowledge about the key conditions necessary to achieve progress towards water-wise cities that are able to address the challenges of water, waste and climate change. By systematically analysing the water management and water governance in cities, an empirically-based understanding of the different levels of urban development towards becoming water-wise will be generated that may facilitate cities in improving their water cycle management step by step. Moreover, this research also aims to provide a more generic contribution to the field of water governance by providing a comprehensive frame that integrates the existing scientific literature into a concrete and applicable analysis that can facilitate decision-makers and policy development. In doing so, an in-depth understanding can be developed of what water-wisdom is and which factors may account for water-wise urban development across the globe.

So, the main research question is: *What factors account for water wisdom in urban areas across the globe?*

This question is subdivided into five sub questions (see figure 1.1). Research questions 1 and 2 focus on water management. They involve the development of an integrated urban water cycle management assessment method and - based on the generated empirical results - the identification of levels of urban development towards water-wisdom. Research question 3 targets the analysis of water governance by analysing the capacity to govern urban water challenges and illustrating this analysis in the field. Research question 4 investigates the relation between water management performance and governance capacity and explores the role of context factors that may influence meaningful capacity development. Based on the answers to the research questions, action perspectives can be formulated to facilitate cities to become water-wise.

SQ1 What are the characteristics of a comprehensive framework for assessing water cycle management in urban areas around the world?

We first need to develop an integrated assessment framework that empirically assesses the most important components of the entire urban water cycle. An integrated set of quantitative indicators is developed in order to consistently analyse the water cycle management of different cities around the world. In order to get a clear insight into the key points of management improvement, it is important to strictly separate management performance from its social, environmental and financial context. The comprehensive framework is developed in chapter 3. The developed framework forms the basis for the identification of levels of urban water cycle development which are central to all the other chapters.

SQ2 What levels of water-wisdom can be identified based on empirical urban water cycle management assessments?

Based on the empirical results of the water cycle assessment frameworks in 45 cities, we can identify levels of urban development towards achieving water-wisdom (chapter 4). These developments are happening in many cities around the world in different phases and pathways. Therefore, a clear heuristic identification of levels of urban development may provide a good starting point to understand and explore optimal trajectories for groups of cities with similar characteristics. Moreover, based on these empirical findings we can define the ultimate goals these cities may have and that is to achieve water-wisdom. These levels of urban development towards water-wisdom and the definition of water-wise management are key to conceptualizing the governance of improving the urban water cycle and forms the content of chapters 5, 6 and 7.

SQ3 What are the characteristics of a comprehensive framework for assessing water governance capacities in cities around the world?

To answer this research question a governance capacity framework is developed, operationalized and validated. This framework contains all relevant governance conditions necessary for dealing with the challenges of water, waste and climate change in cities. Through this framework the key governance conditions that together determine the overall governance capacity to address water challenges are quantified, operationalized and illustrated in the city of Amsterdam, the Netherlands. The developed framework allows for empirically-based knowledge development of the key elements of governance capacity in a number of cities covering several reoccurring water challenges. The consistent governance analysis of cities enables the exploration of the influence that the national context can have on local urban water governance (chapter 6). It also allows for the identification of reoccurring barriers that cities may experience and how water management performance is related to governance capacity (chapter 7). In this way, the governance capacity analyses form the basis to understanding the most important improvement options for cities to become water-wise.

SQ4 What contextual factors influence the development of governance capacity?

In the formulation of transferable lessons and action perspectives for cities with similar features, it is important to understand the role of the contextual background of each city. National policies, financial arrangements and other context variables may influence the relative importance of each governance condition. It enables an optimal interpretation of the obtained insights that the water governance assessments provide, e.g. who can be held responsible, to what extent are local stakeholders empowered to act, and how can we optimize a meaningful exchange of knowledge and experiences between cities with varying contextual backgrounds.

SQ5 How does water management performance relate to observed differences in governance capacity between cities?

An empirically-based understanding of the capacity development priorities of cities to govern water challenges is obtained by exploring the relation between water management performances and governance capacity in several cities. In this way, the status of water cycle management performance and which governance conditions account for this can be understood (chapter 8).

In sum, figure 1.1 provides the research framework that connects the research questions with specific steps and activities. First, two diagnostic urban water cycle assessments are developed in order to answer research question 1. Second, reseach question 2 is addressed by identifying levels of urban development towards water-wisdom based on the data from the two developed assessment frameworks applied in 45 municipalities and regions. The third research question regards the development of a comprehensive framework for assessing water governance capacities in cities. The resulting governance capacity analysis is developed, tested in the city of Amsterdam and than applied 15 other cities across five continents and with respect to 41 water challenges respectively. Beyond, the governance conditions that attribute to water-wisdom, also contextual factors may play an important role which is explored through a comparative case study in four cities with respect to flood risk governance. Next, based on a comparative case study of seven cities, the relation between water management performance and governance capacity is explored. Based on these research steps, all five research questions are answered and the overall objective is addressed.

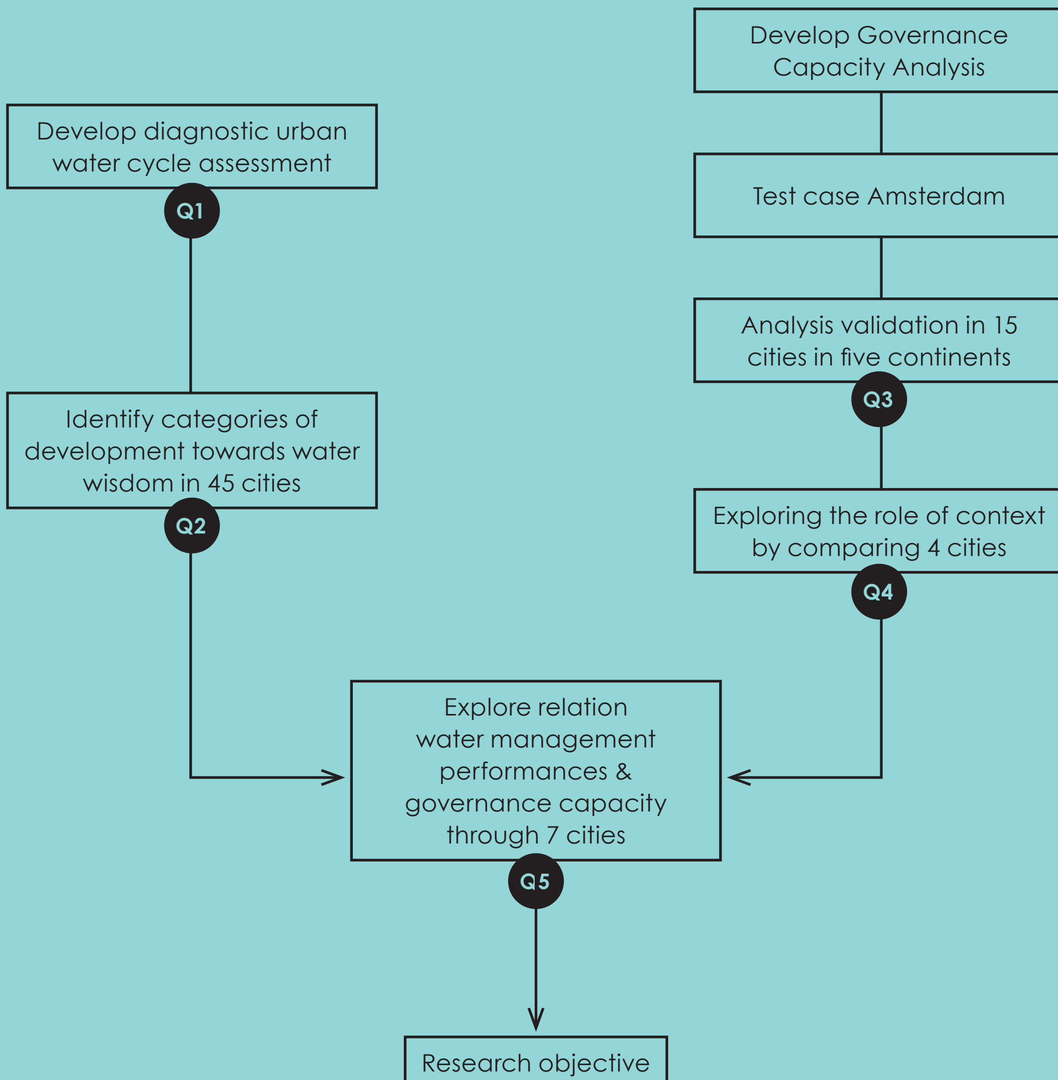

FIGURE. 1.1 — Research framework connected to the research questions.

1.6 METHODS

METHODS APPLIED TO ANSWER THE RESEARCH QUESTIONS

RQ1: What are the characteristics of a comprehensive framework for assessing water cycle management in urban areas around the world?

- **Desk study:** Detailed analysis of publicly available datasets, analysis of policy documents, reports and literature was used to develop a water cycle management assessment frameworks based on the previous work of the City Blueprint methodology. It includes scientific literature on the debate on urban water management, climate adaptation and solid waste treatment as well as reflections on other indicator approaches, in particular those focused on sustainability. Publicly available datasets have been explored to find data sources for the indicator scoring. Additional policy documents, reports and action plans were studied to enlarge the scope of the assessment, to gather data and assess the data feasibility of the indicators.

RQ2: What levels of water-wisdom can be identified based on empirical urban water cycle management assessments?

- **Questionnaire:** An interactive questionnaire has been developed and applied in order to verify the gathered data with the city and to collect additional data (EC 2017a,b).
- **Statistical analysis:** Basic statistics have been applied on the indicator scores in order to test the indicator's variance, and Pearson correlations coefficients between the indicators. In addition, intra-category Pearson correlation coefficients were calculated in order to test, iteratively improve and ensure a balanced assessment of the most important urban water management aspects and refine the indicator scoring method. Furthermore, Pearson correlations have been used to provide insight into how the city's water management performance relates to social, economic and environmental factors in the 45 municipalities and regions assessed, without suggesting causal relations. Finally, hierarchical clustering of the indicators results of 45 municipalities and regions has been applied to categorize cities based on key traits using squared Euclidean distances.

RQ3: What are the characteristics of a comprehensive framework for assessing water governance capacities in cities around the world?

- **Desk study:** Detailed literature study to identify and construct a cohesive framework of governance conditions that together determine the governance capacity to improve integrated water management in cities (i.e. the Governance Capacity Analysis). A score chart was developed by formulating a Likert scale for each indicator. The score chart was applied to analyse the status of governance conditions.
- **Interviews:** Semi-structured in-depth interviews were conducted, to analyse which governance conditions were the most important in governing the urban challenges of water scarcity, flood risk, wastewater treatment, solid waste treatment and urban heat islands.
- **Expert review:** Expert review has been applied to explore the framework's comprehensiveness, and embedding in existing literature on urban water governance, governance capacities and adaptive governance. Experts were asked to comment on a written summary of the preliminary Governance Capacity Analysis.
- **Test-case Amsterdam:** During the operationalization of the Governance Capacity Framework in Amsterdam interactive workshops with different experts have been organized in order to improve and verify the framework and identify key stakeholders to be addressed in the operationalization of the framework.

RQ4: What contextual factors influence the development of governance capacity?

- **Comparative case-study:** In order to understand the role that contextual background and supranational, national and regional policy frame has on the local capacity to govern a water challenge, the flood risk of two cities in United Kingdom and the Netherlands were compared according to the Governance Capacity Analysis. In addition, the policy frames of both countries were analysed by studying policy documents and scientific literature.

RQ5 How does water management performance relate to observed differences in governance capacity between cities?

- **Combining the developed and applied tools:** The relation of management performance (as assessed by the City Blueprint performance Framework) and the capacity to govern the challenges of flood risk, water scarcity and wastewater treatment has been scrutinized. First, cities were assessed with respect to their capacity to govern challenges of flood risk, water scarcity and wastewater treatment (according to the Governance Capacity Analysis). Next, the separate topical capacity profiles were aggregated into a single governance capacity profile for each of the seven cities. Finally, these 27 capacity indicators were aggregated into one overall index, the Governance Capacity Index (GCI). This index was correlated with the aggregated score of the 25 water management performance indicators, i.e., the Blue City Index (BCI). In total, the governance capacity of seven cities was analysed with respect to all three challenges. In addition, eight other cities were assessed with respect to their capacity to govern one or two of these challenges. All 15 cities were assessed for their water management performances. The correlation between water management performances and governance capacity was calculated for seven cities. This calculation was also extended to include all 15 cities.

For research questions 1 and 2, 45 cities were analysed by developing and applying a framework of 25 quantitative performance-oriented indicators (the *City Blueprint Framework*) and 18 descriptive indicators and sub-indicators (the *Trends and Pressures Framework*). For research questions 3, 4 and 5, 27 ordinal-scaled indicators have been developed and applied in 15 cities different water challenges according to the *Governance Capacity Analysis* (Fig. 1.2). A total of 41 water challenges have been analysed in these cities. The development and application of both analyses forms the core of this dissertation's effort to identify key factors that account for water-wisdom in cities across the globe. Therefore, a brief introduction into these methods is provided that outlines their key characteristics in terms of validity, reliability and generalisability. Next, a brief description of the methodological approach is provided for each research question.

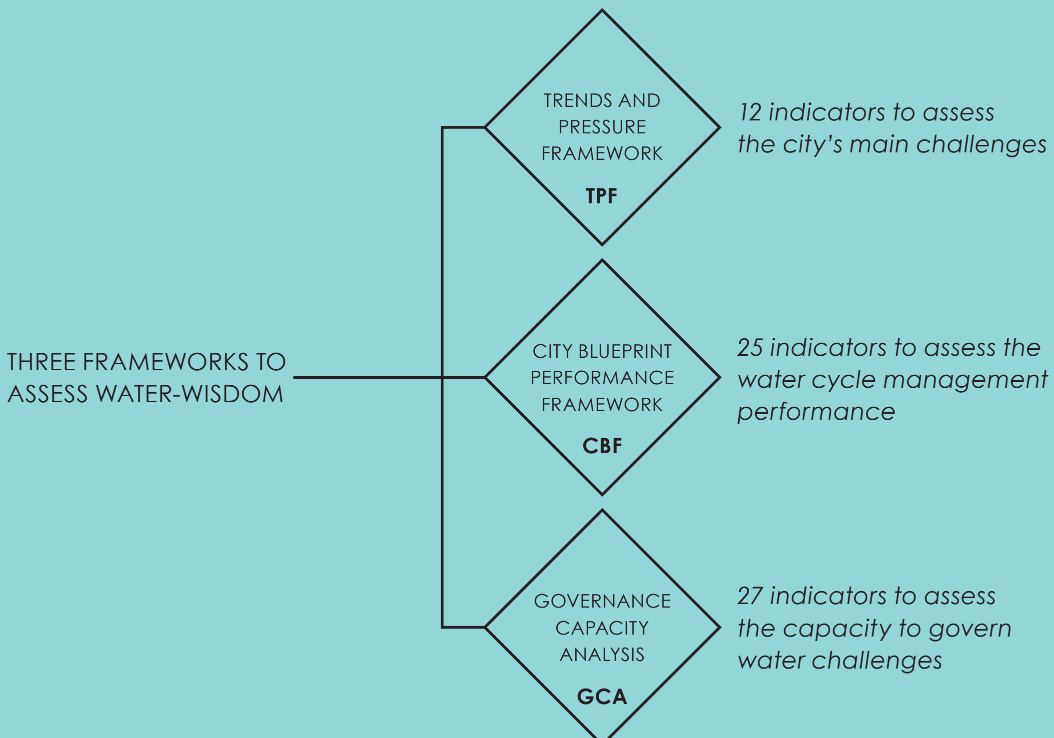

FIGURE. 1.2 — Overview of the methods developed in this dissertation in order to assess key factors that account for water-wisdom. The Tends and Pressures Framework and City Blueprint Framework are related to research question 1 and 2, the governance capacity analysis is related to research questions 3, 4 and 5.

VALIDITY & RELIABILITY OF THE FRAMEWORKS DEVELOPED IN THIS DISSERTATION

The Trends and Pressures Framework and City Blueprint Framework: Both frameworks are based on a detailed study of policy documents, reports, grey literature, scientific papers as well as face-to-face and written contact and their approval. Different actors are involved such as various departments of the municipality, organisations related to drinking water and sanitation services, flood risk authorities, universities etc. The indicators are scored according to a standardized calculation method that is publicly available (see EC 2017a,b). For each indicator, the required data originates from publicly available documents that are referenced consistently. The data sources, accuracity and data quality provided by the city is checked by the researcher for reliability. Often several suggestions were given to improve the accuracy before the indicator scores were definitive. The indicators encompass the urban water cycle and accordingly the municipal boundaries form the indicator spatial boundaries. In addition, the most recent data is used to score the indicators. The indicators have a quantitative nature, and some have an ordinal scoring system which is clearly defined to ensure that what is being measured is consistent for all city analyses. The Trends and Pressures Framework (18 indicators and subindicators) and the City Blueprint performance Framework (25 indicators). Since they have been applied in 45 cities, these analyses have resulted in respectively 810 and 1125 indicator scores.

The Governance Capacity analysis: In total, 220 in-depth interviews were conducted in 15 cities across six continents (for more detail see appendix 1). A total of 13 students have applied the governance capacity analysis in these cities (outlined in chapter 5) as part of their master thesis, under supervision of the PhD Candidate and based on a thorough methodological instruction. Through their experiences, feedback and collected data, this dissertation could fulfil the high ambitions with respect to its empirical focus and geographical coverage. It also enabled the development of a well-tested, reproducible and reliable data collection method. Beyond interviews, the analysis of each city started with a literature study and stakeholder analysis.

After the interviews were conducted, a preliminary score and substantiation of the score was provided. The interviewees were given the opportunity to provide feedback on this preliminary analysis by providing additional argumentation, information sources et cetera.. This feedback has been used to improve the accuracy of the analyses. The in-depth interviews, literature study and feedback are aggregated to a substantiated score for each individual indicator in each city. The individual steps and the result of it – i.e. the justified indicator scores – in 41 analyses divided over 15 cities, are accessible: http://beta.tools.watershare.eu/gca/$/. In order to protect the personal information of the interviewees, different tiers of access were developed. The first tier is the *administrator*. The administrator has access to all reported information and reviews all data as part of quality assurance process. Second, an access for *external review* can be granted for specific city reports. An example of such an access is with the review of scientific work that includes governance capacity analyses (such as the access granted to the reviewers of this dissertation). A third tier of access is that of a *registered city participant*. This can be anyone who is interested. This person can request access to the score justifications of a specific city or cities. However, registed city participants do not have access to interviewee information, in order to protect their privacy. The last tier of access is that of a *public visitor*. Public visitors do not need to request access. These users can see the overall scores of the indicators of all the cities that have been included in the software. In this way, the online database provides full transparency of the governance capacity analysis while the personal privacy of the interviewees is not compromised. The database structure enables other researchers to use this software and get a peer-reviewed data quality check before it is added to the database. In this way, consistency, reliability and reproducibility have been maximized, contributing to the empirical knowledge. The governance capacity analysis (27 indicators) has been applied to 41 challenges in 15 cities. Hence, there are a total of 1107 indicator scores.

Overall, there is a fair balance between all scores, i.e., the main social, environmental and financial trends and pressures

(810 indicator scores), water cycle management performance (1125 scores) and governance capacities to address the water challenges (1107 scores). Furthermore, the 15 cities in which the governance capacities were analysed were selected based on their diversity in water management performances (measured by the City Blueprint performance Framework). In this way a comprehensive and balanced scope was ensured. Both aspects may be considered as preconditions for the formulation of key factors that account for water-wisdom in cities across the globe.

1.7 OUTLINE OF THE DISSERTATION

Chapter 2 provides an introductory overview of the challenges of water, waste and climate change which form the scope of this dissertation. This chapter also stresses the importance of good governance to enable cities to improve their water management to address these challenges.

Chapters 3 and 4 are about developing an integrated water cycle assessment to identify levels of urban development towards achieving water-wisdom. In chapter 3, an integrated indicator framework is developed to consistently assess the urban water cycle. This consists of water management performance indicators covering the most relevant aspects of the entire urban water cycle. Chapter 4 applies this newly developed integrated urban water management assessment to 45 municipalities and regions in 27 countries. The results provide insight into cities with similar scoring patterns and clusters cities based on their specific traits.

Chapters 5, 6 and 7 are about the development and appliction of a governance capacity analysis that identifies key conditions that limit or enhance the overall capacity to govern challenges of water, waste and climate change. In chapter 5, the assessment is developed and illustrated by a case study of the city of Amsterdam, the Netherlands. Chapter 6 aims to identify cross-cutting contextual factors that may point to capacity-development priorities within different institutional contexts. Chapter 7 provides an overview of the application of the governance capacity analysis in seven cities to explore the relation between water management performances and governance capacity. In chapter 8, the dissertation finishes with the main conclusions and reflections.

Each chapter has been written as a independent article that are published different journals.

SETTING THE SCENE: URBAN CHALLENGES WATER, WASTE AND CLIMATE CHANGE

CHAPTER 2 — The challenges of water, waste and climate change in cities

Introduces all RQs. Koop and Van Leeuwen 2017. The challenges of water, waste and climate change in cities. Environment, Development and Sustainability. 19(2), 385-418

DIAGNOSIS OF URBAN WATER CYCLE MANAGEMENT

CHAPTER 3 — Developing the City Blueprint approach

Addresses RQ1: *What are key characteristics of an urban water cycle management framework?* Koop and Van Leeuwen 2015a. Assessment of the Sustainability of Water Resources Management. A Critical Review of the City Blueprint Approach. Water Resources Management 29(15), 5649-5670

CHAPTER 4 — Applying the City Blueprint Framework in 45 Municipalities and Regions

Addresses RQ2: *What levels of urban development towards water-wisdom?* Koop and Van Leeuwen 2015b. Application of the Improved City Blueprint Framework in 45 Municipalities and Regions. Water Resources Management 29(13), 4629-4647

DIAGNOSIS OF THE CAPACITY TO GOVERN WATER CHALLENGES

CHAPTER 5 — Assessing the governance capacity of cities to address challenges of water, waste, and climate change

Addresses RQ3: *What are key characteristics of a framework to assess governance capacity?* Koop, Koetsier, Doornhof, Driessen, Dieperink, Van Leeuwen and Reinstra 2017. Introducing a framework to assess the water governance capacity in cities: The results from Amsterdam, the Netherlands. Water Resources Management 31(11), 3427-3443

CHAPTER 6 — Assessing the capacity to govern flood risk in cities and the role of contextual factors

Addresses RQ4: *What contextual factors influence capacity development?* Koop, Monteiro Gomes, Schoot, Driessen, Dieperink, and Van Leeuwen 2017. Assessing the capacity to govern flood risk in cities and the role of contextual factors. Sustainability 10(8), 2869

CHAPTER 7 — Relating water management performance with governance capacity: what are capacity-development priorities?

Addresses RQ5: *What is the relation between water management performances and governance capacity?* Koop, Driessen, Dieperink, and Van Leeuwen 2018 Optimizing city-to-city learning to improve urban water governance (in the context of climate change)

CONCLUSIONS & REFLECTIONS

CHAPTER 8 — Conclusions, reflections and action perspectives for water-wise management
Addresses main question: What factors account for water wisdom in urban areas across the globe?

CHALLENGES OF WATER, WASTE & CLIMATE CHANGE IN CITIES

Chapter 2
The challenges of water, waste and climate change in cities

CHAPTER 2

THE CHALLENGES OF WATER, WASTE AND CLIMATE CHANGE IN CITIES

This chapter is published as: Koop S.H.A. and Van Leeuwen C.J. (2017) The Challenges of water, waste and climate change in cities. Environment, Development and Sustainability. 19(2), 385-418

ABSTRACT

This chapter addresses all research questions by providing the scope and focus of the other chapters that each address one research question respectively.

Cities play a prominent role in our economic development as more than 80 % of the gross world product (GWP) comes from cities. Only 600 urban areas with just 20 % of the world population generate 60 % of the GWP. Rapid urbanization, climate change, inadequate maintenance of water and wastewater infrastructures and poor solid waste management may lead to flooding, water scarcity, water pollution, adverse health effects and rehabilitation costs that may overwhelm the resilience of cities. These megatrends pose urgent challenges in cities as the cost of inaction is high. We present an overview about population growth, urbanization, water, waste, climate change, water governance and transitions. Against this background, we discuss the categorization of cities based on our baseline assessments, i.e. our City Blueprint research on 45 municipalities and regions predominantly in Europe. With this bias towards Europe in mind, the challenges can be discussed globally by clustering cities into distinct categories of sustainability and by providing additional data and information from global regions. We distinguish five categories of sustainability: (1) cities lacking basic water services, (2) wasteful cities, (3) water-efficient cities, (4) resource-efficient and adaptive cities and (5) water-wise cities. Many cities in Western Europe belong to categories 3 and 4. Some cities in Eastern Europe and the few cities we have assessed in Latin America, Asia and Africa can be categorized as cities lacking basic water services. Lack of water infrastructures or obsolete infrastructures, solid waste management and climate adaptation are priorities. It is concluded that cities require a long-term framing of their sectorial challenges into a proactive and coherent Urban Agenda to maximize the co-benefits of adaptation and to minimize the cost. Furthermore, regional platforms of cities are needed to enhance city-to-city learning and to improve governance capacities necessary to accelerate effective and efficient transitions towards water-wise cities. These learning alliances are needed as the time window to solve the global water governance crisis is narrow and rapidly closing. The water sector can play an important role but needs to reframe and refocus radically.

2.1 INTRODUCTION

2.1.1 POPULATION GROWTH

The world population is projected to increase by more than one billion people within the next 15 years, reaching 8.5 billion in 2030, and to increase further to 9.7 billion in 2050 and 11.2 billion by 2100 (UN 2015). Approximately 60 % of the global population lives in Asia (4.4 billion), 16 % in Africa (1.2 billion), 10 % in Europe (738 million), 9 % in Latin America and the Caribbean (634 million), and the remaining 5 % in Northern America (358 million) and Oceania (39 million). Population growth patterns are different across the globe. Figure 2.1 shows population growth in some world regions from the year 1600 to 2100 (Klein Goldewijk et al. 2010; UN 2015a). Many countries in Africa are still growing exponentially. This implies that their claims on resources also increase rapidly. In Western Europe and India? (India, Bangladesh, Nepal, Sri Lanka, Bhutan, Pakistan, Afghanistan and Maldives), population growth is gradually levelling off (logistic growth), while in China growth will soon decline due to the one-child family policy. This policy was introduced in 1979 to halt the rapid growth in the Chinese population, and it included late marriage and childbearing (delaying the start of reproduction) as well as the restriction on family size to just one child per family with high penalties for infringement (Hesketh et al. 2005). In fact, the maximum population densities in China? (China, Hong Kong, Macao and Mongolia), Western Europe and India? are expected in the year 2026 (1428 million), 2045 (424 million) and 2069 (2554 million), respectively (UN 2015a). Urbanization will continue in both the more developed and the less developed regions so that, by 2050, urban dwellers will likely account for 86 % of the population in the more developed regions and for 64 % of that in the less developed regions. Overall, the world population is expected to be 67 % urban in 2050 (UN 2012). Thus, urban areas of the world are expected to absorb all the population growth over the next decades.

2.1.2 CITY BLUEPRINT METHODOLOGY

The development of the City Blueprint methodology to assess the sustainability of integrated water resources management (IWRM) in municipalities and regions started in 2011 (Van Leeuwen et al. 2012). A baseline assessment was developed as part of the strategic planning process in cities as described in the training modules developed in the SWITCH project (managing water for the city of the future). The assessment was kept as short, clear

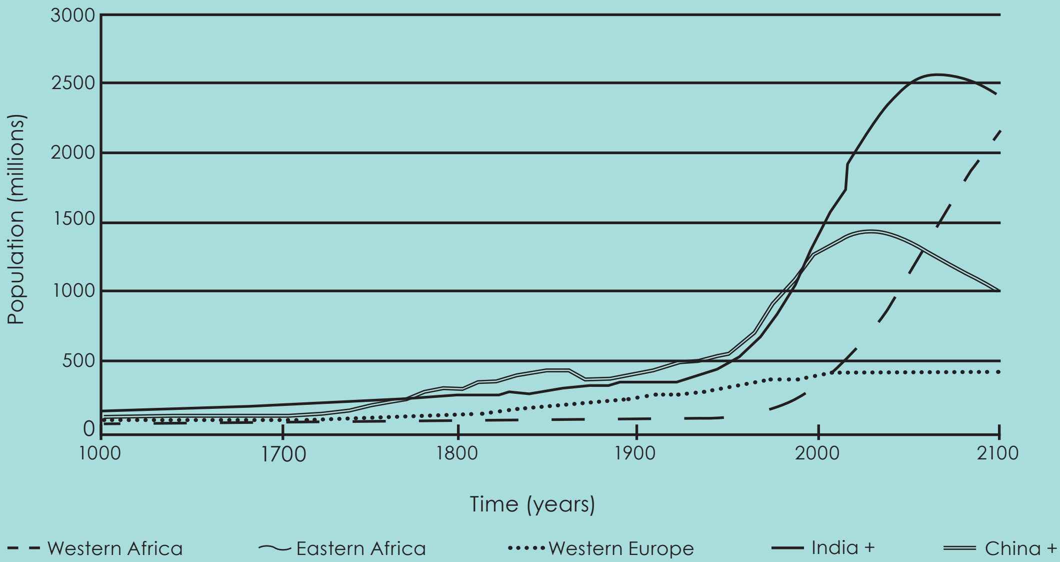

FIGURE. 2.1 — Total population estimations of India? (India, Bangladesh, Nepal, Sri Lanka, Bhutan, Pakistan, Afghanistan and Maldives), China? (China, Hong Kong, Macao and Mongolia), Eastern Africa, Western Africa and Western Europa based on the HYDE 3.1 database (Klein Goldewijk et al. 2010), and the UN medium variant of the world population predictions (UN 2015a).

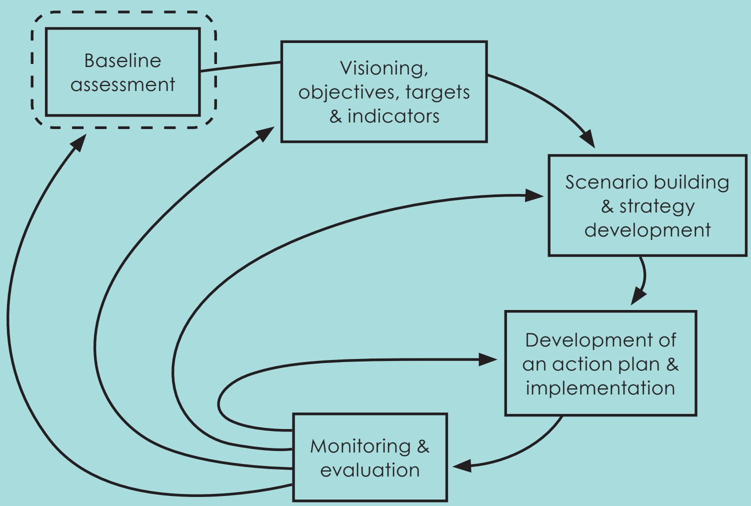

FIGURE. 2.2 — Function of the City Blueprint (baseline assessment) in the strategic planning process for IWRM according to SWITCH (Philip et al. 2012).

and simple as possible. The strategic planning process and the role of the City Blueprint are provided in Fig. 2.2. The indicators in the City Blueprint are based on the 3 Ps (People, Planet and Profit) in the water cycle (Van Leeuwen et al. 2012, Koop and Van Leeuwen 2015a). Use has been made of several other assessment frameworks (Van Leeuwen et al. 2012), including the Green City Index (2015). Similar assessment schemes have been published by SDEWES (2015).

The sustainability of IWRM is assessed in an interactive process involving the most important IWRM actors (Philip et al. 2011). This interactive approach has been used for the assessment of all cities, except for Rotterdam, Ankara and London. For these cities, an extensive literature search was completed. For all other cities, a comprehensive questionnaire was completed by municipalities and regions, which takes them a few days (EC 2015a). The City Blueprint offers cities a threefold benefit: (1) an interactive quick scan of their own water cycle, (2) access to best practices in other cities (Koop et al. 2015) and (3) participation in an international platform (EC 2015a). After the completion of the questionnaire, a radar chart of all 25 performance indicators (the City Blueprint) and the Blue City Index (BCI) are provided both varying from 0 (concern) to 10 (no concern). This initiative has been scaled up to an action under the flag of the European Innovation Partnership on Water of the European Commission (EC 2015a) in the framework of the European Blueprint for water (EC 2012). The City Blueprint provides municipalities and regions with a practical and broad framework to define steps towards realizing a more sustainable and resilient water cycle in collaboration with key stakeholders.

2.1.3 OUTLINE OF THIS STUDY

The aim of this study is to present an overview of the challenges of water, waste and climate adaptation in cities and to link the City Blueprint activities to major developments such as: the challenges of urbanization (Sect. 2), water governance (Sect. 3) and transitions in cities (Sect. 4). In Sect. 5, we summarize our work on City Blueprints and discuss their role in learning alliances of cities (Sect. 6). Concluding remarks are provided in Sect. 7.

2.2 URBANIZATION AND THE DYNAMICS OF THE CITY

2.2.1 HOMES

Most people live in cities. There are more than 400 big cities (urban areas with more than one million inhabitants) and 23 megacities (metropolitan areas with a population of more than 10 million). Most of these megacities are in Asia (UN 2012). The United Nations (UN) estimates that 54 % of all people live in cities, and by 2050, this will increase to 66 % (UN 2015a). In developed countries, this percentage is even higher (more than 80 %). Global urbanization is taking place at a high speed. In 1970, for example, there were only two megacities (Tokyo and New York); in 1990, there were 10; in 2011, there were 23, and by 2025, there will be 37 megacities. Tokyo, the largest megacity, will grow from 37 million to about 40 million people in 2025 (UN 2012.

The United Nations (UN 2015a) estimates that between 2015 and 2050 the world population will grow from 7.32 to 9.55 billion. At the same time, the population in cities will increase from 3.96 to 6.34 billion, while the number of people living in rural areas will decline. Due to population growth and migration from rural areas to cities, approximately 190,000 people per day will need to find a new place to live. In other words, over the next 40 years, we will build approximately 3000 big cities with a population size of Amsterdam. It should be noted that there are major differences in the rate of population growth and urbanization in different parts of the world (UN 2012, 2015a). Developing countries account for 93 % of the urbanization globally, 40 % of which is the expansion of slums. By 2030, the urban population in Africa and Asia will double (UNESCO 2015a).

2.2.2 WORK

Cities play a prominent role in economic development. More than 80 % of the gross world product (GWP) comes from cities. Only 600 urban areas with just 20 % of the world population generate 60 % of the GWP (Dobbs et al. 2011). Cities are therefore also job generators and centres of communication, innovation and creativity. They also play a large part in social and cultural matters (EC 2011; BAUM 2013). Cities can also take the lead in sustainable development as they offer many economies of scale per head of the population in terms of raw material use, energy consumption, waste recycling and transport (BAUM 2013).

The continued acceleration of change or ‘rapidification’ of our planet, our life and the global economy is higher than ever (Francis 2015). The transformation of China due to urbanization and industrialization is taking place on a scale 100 times greater and ten times faster as compared to UK a century ago (Dobbs et al. 2012). This comes with unavoidable consequences (Van Leeuwen 2008). To illustrate this, two examples are provided: one looking back and the other forward: first of all, a backward glance based on the turnover of the chemical industry over the last 10 years. In 2003, the production of the chemical industry was roughly equally divided between Europe, North America and the rest of the world. In 10 years' time sales, figures have almost doubled to €3156 billion, but the hub has shifted to Asia with a share of 57 % in 2013 (CEFIC 2014).

The second example has been taken from a report by Dobbs et al. (2012). Emerging cities create opportunities. That is why entrepreneurs increasingly focus on cities with great economic growth potential as in 2025 one billion new consumers are expected. This will create many opportunities and is undoubtedly the main reason why people are moving on such a massive scale to the city. There will be acceleration in the shift of the economic hub from the old developed countries to the new developing or transitioning countries, particularly in Asia. The population growth of Chinese cities until 2025 and the accompanying growth in gross domestic product (GDP) and drinking water supply needs has been estimated at 30.9, 39.7 and 25.6 %, respectively, whereas growth in European cities has been estimated at 1.8, 5.7 and 1.7 %, respectively. This means that after about five centuries (since the discovery of America), Asia will again become the global economic epicentre (Dobbs et al. 2012).

2.2.3 CHALLENGES OF URBANIZATION

The concentration of homes and employment in cities also has its downside. Cities currently take up about 2 % of the land surface on Earth, but account for 60–80 % of the energy consumption and 75 % of global CO^2 emissions (UN 2013a). Roughly the same percentage will also apply to the use of raw materials (e.g. metals, wood, plastics) for infrastructure, houses, cars and numerous other consumer items. Cities are concentrated centres of production, consumption and waste (Grimm et al. 2008; Bai 2007). Ecological studies of cities have shown that they sometimes exceed their environmental footprint by a factor 10–150 (Doughty and Hammond 2004). This creates enormous pressure not only on water supply, solid waste recycling and wastewater treatment (Grant et al. 2012), but also on nature and the built environment too, including soil, air and water pollution (UN 2013a; Hoekstra and Wiedman 2014). Water pollution reduces the availability of healthy water (Schwarzenbach et al. 2006; WHO 2008; Van Leeuwen and Vermeire 2007). Cities are therefore becoming increasingly dependent on rural areas for the supply of energy, water, building materials and food, as well as for the removal of waste and waste substances (OECD 2015a; UN 2014a). A summary of some of the challenges in cities is provided in Fig. 2.3.

The consequences of urbanization extend to areas far beyond the city, areas which are vital to supply cities with important 'ecosystem services' (OECD 2015a). An example is provided by the megacity Istanbul, where water is now supplied from a basin by a 180-km- long pipeline (Van Leeuwen and Sjerps 2016). Habitat preservation, i.e. the conservation of the forests surrounding Istanbul—vital habitats for the water supply—is extremely important for the future of Istanbul (Atelier Istanbul 2012).

2.2.4 WATER CHALLENGES IN THE CITY

Drinking water consumption in cities makes up a small fraction of the total water footprint. For example, people in the Netherlands use about 2300 m3 of water per person per year of which 67 % is for agriculture, 31 % is used in industry, while only 2 % makes up household water (Van Oel et al. 2009). This means that water challenges in cities need to be solved predominantly by actors outside the traditional water sector. In fact, half of all cities with

Urbanization
Urban areas of the world will absorb all of the population growth. Overall, the world population is expected to be 67 per cent urban in 2050

Water use & water scarcity
Water withdrawals have tripled over the last 50 years. In 2030, there will be a 40% supply shortage of water.

Human health
Currently, 3.4 million people - mostly children - die from water-borne diseases every year.

Climate change
Climate change may worsen water services and quality of life in cities.

Sanitation
Currently, 2.5 billion peopla are without improvised sanitation facilities.

Hazards
Water-related hazards account for 90% of all natural hazards.

FIGURE. 2.3 — Megatrends pose urgent challenges in cities (Van Leeuwen 2013) populations greater than 100,000 are located in water-scarce basins. In these basins, agricultural water consumption accounts for more than 90 % of all freshwater depletions (Hunger and Döll 2008; Richter et al. 2013). In a critical analysis, Richter et al. (2013) point out that nearly all water used for domestic and industrial purposes is eventually returned to a water body. For instance, toilets are flushed and purified wastewater as well as cooling water in power plants is often returned to rivers. Because much of this water is not consumed, efforts to reduce urban water use or to recycle water with the aim to alleviate water scarcity per se, hardly makes any difference. In total, the domestic, industrial and energy sectors account for less than 10 % of global water consumption (Richter et al. 2013; Hoekstra et al. 2012). Of course, proper urban use and reuse of water, as well as adequate sanitation, contribute significantly to pollution reduction, local water availability, as well as to energy efficiency, energy and nutrient recovery.

Hoekstra et al. (2012) estimate that agriculture accounts for 92 % of the global blue water footprint. Land, energy and climate studies have shown that the livestock sector plays a substantial role in deforestation, biodiversity loss and climate change. Livestock also significantly contributes to humanity's water footprint, water pollution and water scarcity (Jalava et al. 2014; Hoekstra 2014). Furthermore, the Food and Agriculture Organization of the United Nations (FAO) estimates that 32 % of all food produced in the world was lost or wasted in 2009 (Lipinski et al. 2013; FAO 2011a). Therefore, consumers, i.e. citizens, can play a major role in the reduction in the global water footprint by both reducing the fraction of animal products in their diets and by curbing their food waste.

With a changing climate comes a greater demand for proactive adaptation processes, as well as knowledge of how adaptation policies and measures could be implemented successfully. Accidents often lead to major policy changes. In 1953, almost 2000 people drowned in the Netherlands. As a result of this catastrophe, a long-term plan was devised, the Delta Plan, with a Delta Fund, and a Delta Commissioner appointed, reporting directly to the Dutch Minister-President (Delta programme 2013). Another example of a reactive adaptation policy can be observed in the city of Melbourne. Melbourne is a city of extremes: floods due to excessive rainfall, but drought too. A 10-year period of drought has recently come to an end. This has forced the city to take rigorous measures: (1) the construction of a costly desalination plant as backup for drinking water supply, (2) rain- water harvesting and (3) the reuse of wastewater (Van Leeuwen 2015). Melbourne has become ‘water sensitive’ or water-wise (Brown et al. 2009), and the citizens ‘do their bit’, e.g. by limiting water use and installing rainwater tanks on a wide scale to make good use of the rain when it does fall.

Disasters quickly raise awareness, whether that be about defending against flooding or dealing with drought (Koop and Van Leeuwen 2015a, b). Hence, adaptation measures are mainly reactive (Amundsen et al. 2010; Reckien et al. 2015), ad hoc, and often ineffective and expensive (UNEP 2013). Globally, the main challenge is to move from reactive measures to proactive transitions, by taking bold decisions based on a cohesive long-term process as shown in Fig. 2.2.

2.2.5 SOLID WASTE AND WATER

Cities generate massive amounts of solid waste. Poor waste management, ranging from non-existing collection systems to ineffective disposal, causes air, water and soil contamination. Open and unsanitary landfills contribute to contamination of drinking water and increase infection and transmit diseases. Managing solid waste is another challenge of urban areas of all sizes, from megacities to the small towns and large villages (UN-Habitat 2010a).

Plastics easily enter rivers and ultimately oceans. Jambeck et al. (2015) calculated that 275 million metric tons of plastic waste was generated in 192 coastal countries in 2010. Approximately 1.7–4.6 % of this plastic enters oceans (Jambeck et al. 2015). Plastic waste does not readily biodegrade but degrades into smaller pieces that affect marine ecosystems (Derraik 2002). The plastics form ‘soups’ in five major ocean gyres: two in the Pacific, one in the Indian and two in the Atlantic and affect many marine animals by ways of ingestion (Zarfl et al. 2011; McFedries 2012). Also consumer products contribute to the emission of microplastics to surface water such as cosmetics and personal care products, cleaning agents, paint and coatings (Van Wezel et al. 2015). Recently, a detailed study was made for the river Rhine, one of the largest European rivers. Microplastics were found in all samples, with 892,777 particles per km2 on average. These microplastics concentrations were diverse across the river, reflecting various sources and sinks such as wastewater treatment plants, tributaries and weirs (Mani et al. 2015).

Recycling leads to substantial resource savings (EMF 2014, 2015a) and to significant reductions in greenhouse gas (GHG) emissions. GHG emissions from open dump land-filling are about 1000 kg CO^2-eq. tonne-1 of solid waste, whereas this can be largely reduced to 300 kg CO^2-eq. tonne-1 for conventional landfilling. Actually, it can even be a net sink of carbon when most material is recycled or the energy is recovered (Manfredi et al. 2009). The global GHG emissions of solid waste disposal sites are estimated to be approximately 5–20 % of the global anthropogenic methane emission, which is equal to about 1–4 % of the total anthropogenic GHG emissions (IPCC 2006).

The order of preference of managing waste also known as the Lansink's ladder has been laid down in the Dutch Environmental Management Act (VROM 2001) and subsequently across Europe, as the waste hierarchy in the Waste Framework Directive (2008). The waste hierarchy is a preference order from: prevention, preparing for reuse, recycling, other recovery (e.g. energy recovery) and disposal.

Recently, the European Commission announced a plan for the circular economy. One of the reasons is that Europe currently loses around 600 million tonnes of materials contained in waste each year, which could potentially be recycled or reused. On average, only 40 % of the waste produced by EU households is recycled ranging from 5 % in some areas to 80 % in others. Turning waste into a resource is an essential part of increasing resource efficiency and part of this circular economy package (EC 2015b; EMF 2015b).

Solid waste data in many cities are largely unreliable. Available data show that cities can improve on their solid waste management as waste collection rates for cities in low- and middle-income countries range from 10 % in peri-urban areas to 90 % in commercial city centres (UN-Habitat 2010a). Even in Europe, recycling rates are rather low (EEA 2013). As the sustainability of IWRM in municipalities and regions is intrinsically linked to proper solid waste management, it was decided to include the following three indicators in the improved City Blueprint framework (Koop and Van Leeuwen 2015a), i.e. solid waste collected (the per capita non-industrial solid waste that is collected; kg/cap./year), solid waste recycled (% of collected non-industrial solid waste that is recycled or com- posted) and solid waste energy recovery (% of collected non-industrial waste that is incinerated with energy recovery). This information has been gathered for 45 municipalities and regions (Koop and Van Leeuwen 2015b, c).

2.2.6 THE COST OF URBAN WATER INFRASTRUCTURE

Cities need to protect their citizens against water-related disasters (e.g. droughts and floods), to guarantee water availability and high-quality groundwater, surface water and drinking water. Cities also need to have adequate infrastructure in response to climate, demographic and economic trends (OECD 2015a). The cost of urban infrastructure is high. The UNEP (2013) estimates that for the period 2005–2030 about US$ 41 trillion is needed to refurbish the old (in mainly developed countries) and build new (mainly in the developing countries) urban infrastructures. The cost of the water infrastructure (US$ 22.6 trillion) is estimated at more than that for energy, roads, rail, air and seaports put together. The wastewater infrastructure is responsible for the largest share of this 22.6 trillion. The report also warns that: *'Sooner or later, the money needed to modernise and expand the world's urban infrastructure will have to be spent. The demand and need are too great to ignore. The solutions may be applied in a reactive, ad hoc, and ineffective fashion, as they have been in the past, and in that case the price tag will probably be higher than US$ 40 trillion'.*

To support projected economic growth between now and 2030, McKinsey (2013) has estimated that the investments on global infrastructure need to increase by nearly 60 % from the US$ 36 trillion spent on infrastructure over the past 18 years. Therefore, an investment of US$ 57 trillion over the next 18 years is necessary. This is approximately 3.5 % of anticipated global GDP. These figures do not account for the cost of addressing the large maintenance and renewal backlogs and infrastructure deficiencies in many economies (McKinsey 2013). Cashman and Ashley (2008) have estimated the required annual expenditure on water and sanitation infrastructure for high-, middle- and low- income countries at, respectively, 0.35–1.2 %, 0.54–2.60 % and 0.71–6.30 % of the annual GDP.

Water goals have big costs but also big returns. Conservative estimates of global investments in a post-2015 water for sustainable development and growth agenda have been estimated (UN University 2013). Between 1.8 and 2.5 % of the annual global GDP is needed for implementation of water-related sustainable development goals. This would also generate a minimum US$ 3108 billion in additional economic, environmental and social benefits, i.e. a net annual benefit of US$ 734 billion.

2.2.7 TIME IS RUNNING OUT

In many countries, awareness of the urban challenges is low. Nevertheless, there are developments which cannot be ignored:

- The UN (2012) estimates that in 2025 about 2 billion people will have an absolute water shortage and that two-thirds of the world population will be affected by water scarcity. Estimates for 2030 assume 40 % more demand for water than is actually available (2030 Water Resources Group 2009).
- The world population growth and immigration will take place mainly in cities (UN 2012).
- Many cities lie in high-risk areas (UN 2012, 2013b). It is estimated that two-thirds of the world's largest cities will be vulnerable to rising sea levels. At the same time, many delta cities suffer from severe land subsidence. Consequently, the vulnerability of cities to both marine and fluvial flooding is expected to increase (Molenaar et al. 2015). It is predicted that the frequency, intensity and duration of extreme precipitation events will increase, as well as the frequency and duration of droughts (EEA 2012; Jongman et al. 2014).
- Large areas of productive agricultural land is fed by groundwater which is becoming increasingly depleted (UNEP 2007).
- Sea water intrusion, salinization of irrigated land, erosion and desertification are growing problems affecting global water and food security (FAO 2011b; UNESCO 2015a).
- Wastewater treatment in Asia and Africa is sparse, and nutrient emissions are projected to double or triple within 40 years as a result of rapid urbanization (Fig. 2.1). This will strongly enhance eutrophication, biodiversity loss, and threaten fisheries, aquaculture, tourism, and drinking water (Ligtvoet et al. 2014).
- Adequate sanitation remains a challenge for 2.5 billion people and lack of improvement will continue to lead to mortality, particularly among children (WHO 2008).

Sustainable water management is a major challenge. This is probably also the reason why the World Economic Forum (2014) ranked the water crisis and water-related risks as major global risks in terms of both probability and impact. Water is also high on the agenda of many other international organizations, such as the Organisation for Economic Co-operation and Development (OECD 2011a), the UN, the World Health Organization (WHO) and the Food and Agriculture Organization (FAO 2011b).

2.2.8 BENEFITS OF SMART ADAPTATION

The cost of preventable accidents in urban areas is high, and smart coherent transitions in cities are likely to prevent both human and capital losses. For instance, the overall economic impacts of water scarcity and drought events in the past 30 years were estimated at € 100 billion in the European Union (EU). From 1976–1990 to the following 1991–2006 period, the average annual impact doubled, rising to € 6.2 billion per year in the most recent years. The price tag of the exceptional European heat wave in 2003 was estimated at € 8.7 billion and caused up to 70,000 excess deaths over a four-month period in Central and Western Europe (EEA 2012).

Assets can be directly damaged by droughts, floods and severe storms. Floods are the most prevalent natural hazard in Europe. In a recent analysis, it was estimated that EU floods cost € 4.9 billion a year on average from 2000 to 2012, a figure that could increase to € 23.5 billion by 2050 (Jongman et al. 2014). In addition, large events such as the European floods in 2013 are likely to increase in frequency from an average of once every 16 years to a probability of every ten years by 2050. A well-known example is the City of Copenhagen. During a two-hour thunderstorm, 150 mm of rain fell in the city centre on 2 July 2011. Sewers were unable to handle this amount of water, and many streets were flooded and sewers overflowed into houses, basements and onto streets, thereby flooding the city. The first estimate of the damage was € 700 million (EEA 2012), but a more in- depth review showed that the damage was actually nearly €1 billion (Leonardsen 2012). Hurricane Katrina was one of the deadliest hurricanes ever to hit the USA. An estimated 1836 people died. Total property damage from Katrina was estimated at US$ 81 billion, which was nearly triple the damage inflicted by Hurricane Andrew in 1992 (Zimmerman 2012). Casualties, pollution and social stress are more difficult to quantify financially, but in general it can be concluded that the real costs of flooding in cities are seriously underestimated.

There is an increasing amount of information and evidence on the impacts of climate change and also on adaptation.

However, information on the costs of inaction (future losses as a result of non-adaptation) remains limited, and there is an even larger gap for the costs of adaptation (EEA 2007, 2012). Preliminary estimates suggest that benefits often exceed costs. Taking advantage of opportunities related to urban renewal as well as designing multi-purpose solutions will often result in adaptation benefits exceeding the costs. More recent information shows that cost of inaction is significant. The global expected losses of the asset management industry as a result of climate change are valued at US$ 4.2 trillion (Economist Intelligence Unit 2015). An example of smart adaptation is provided by the City of Copenhagen. The cost of inaction for climate adaptation in Copenhagen has been valued at € 4–4.7 billion, and the climate adaptation cost at € 1.3–1.6 billion, resulting in future savings of € 2.6–3.2 billion (Leonardsen 2012).

The economic gain from materials savings alone is estimated at over a trillion US$ a year. A shift to innovative reusing, remanufacturing and recycling products could lead to significant job creation. For instance, 1000,000 jobs have been created by the recycling industry in the EU alone (EMF 2014). These figures may even rise when also wastewater utilities will be considered as 'profit centres', i.e. as sources of energy (Grant et al. 2012; Van Leeuwen and Bertram 2013) and nutrients (Van Leeuwen and Sjerps 2015a), as phosphate is on the EU list of critical raw materials (EC 2014). The consequence of all these developments, the short-term framing of many politicians and the long-term existence ('generation time') of cities (Table 2.1), may be perceived as a recipe for disaster. Cities require an integrated long-term framing of their plans and actions (proactive transitions) as there will not be a second chance to plan and build cities in a smart, sustainable, flexible and adaptive manner. Time is pressing, and the reality is increasingly becoming more a matter of now or never, of make or break.

2.3 WATER GOVERNANCE

2.3.1 WHAT IS WATER GOVERNANCE?

To tackle the challenges of water in the city, it is necessary to take numerous aspects, interests and actors into account (Philip et al. 2011). These can be brought together under the heading of water governance. Hofstra (2013) considered a number of definitions. The Water Governance Centre (2012) and the OECD (2011a) have adopted the definition of the Global Water Partnership (GWP) on governance: '*the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society and for different purposes*'.

According to the GWP, water governance covers the mechanisms, processes and institutions by which all stakeholders—government, the private sector, civil society, pressure groups—on the basis of their own competences, can contribute their ideals, express their priorities, exercise their rights, meet their obligations and negotiate their differences. Recently, the OECD (2015b) adopted the following definition of water governance: *the range of political, institutional and administrative rules, practices and processes (formal and informal) through which decisions are taken and implemented, stakeholders can articulate their interests and have their concerns considered, and decision-makers are held accountable for water management.*

Driessen et al. (2012) carried out an analysis of various governance models. The authors differentiated between central, decentral, public–private and interactive governance, as well as self-governance. Lange et al. (2013) elaborated this further in

TABLE 2.1 — Generation times for some species (modified after Van Leeuwen and Vermeire 2007)

SPECIES	GENERATION TIME
Bacteria	≈ 0.1 days
Green algae (*Chlorella* sp.)	≈ 1 day
Water fleas (*Daphnia* sp.)	≈ 10 days
Snails (*Lymnae* sp.)	≈ 100 days
Rats	≈ 1 year
Politicians	≈ 5 years
Man	≈ 25 years
Cities	> 100 years

a multidimensional approach in which a distinction was made between political processes (politics), institutional structures (polity) and policy content (policy). The recently published UN guidelines on water governance (UNDP 2013) set out four dimensions: the economic, social, political and ecological dimensions, in which the UNDP makes no distinction between the political and administrative dimension but combines both aspects in the political dimension.

Governance is the work of people and is all about 'who does what?' According to Kuijpers et al. (2013), the term actually covers three essentially different aspects, i.e.:

1. **Governing:** holding responsibility for and directing the management of a water or other system;
2. **Managing:** ensuring adequate capacity and overseeing the operation, etc. of a managed water or other system;
3. **Supervising:** exercising influence and intervening in the water or other system for the purpose of its management.

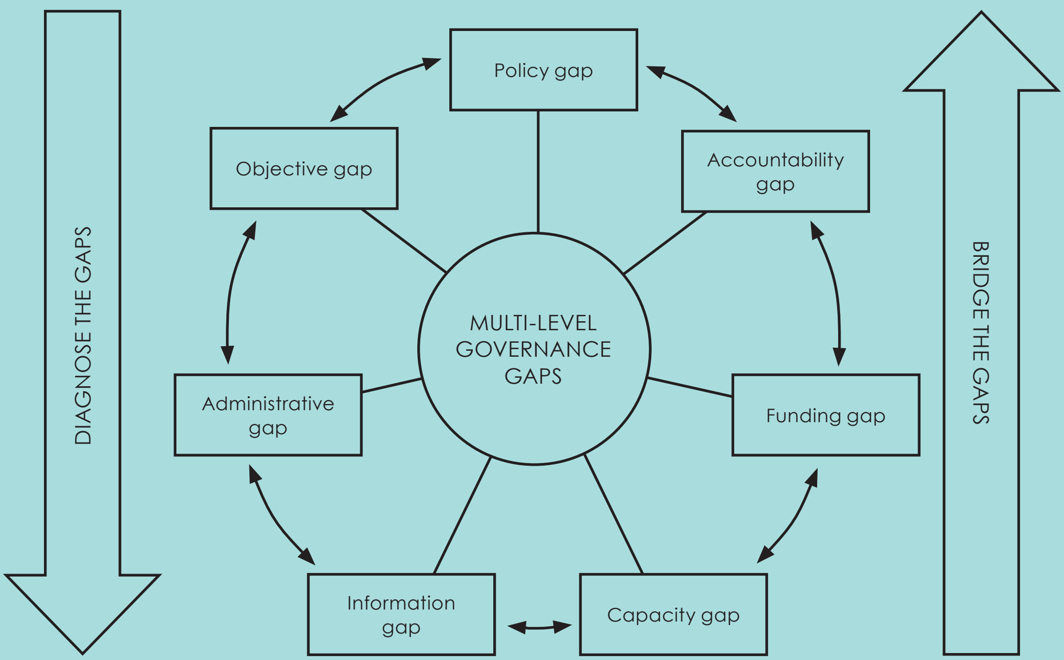

FIGURE 2.4 — OECD multi-level governance framework (OECD 2015b)

2.3.2 GOVERNANCE GAPS AND CAPACITIES

An OECD study on water governance in 17 OECD countries (OECD 2011a) revealed that obstacles can be found at several levels. The OECD listed seven of them (Fig. 2.4). The biggest challenges, according to the OECD, are institutional fragmentation, ambiguous legislation, poor implementation of multi-layered governance, as well as matters such as limited capacity at local level, unclear allocation of roles and responsibilities, fragmented financial management and uncertain allocation of resources. Often there are also no long- term strategic plans and insufficient resources to be able to measure performance. This leads to weak accountability and little transparency. All these challenges are often rooted in inadequately coordinated goals and insufficient steering of the interactions between stakeholders, the actors in the water cycle. In short, many plans sprouting in various directions, but, all in all, they do not add up to a clearly signposted route heading in a common sustainable direction. Recently, the OECD published their principles on water governance as well as a review of water governance in 48 cities (OECD 2015b, c). One of the conclusions is that building adequate governance capacities is a premise for sustainable futures of cities (OECD 2015c).

2.4 TRANSITIONS

By the year 2100, the total world population is estimated at 11 billion and about 80 % will live in cities (UN 2015a). This raises questions about options we may have to make our cities more sustainable and resilient, particularly with regard to water. How can we successfully transform our cities with future generations (our children and grandchildren) in mind? Transitions are understood as multilevel, multiphase processes of structural change in societal systems; they realize themselves when the dominant structures in society (regimes) are put under pressure by external changes in society, as well as endogenous innovation (Loorbach 2010). Gleick (2003) talked about soft-path solutions. Three important considerations are raised by Loorbach (2010):

1. All societal actors exert influence and thus direct social change, being aware of the opportunities as well as the restrictions and limitations of directing;
2. Top-down planning and market dynamics only account for part of societal change; network dynamics and reflexive behaviour account for other parts;
3. Steering of societal change is a reflexive process of searching, learning and experimenting.

Examples of transition practices are provided by Loorbach and Rotmans (2010). Strategies, actors and resources are discussed by Farla et al. (2012) and Gupta et al. (2010), whereas Markard et al. (2012) provide a review on the conceptual framework of sustainability transitions. Many international organizations address these issues too (BAUM 2013; OECD 2011a, 2015a, b; EC 2011, 2012). Practical guidance on the governance of transitions is provided by UNDP (2013), OECD (2015b), and in training modules (Philip et al. 2011).

Frijns et al. (2013) discuss the future challenges in the Dutch water sector such as (1) unstable economy, (2) citizen centric, (3) changing demographics, (4) sustainability, (5) raw material shortages/prices, (6) NBIC convergence (the convergence and growing importance of nano, bio, information and cognitive technologies), (7) transsectorial innovation, (8) shifts in governance, (9) the city and (10) social networks. When this is scaled up to a global approach, there will be numerous added factors, including social and cultural differences in policy formulation and, especially, in the areas of implementation and enforcement. In practical terms, how to deal with corruption and how to communicate with people who are hungry, living under appalling conditions and are still illiterate too? With no pretence to be complete, seven points for successful transitions can be brought forward:

1. Develop a shared long-term vision
2. Stakeholder participation: involve civil society, the commercial sector along with other stakeholders
3. SMART transitions with a focus on co-benefits
4. Not only technology development
5. Make data accessible and applicable
6. Carry out a thorough cost–benefit analysis and remove financial barriers
7. Monitor implementation.

2.4.1 DEVELOP A SHARED LONG-TERM VISION

Developing a long-term vision together is an important prerequisite to bring about change. This can be summarized as participative scenario planning and backcasting. This approach aims to envision a coherent future picture for the long term together with the actors/ stakeholders involved and from that, by working backwards (backcasting) to arrive at a plan of action for that period (i.e. for the short term). This process begins by involving the most relevant actors (open and inclusive development), and doing so as early as possible in the process (Van Leeuwen and Vermeire 2007). There are many actors in IWRM, as described in the excellent training modules of SWITCH (Philip et al. 2011), the guide for water governance (UNDP 2013) and the OECD (2011a; 2015b).

2.4.2 STAKEHOLDER PARTICIPATION: INVOLVE CIVIL SOCIETY, THE COMMERCIAL SECTOR ALONG WITH OTHER STAKEHOLDERS

Governance is a concept that has emerged in political, environmental and sustainability studies in response to a growing awareness that the authorities are no longer the only relevant actors when it comes to managing society's public affairs (Lange et al. 2013). This is reflected in the European Green City Index (2009) in Europe that was commissioned by Siemens. This index shows how sustainable European cities are. This study of 30 European cities showed a surprisingly strong correlation between the green city index and the voluntary participation index. In the notes to this report, it is also concluded that achieving the CO^2

reduction targets in London had more to do with the involvement of the people and businesses than the authorities. It provides a good example of the opportunities available for achieving ambitious goals in IWRM. The process is supported by a common interest and a 'broadly accepted' purpose among the parties involved (Kuijpers et al. 2013).

2.4.3 SMART TRANSITIONS WITH A FOCUS ON CO-BENEFITS

Today, the consequences of short-term governance are particularly clear in the fragmentation of urban development and transitions. Far more coherence is needed between urban, regional and national policies (UN-Habitat 2013; OECD 2015a). According to the OECD (2011a;2015a, b), water governance often shows many gaps (Fig. 2.4). In some countries, even at central level, sometimes ten or more ministries are actively concerned with water policy. This is worrying when you realize that 21 of the 33 cities which in 2015 will have more than 8 million inhabitants are along the coast (UN 2013b).

Ideally, cities should develop a cohesive set of long-term objectives that should be SMART: Specific (target a specific area for improvement), Measurable (quantify or at least s uggest an indicator of progress), Assignable (specify who will do it), Realistic (state what results can realistically be achieved, given available resources), Time-related (specify when the result(s) can be achieved). Very often clear objectives are not set and—as a result—many cities are neither smart nor future proof. The cost of inaction (or ad hoc sectorial action) is generally very high (Economist Intelligence Unit 2015; UNEP 2013; Leonardsen 2012).

Governance of cities is never simple (Fig. 2.4). It is a matter of cooperation in complexity. Transparency, accountability and participation are the criteria for good governance. In the development of a long-term vision for a city with different stakeholders, there will be differences of outlook, interests, short-term and long-term perspectives, 'generation times', planning horizons, investments and returns. The transitions in infrastructure, in particular, need to be flexible and adaptive, because, as indicated above, the investments are huge and, in principle, must create value (Kuijpers et al. 2013). Colliding short- and long-term interests will threaten the success of the process. Long-term goals are often not served by short-term political thinking as cities have long generation times (Table 2.1).

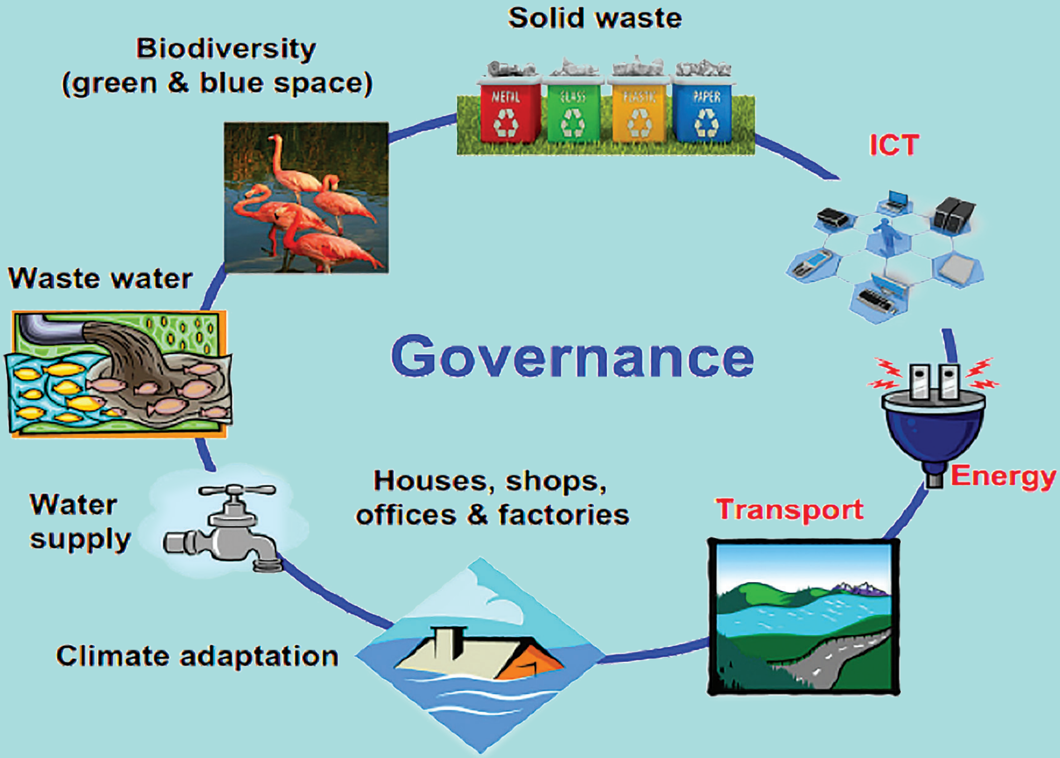

FIGURE 2.5 — Simplification of a city. The red items ICT, transport and energy are part of the EU Smart City Policy (EC 2013). Governance is considered to be a horizontal activity. Recently, water and waste have been included in the EU policy on smart cities (EC 2015d)

Over the past 20 years, a different view of the role of government has evolved, both in government itself and in society. To an increasing degree, government sees for itself only a legislating and facilitating role. Under this new political and social philosophy, government is operating more at arm's length and new initiatives are increasingly being developed by society. It is said, however, that steering is necessary, but it no longer needs to be government which arranges and decides on everything (Lange et al. 2013; Kuijpers et al. 2013). All these actors, government included, need sufficient expertise at their disposal. Local stakeholder needs 'knowledge receptors' too in order to properly manage or co-manage these complex governance processes. Both the City of Amsterdam (Van Leeuwen and Sjerps 2015a; Van Leeuwen et al. 2015) and Melbourne (Van Leeuwen 2015) are examples of adequate water governance at local level. The secret of Melbourne's success was the transparent governance structure that has been set up in a reaction to the 'Millennium Drought' and success has come from many organizations working together to a common goal (Van Leeuwen 2015). Amsterdam has a long tradition in water management, and its current focus is on the integration of water, energy and material flows (Van der Hoek et al. 2015).

In the development or reconstruction of cities, optimal use should be made by exploring options for win–win's or co-benefits for the different issues that need to be addressed in cities. For instance, road reconstruction can be combined with the renewal or installing of water distribution networks, sewer systems, and the creation of blue and green space. This would save a lot of time, money and nuisance for citizens (Fig. 2.5; Table 2.2). Figure 2.5 represents a simplified city in which nine urban sectorial agendas are shown: ICT (information and communications technology), energy and transport (EC 2013), solid waste, green and blue space, water supply, wastewater, climate adaptation, houses and factories. Governance is considered to be a horizontal issue linked with all other agendas in a city. At a recent public consultation, the European Commission has decided for an upgraded and more holistic Smart Cities and Communities policy to better integrate and connect energy, transport, water, waste and ICT (EC 2015d). From Table 2.2, it can be demonstrated that a smart city policy addressing only ICT, transport and energy can be considered as a maximization of missed opportunities in cities as more than 90 % of the potential interactions or win–wins between these sectorial agendas are not explored. The recent decision to also include waste and water is a step forward, but still many opportunities (58 %; Table 2.2) are not explored, including climate adaptation in cities, which is another omission. The obvious conclusion is that smarter cities need to develop a cohesive long-term plan and integrate/combine agendas as this will save time and money and better serves the needs of their taxpayers.

Often, there are governance gaps and barriers, not only for water governance (OECD 2015b, c), but also for all other urban adaptation and mitigation plans (Reckien et al. 2015), making smart long-term transitions, easier said than done. Nevertheless, inspiring examples are provided by the city of Melbourne on water and climate adaptation (Van Leeuwen 2015), by the city of Hamburg on energy efficiency and the introduction of the water cycle concept in city planning (Van Leeuwen and Bertram 2013), and by the city of Amsterdam on the integration of water, energy and material flows (Van der Hoek et al. 2015; Van Leeuwen and Sjerps 2015a).

TABLE 2.2 — Illustration of the relevance of co-benefits of integration in city planning as part of a cohesive long-term strategy for cities

POLICY	NUMBER OF ISSUES (n)	NUMBER OF P.I.[A]	ISSUES ADDRESSED	INTERACTIONS ADDRESSED	MISSED P.I.	MISSED P.I.(%)
Smart cities [B]	9	36	3	3	33	92
Smart cities [C]	9	36	6	15	21	58
Smart cities [D]	9	36	9	36	0	0

The total number (*n*) of issues in cities is nine. Governance is considered to be a horizontal aspect interacting with all other issues in cities.

A P.I. is the total number of potential interactions. The number of potential interaction is calculated as follows. P.I. = 1/2n X (n - 1)
B Issues addressed are ICT, transport and energy (European Commission 2013)
C Issues addressed are ICT, transport, energy, waste (taken as solid waste and wastewater) and water (European Commission 2015c)
D Example of a cohesive integral Urban Agenda addressing all nine topics in a city

2.4.4 NOT ONLY TECHNOLOGY DEVELOPMENT

The recent attention devoted to the complex issue of water governance follows a general shift in the focus on 'technical' infrastructure-driven solutions to demand-driven solutions which underline the role of institutions, along with economic and social processes (OECD 2011a, 2015b; Van Someren and Van Someren-Wang 2013). According to European Commissioner Hahn (BAUM 2013) *'technology is important to implement an intelligent city concept, to create new business opportunities, to attract investments and to generate employment. But technology alone would not bring about any wonders. Good governance and the active involvement of citizens in the development of new organisation models for a new generation of services and a greener and healthier lifestyle are also important'*. At the global level, there seems to be a greater need for smart implementation of state-of-the-art technologies, i.e. communities of practice, rather than in the development of new technologies for two reasons: (1) developing countries account for 93 % of urbanization globally, 40 % of which is the expansion of slums (UN 2015b), and (2) major improvements in urban water cycle services can be obtained by cleverly combining best practices in cities as clearly demonstrated in a study of 11 municipalities and regions (Van Leeuwen 2013). Therefore, it is important to speed up implementation by investing in smart demonstration projects on water, waste and climate mitigation and adaptation with affordable and adaptive state-of-the-art technologies (CCS 2008). Good water governance is critical to manage water-related risks at an acceptable cost and in a reasonable time frame so that the next generation does not inherit liabilities and costs from either inaction or poor decisions taken today (OECD 2015c). This is the real challenge for the upcoming HABITAT III conference (UN-HABITAT 2015).

2.4.5 MAKE DATA ACCESSIBLE AND APPLICABLE

Utilities in general obtain a lot of information on their water and wastewater services. One of the recommendations of the OECD (2011a) is to create, update and harmonize information systems and databases in order to share water policy at river basin, national and international levels. Most of the data for the baseline assessments (City Blueprints) of cities have been collected and provided by the cities or their utilities (Koop and Van Leeuwen

2015a, b). The collection of data is time-consuming, both for the utility and for the scientists who gather these data in order to provide baseline assessments of IWRM. Some of this knowledge is collated and held by water management actors including the utility operators and the different levels of environmental authorities; all of which may have their own distinct reference points and definitions (EEA 2014b).

Benchmarking improves performance by identifying and applying best demonstrated practices to operations and sales. The objectives of benchmarking are (1) to determine what and where improvements are called for, (2) to analyse how other organizations achieve their high-performance levels and (3) to use this information to improve performance. Benchmarking networks collect data from their members. The European Environment Agency (EEA 2014b) observed that the data policies for benchmarking networks are defined by their members and that results are often presented in an aggregated or anonymous form, preventing individual plants/utilities to be identified directly. Often, the underlying data are considered confidential (EEA 2014b). In order to meet the enormous water challenges as described above, this policy needs to change. Transparency and accountability are crucial for utilities, and certainly utilities paid by the taxpayers. These asymmetries of information (quantity, quality, type, scale and confidentiality) between different stakeholders are one of the key coordination gaps in (water) policy (Fig. 2.4). Secondly, there is the problem of scale. Given that cities are becoming increasingly important, then it is necessary to have harmonized and up-to-date data at city level (urban hydro-informatics). Applicable knowledge that is understandable for all stakeholders is necessary to enhance public engagement and well-informed decisions.

2.4.6 CARRY OUT A THOROUGH COST – BENEFIT ANALYSIS AND REMOVE FINANCIAL BARRIERS

To start at the end: scarce financial resources need not necessarily be an obstacle. On the contrary, limited resources often inspire creativity and foster cooperation between public and private investors, as well as the involvement of civil society. Civil society underpins urban development and will strive for cost-effective operations in cities with a maximum of cost-saving options (Table 2.2). It is primarily all about three things: communication, involvement and ownership. The decisive factor is that through transparency, inspiring confidence and specifying the tangible benefits, private individuals will get behind a common ideal. This will enable civil society to strongly identify with the city and urban society. Ordinary people will then feel involved as individuals and support developments with their time and money (BAUM 2013). Groups of people, private institutions, societies, clubs, religious communities, charitable organizations, pressure groups, i.e. non-govern- mental organizations (NGOs), should not be overlooked (Philip et al. 2011). Financial limitations are therefore not always an obstacle but often provide the impetus for creative solutions because it is then necessary to look for ways to link up with other interests and solutions (Table 2.2). Further to which, a thorough cost–benefit analysis of various promising solutions is required. Often it turns out that these solutions are also more affordable when considered over the longer term. Institutional investors—pension funds, insurance companies and mutual funds—are able to invest in high yield, smart and sustainable infrastructures (OECD 2011b). It is therefore mainly a matter of making trans- parent long-term plans which will create value.

2.4.7 MONITOR IMPLEMENTATION

It was once said by the American delegation during the negotiations on the European REACH regulation that legislation is only as good as its implementation and enforcement. That also applies to city planning. Furthermore, continuous monitoring is necessary for learning, maintaining flexibility and securing continuous improvement.

2.5 CITY BLUEPRINT FRAMEWORK

2.5.1 RESULTS

The City Blueprint provides municipalities and regions with a practical and broad framework to define steps towards realizing a more sustainable and resilient water cycle in collaboration with key stakeholders. This assessment methodology has been applied to 45 municipalities and regions, mainly in Western Europe (Van Leeuwen et al. 2015b). Detailed reviews are available for Malmö (Mottaghi et al. 2015), Rotterdam (Van Leeuwen et al. 2012), Hamburg (Van Leeuwen and Bertram 2013), Amsterdam (Van Leeuwen and Sjerps 2015a) and Istanbul (Van Leeuwen and Sjerps 2016). Detailed reviews of cities outside Europe are available for Dar es Salaam (Van Leeuwen and Chandy 2013), Ho Chi Minh City (Van Leeuwen et al. 2016) and Melbourne (Van Leeuwen 2015).

Recently, the City Blueprint approach was critically reviewed to better separate cities' IWRM performance from general trends and pressures that can hardly be influenced directly (Koop and Van Leeuwen 2015a). The Trends and Pressures Framework (TPF) comprises indicators for social, environmental and financial classes and these indicators have been scaled from 0 to 4 points, where a higher score represents a higher urban pressure or concern. The following ordinal classes, expressed as 'degree of concern', have been used: 0–0.5 points (no concern), 0.5–1.5 (little concern), 1.5–2.5 (medium concern), 2.5–3.5 (concern) and 3.5–4 (great concern). In this way, a TPF is provided that depicts the most relevant topics that either hamper sustainable IWRM or, on the contrary, pose opportunity windows (Koop and Van Leeuwen 2015a). The results for 45 municipalities and regions are provided in Fig. 2.6.

The performance-oriented set of indicators of the City Blueprint Framework (CBF) provides a snapshot of the current IWRM performance. The Blue City Index® or BCI is the geometric mean of 25 indicators which varies from 0 to 10 (Koop and Van Leeuwen 2015a). The BCIs for 45 municipalities and regions are also provided in Fig. 2.6. The CBF consists of 25 indicators divided over the following seven categories: water quality, solid waste treatment, basic water services, wastewater treatment, infrastructure, climate robustness and governance. The indicator scores of each city are shown in a spider diagram (Koop and Van Leeuwen 2015a). The methodology is summarized in a simple brochure (Van Leeuwen and Elelman 2015), two publications (Koop and van Leeuwen 2015a, b) and in a detailed report (Koop and Van Leeuwen 2015c).

FIGURE 2.6 — Results of the City Blueprint analysis of 45 municipalities and regions in 27 different countries. Bottom TPI (arithmetic average of 12 indicators), where green, red and blue represent the share of the environmental, financial and social indicators, respectively, to the overall TPI. Top BCI (geometric mean of 25 indicators) of the City Blueprint according to Koop and Van Leeuwen (2015a, b, c)

TABLE 2.3 — Categorization of different levels of sustainable IWRM in cities (Koop and Van Leeuwen 2015b)

BCI SCORE	CATEGORIES OF IWRM IN CITIES
0 - 2	**Cities lacking basic water services** Access to potable drinking water of sufficient quality and access to sanitation facilities are insufficient. Typically, water pollution is high due to a lack of wastewater treatment (WWT). Solid waste production is relatively low but is only partially collected and, if collected, almost exclusively put in landfills. Water consumption is low, but water system leakages are high due to serious infrastructure investment deficits. Basic water services cannot be expanded or improved due to rapid urbanization. Improvements are hindered due to governance capacity and funding gaps
2 - 4	**Wasteful cities** Basic water services are largely met but flood risk can be high and WWT is poorly covered. Often, only primary and a small portion of secondary WWT is applied, leading to large-scale pollution. Water consumption and infrastructure leakages are high due to the lack of environmental awareness and infrastructure maintenance. Solid waste production is high, and waste is almost completely dumped in landfills. Governance is reactive and community involvement is low
4 - 6	**Water efficient cities** Cities implementing centralized, well-known, technological solutions to increase water efficiency and to control pollution. Secondary WWT coverage is high, and tertiary WWT is rising. Water-efficient technologies are partially applied, infrastructure leakages are substantially reduced but water consumption is still high. Energy recovery from WWT is relatively high, while nutrient recovery is limited. Both solid waste recycling and energy recovery are partially applied. These cities are often vulnerable to climate change, e.g. urban heat islands and drainage flooding, due to poor adaptation strategies, limited storm water separation and low green surface ratios. Governance community involvement has improved
6 - 8	**Resource efficient and adaptive cities** WWT techniques to recover energy and nutrients are often applied. Solid waste recycling and energy recovery are largely covered, whereas solid waste production has not yet been reduced. Water-efficient techniques are widely applied, and water consumption has been reduced. Climate adaptation in urban planning is applied, e.g. incorporation of green infrastructures and storm water separation. Integrative, (de)centralized and decentralized as well as long-term planning, community involvement, and sustainability initiatives are established to cope with limited resources and climate change
8 - 10	**Water wise cities** There is no BCI score that is within this category so far. These cities apply full resource and energy recovery in their WWT and solid waste treatment, fully integrate water into urban planning, have multi-functional and adaptive infrastructures, and local communities promote sustainable integrated decision-making and behaviour. Cities are largely water self-sufficient, attractive, innovative and circular by applying multiple centralized and decentralized solutions

The indicator scores may facilitate sharing of knowledge, experiences and best practices between cities (Van Leeuwen 2013). The potential performance improvement (PPI) for each indicator is the maximum indicator score minus the actual score. The PPI may guide cities in their transitions towards more sustainable IWRM and innovative urban planning, leapfrogging arrangements that have locked-in many cities (Brown et al. 2009; OECD 2015a).

2.5.2 CATEGORIZATION OF DIFFERENT LEVELS OF SUSTAINABILITY IN CITIES

Although our City Blueprint research is focused on the performance of IWRM in European cities, we have tried to include also other geographical regions. The selection of cities is therefore not random at all, but regionally biased towards Western Europe. With these limitations in mind, the challenges on water, waste and climate change can be discussed globally by clustering

FIGURE 2.7 — Municipalities and regions assessed with the City Blueprint. Red, orange, black and blue represent municipalities and regions with a geometric BCI between 0–2 (cities lacking basic water services), 2–4 (wasteful cities), 4–6 (water-efficient cities), and 6–8 (resource-efficient and adaptive cities), respectively (Koop and Van Leeuwen 2015b). Most cities are from north-western Europe. Cities outside Europe are: Ankara and Istanbul (Turkey), Jerusalem (Israel), Kilamba Kiaxi (Angola), Dar es Salaam (Tanzania), Ho Chi Minh City (Vietnam), Belém (Brazil), Melbourne (Australia) and New York

cities into distinct categories of sustainability and by providing additional data and information for various global regions. The categorization of cities is based on hierarchical clustering with the squared Euclidean distances for all 25 indicators (Koop and Van Leeuwen 2015b) and provided in Table 2.3.

TABLE 2.4 — Basic socio-economic and IWRM performance in different world regions

	NORTH-WESTERN EUROPE [AMSTERDAM]	EASTERN EUROPE AND TURKEY [ISTANBUL]	AFRICA [DAR ES SALAAM]	AUSTRALIA [MELBOURNE]	SOUTH-EAST ASIA [HO CHI MINH CITY]	LATIN AMERICA [BELÉM]	NORTH AMERICA [NEW YORK CITY]
Social economic content							
Urbanization Rate (%)[a]	0.9 [1.0]	2.0 [2.0]	3.7 [5.4]	1.3 [1.6]	2.9 [2.9]	1.4 [1.2]	1.3 [1.0]
GDP (US$ 2013/capita)[b]	58,334 [47,651]	10,777 [10,745]	2,148 [690]	52,311 [64,157]	9,977 [1,896]	9,058 [10,958]	38,645 [52,839]
Poverty rate (% pop. < 2US$)[c]	0.4 [0.4]	1.0 [2.6]	34.4 [33.6]	1.4 [1.4]	11.9 [12.5]	3.4 [6.8]	2.2 [1.7]
Water							
Access to drinking water (%)[d]	99.9 [100.0]	99.3 [100.0]	89.1 [60.0]	100.0 [100.0]	95.5 [84.0]	97.3 [70.0]	98.7 [100.0]
Access to sanitation (% of urban pop.)[e]	98.4 [100.0]	96.0 [95.0]	47.7 [56.0]	100.0 [100.0]	88.6 [12.0]	88.9 [7.0]	96.0 [100.0]
Secondary WWT (%)[f]	85.4 [99.0]	47.8 [35.0]	- [5.0]	88.0 [100.0]	- [6.0]	- [7.7]	68.3 [72.0]
Nutrient recovery (%)	45.2 [100.0]	5.4 [11.8]	- [0.0]	- [0.0]	- [0.0]	- [0.0]	- [72.0]
Leakages (%)	12.9 [5.4]	30.7 [25.0]	- [30.0]	- [11.0]	- [23.0]	- [48.0]	- [8.0]
Storm water seperation (%)	55.7 [82.8]	47.1 [70.0]	- [20.0]	- [100.0]	- [5.0]	- [30.0]	- [40.0]
Solid waste							
Solid waste collected (kg/cap/year)[g]	546.6 [600.0]	360.4 [419.0]	195.3 [365.0]	640.0 [640.0]	281.3 [296.0]	331.7 [383.2]	617.9 [730]
Solid waste recycled (%)[g]	29.6 [99.0]	11.4 [1.0]	3.0 [5.0]	30.3 [42.0]	10.2 [5.0]	5.4 [0.0]	18.0 [46.0]

2.5.3 REGIONAL CHALLENGES

The geographical distribution of municipalities and regions and their categorization is shown in Fig. 2.7. Basic information on regions and cities is provided in Table 2.4. As stated before, the selection of cities is not random at all, but regionally biased towards Western Europe. Therefore, further research of cities in other global regions is needed. With this limitation in mind, the following general observations can be made.

- The challenges of water, waste and climate change development vary from one region to another.
- South-east Asia. Rapid population growth and rapid socio-economic changes place increasing pressure on natural resources (Dobbs et al. 2012; Green City Index 2015). Excessive water abstraction, land subsidence, decline in groundwater level, saline water intrusion and pollution can be observed in Ho Chi Minh City and many other cities in south-east Asia (Van Leeuwen et al. 2015a). This is in line with observations by UNESCO (2015a, b). Solid waste collection and recycling (Jambeck et al. 2015) as well as water infrastructure upgrading are major challenges as well (Van Leeuwen et al. 2015a).
- Africa. By 2030, the urban population in Africa and Asia will double (UNESCO 2015a). Dar es Salaam in Tanzania is among the ten fastest growing cities in the world (Green City Index 2015). Little more than half of the population in Dar es Salaam has access to some form of sanitation, but the wastewater generated by 15 % of the city residents who are connected to the sewer system is discharged into the sea untreated (Van Leeuwen and Chandy 2013). There is also no regular waste collection and many residents simply burn their rubbish (Koop and Van Leeuwen 2015c). Based on other cities assessed in Africa (Green City Index 2015), the challenges of Dar es Salaam are no exception. The security of water, food and energy are major challenges, and sustainable development is perhaps more important for Africa than other regions of the world (UNESCO 2015a).
- Australia. Melbourne is the only city in this world region that has been assessed with the City Blueprint approach (Van Leeuwen 2015). The challenges of Melbourne under a changing and uncertain climate became apparent during the 'Millennium drought', a decade long period of extreme dry conditions across southern Australia throughout the 2000s. Melbourne scores highly in areas such as water efficiency, wastewater

efficiency, energy recovery, and climate change commitments related to heat and water scarcity. Nearly 30 % of the houses in Melbourne have installed rainwater tanks and plans to increase the use of storm water have recently been published. Energy efficiency of buildings, nutrient recovery (especially phosphate) from wastewater and sewage sludge recycling are topics for improvement. The same holds for the production and proper handling of solid waste. Moreover, the emissions of GHGs in Australia are relatively high (Table 2.4).

- Latin America. Belém is the only city in this world region that has been assessed with the City Blueprint. Flooding is a very serious concern in Belém. Urban environmental concerns such as traffic congestion, land use policies, waste disposal and air quality are immediate concerns to the majority of Latin America's residents, simply because 81 % of the population already lives in cities (Green City Index 2015). Access to sanitation and drinking water are challenges in several cities in Latin America (UNESCO 2015a, b). According to UNESCO (2015a), a major priority for Latin America is to build the formal institutional capacity to manage water resources and bring sustainable integration of water resources management and use into socio-economic development and poverty reduction. Another priority is to ensure the full realization of the human right to water and sanitation in the context of the post-2015 development agenda. Provided that Belém is a representative sample of a city in Latin America, these observations are fully supported by the City Blueprint analysis, as the BCI of Belém is 1.1. In other words, the challenges of Belém expressed as PPI are nearly nine points
- North America. New York is the only city in this world region that has been assessed with the City Blueprint approach. Parts of the North-American continent suffer from droughts, whereas in 2012, New York suffered from hurricane Sandy. Sandy's impacts included the flooding of the New York City subway system, many suburban communities and many road tunnels entering Manhattan. Sandy damaged 200,000 homes and was blamed for 117 US deaths. The total damage in New York was estimated at more than $19 billion (Toro 2013). The USA emits double the average amount of GHGs, while their BCI is about average (World Bank 2015d; Koop and Van Leeuwen 2015c). New York is vulnerable to extreme weather because the urban soil is largely sealed with impermeable concrete, asphalt and

stone (NYC 2010). Rainwater can hardly infiltrate and forms large amounts of runoff which may result in urban drainage flooding and amplifies the impact of extreme weather which happened in 2012. Furthermore, New York produces a lot of solid waste and can improve on solid waste recycling, sewage sludge recycling, sewer maintenance and green space (Koop and Van Leeuwen 2015c). UNESCO (2015a) concludes that increasing resource use efficiency, reducing waste and pollution, influencing consumption patterns and choosing appropriate technologies are the main challenges facing both Europe and North America.

- Europe. The only continent for which an adequate number of municipalities and regions have been assessed using the City Blueprint shows a high variation in IWRM performance (Figs. 2.6, 2.7; Table 2.4). The differences between Western and Eastern Europe is striking, part of which can be explained by non-existing, badly maintained or outdated water infrastructure and technology in Eastern Europe. The overall conclusion of UNESCO (2015a) as quoted for North America also holds for Europe. Upgrading and renewing existing infrastructures remain a challenge and are illustrated by the high leakage rates (>40 %) in some European cities and fully support the conclusions of the OECD (2015a).
- Until now, none of the cities can be categorized as water-wise cities (Koop and Van Leeuwen 2015a, b).

Our research shows that cities with a high BCI are those cities with high ambitions to improve IWRM, with an active civil society (involvement in voluntary work), in countries with greater prosperity (high GDP) and high governmental effectiveness (Koop and Van Leeuwen 2015b). Similar conclusions have been provided by Reckien et al. (2015) in an empirical analysis of urban adaptation and mitigation plans in European cities. Our work is mainly based on an analysis of European cities. There is a great need to assess more cities, especially in other world regions, as a starting point for sustainability transitions and to monitor their progress on the implementation of the Sustainable Development Goals for better urban futures (UN-Habitat 2015).

2.6 CITY-TO-CITY LEARNING

Our work on City Blueprints shows that results can be used for a variety of purposes to:

- Aid in the evaluation and compare outcomes with other cities;
- Translate knowledge and educate;
- Raise/improve awareness (particularly in communicating with the public);
- Enable informed decision-making, i.e. stimulate proactive transitions;
- Refine parts of the assessment, with tailor-made in-depth studies and advanced models, if necessary;
- Monitor progress;
- Stimulate the exchange of best practices (Koop et al. 2015).

An important result from our work is that the wide variation in the way cities deal with their water, wastewater, solid waste and climate adaptation offers key insights for improving their resilience and sustainability, provided that cities share their best practices (Van Leeuwen 2013; Frijns et al. 2013). Theoretically, if cities would share their best practices, the BCI can reach a maximum value of 10 (Van Leeuwen 2013). It also shows that cities that currently perform well can still improve. Of course, this is ultimately the responsibility of the cities themselves. These challenges are too often not taken up, because people are waiting for new technological breakthroughs and fail to make use of existing knowledge and technologies. Therefore, we have three recommendations:

1. Cities require a long-term framing of their sectorial challenges into a proactive and coherent Urban Agenda to maximize the co-benefits and to minimize their cost.
2. Cities are encouraged to participate in learning alliances to actively share knowledge and experiences on implementation of state-of-the-art technologies (city-to-city learning). This is the most efficient way to improve IWRM (Van Leeuwen 2013; Koop and Van Leeuwen 2015b). Recently, a compendium of best practices has been completed that can help cities to choose among options to improve their performance on water, waste and climate adaptation (Koop et al. 2015).
3. Given the megatrends and water challenges in cities, existing technologies and innovations should be better embedded in urban planning. This is mainly a governance challenge

(OECD 2015a). As developing countries account for 93 % of urbanization globally, 40 % of which is the expansion of slums (UNESCO 2015a), new affordable technologies need to be developed. These new and efficient technologies can gradually be introduced in the transition process allowing these cities to leapfrog towards water- wise cities.

2.7 CONCLUDING REMARKS

It has been attempted to shed light on growth and the limits to growth, with particular emphasis on water. Freshwater scarcity is a major challenge (FAO 2011b; UNEP 2012, 2013; World Economic Forum 2014; UNESCO 2015a). The UN (2012) estimates that in 2025 about 2 billion people will have an absolute water shortage and that two-thirds of the world population will be affected by water scarcity. Estimates for 2030 assume 40 % more demand for water than is actually available (2030 Water Resources Group 2009). It means that the window we have for solutions is narrow and rapidly closing.

In the Netherlands, excellent drinking water is readily available by turning on a tap and safety is provided by the Delta Programme, while the history of that too lies in the flood disaster of 1953. Water safety and water security are not a matter of course. Actually, there is not a water crisis but a water governance crisis which now and in the very near future will become manifest in cities (OECD 2011a; Engel et al. 2011; EC 2011, 2015b). The solutions must also come from cities. Cities, as global change makers, must make the difference. And they can too, because there are already many good initiatives (C40Cities 2015; Philip et al. 2011; World Future Council 2014).

According to the European Commission (2013), smart cities are cities that focus on ICT, energy and transport. This definition was recently broadened to include water and waste (European Commission 2015a). Unfortunately, the proposed policy is still not cohesive, but fragmented and will lead to many missed opportunities for cities that are lost in sectorial agenda's and mists of techno-optimism. With the urgency of the water governance crisis, it is time that we cannot afford to lose. The European Commission can take the lead in the development of a practical coherent long-term European Urban Agenda, e.g. a EUA-2050, with cities and based on the needs of cities (EC 2015a, c). Such an initiative may also lead to improved visibility and a better image of Europe for the European citizens, which is a political priority for Europe. An Urban Agenda is even more needed in the rest of the world, where the challenges of water, waste and climate change are much greater than in Europe (Fig. 2.7; Table 2.4). There is a need to move towards *smarter* cities:

- *Smarter cities* are cities with a coherent long-term social, economic and ecological agenda.
- *Smarter cities* are water-wise cities that integrate their sectorial

agendas on water, wastewater, energy, solid waste, transport, ICT, climate adaptation and nature into a forward-looking, coherent Urban Agenda to maximize co-benefits and to minimize the cost.
- *Smarter cities* implement a circular economy (EMF 2014, 2015a; EC 2015b), focus on social innovation (Science Communication Unit 2014) and, last but not least, and greatly improve on governance (OECD 2011a, 2015a, b).

Inaction can be overcome by setting up learning alliances of cities. Globally, we need regional platforms to exchange challenges, policies and best practices between cities. International organizations (e.g. OECD, UN, WHO, FAO, and the European Commission), the scientific community, the private sector, utilities (e.g. transport, water, waste, energy and telecom utilities), the civil society, city planners, architects, coordination providers, and last but not least, all the mayors in the world, are in a remarkably privileged position to contribute to the solutions of these urgent challenges in our cities.

Water utilities have much expertise and an extensive water consumer's network. There are many opportunities for the water sector as a whole and the drinking water sector in particular, but under a number of conditions which can be summarized as the three Rs: 'Reframe, Refocus, Radically'

1. *Reframe.* The Netherlands' drinking water sector has achieved a great deal but is faced by challenges such as salinization and groundwater depletion. There are also promising opportunities for nutrient recovery and energy conservation and production (More et al. 2013; Frijns et al. 2012). Nevertheless, water challenges require a broader framing as water is more than just drinking water (Van Oel et al. 2009; Van Someren and Van Someren-Wang 2013).
2. *Refocus.* In view of the declining level of government involvement, there will be major opportunities for initiatives launched by civil society and the private sector. Participative scenario development and the implementation of sustainability processes in the city—a highly complex environment—make it necessary that the focus be placed primarily on governance. The extensive expertise of the technology and drinking water sectors will be vital for this. But success will not be achieved by looking to technology alone (EC 2011; OECD 2011a, 2015a, b; BAUM 2013).

3. *Radically.* It has been attempted here to give an impression of the speed at which global change is taking place, both economically and ecologically. The challenges are high: urbanization at a rate of 190,000 people per day, the shift in the labour market (e.g. the exodus of businesses and employment from Europe), and the safety of cities in relation to climate change and water security (World Economic Forum 2014; UNESCO 2015a). The same holds for the challenges of irrigation, i.e. food security (UNEP 2007, 2012; FAO 2011b). This together with the high costs for water infrastructure and its maintenance make water a high priority, where procrastination, i.e. the avoidance of doing tasks which need to be accomplished, will not do (UNEP 2013; Cashman and Ashley 2008; UN University 2013). Mahatma Gandhi has raised this too: *'The difference between what we do and what we are capable of doing would suffice to solve most of the world's problems'*.

ACKNOWLEDGMENTS

This paper provides a broad overview of water, waste and climate change in cities. It is an update of a previous paper on water in the city at the University of Utrecht (Van Leeuwen 2014). Our work has been financed by KWR Watercycle Research Institute in the context of Watershare®: sharing knowledge in the water sector (http://www.watershare.eu/). It is a contribution to the European Innovation Partnership on Water of the European Commission and more specifically to the City Blueprint Action Group (EC 2015a), coordinated by both Dr. Richard Elelman of Fundació CTM Centre Tecnologic and NETWERC H2O and Prof. Dr. C.J. van Leeuwen (KWR Watercycle Research Institute). The authors would like to thank Prof. dr. Wim van Viersen, Prof. dr. Annemarie van Wezel, Ir. MBA Idsart Dijkstra and Ir. Jos Frijns (KWR Watercycle Research Institute, the Netherlands), as well as Prof. Dr. Peter Driessen (Utrecht University, the Netherlands) for their practical and stimulating contributions. Last but not least, we would like to thank Richard Elelman, the members of the City Blueprint Action Group, and all partners of the EU BlueSCities project and all cities involved, for their dedication, voluntary contributions and discussions related to the work described in this manuscript. The European Commission is acknowledged for funding TRUST in the 7th Framework Programme under Grant Agreement No. 265122 and for BlueSCities in H2020-Water under Grant Agreement No. 642354.

A CRITICAL REVIEW OF THE CITY BLUEPRINT APPROACH

CHAPTER 3

ASSESSMENT OF THE SUSTAINABILITY OF WATER RESOURCES MANAGEMENT: A CRITICAL REVIEW OF THE CITY BLUEPRINT APPROACH

This chapter is published as: Koop S.H.A. and Van Leeuwen C.J. (2015) Assessment of the Sustainability of Water Resources Management: A Critical Review of the City Blueprint Approach. Water Resources Management. 29(15), 5649-5670

ABSTRACT

This chapter addresses research 1: What are the characteristics of a comprehensive framework for assessing water cycle management in urban areas around the world?

Climate change, urbanization and water pollution cause adverse effects and rehabilitation costs that may exceed the carrying capacity of cities. Currently, there is no internationally standardized indicator framework for urban Integrated Water Resources Management (IWRM). The City Blueprint® is a first attempt and aims to enhance the transition towards water-wise cities by city-to-city learning. This paper provides a three step revision of the City Blueprint Framework (CBF) based on data of 45 municipalities and regions in 27 countries: (1) A distinction has been made between trends and pressures (on which urban IWRM has a negligible influence) and IWRM performances. Therefore, a separate trends and pressures framework has been developed; (2) Only the purely performance-oriented indicators have been selected from the CBF. Furthermore, the indicator accuracy and boundaries have been re-assessed, and new indicators have been added; (3) By analysing correlations and variances, the performance-oriented indicators have been rearranged in order to establish a proportional contribution of all indicators and categories to the overall score, i.e., the Blue City Index®. In conclusion, six indicators have been removed because of insufficient accuracy, overlap or lack of focus on IWRM. Seven indicators have been added, i.e., secondary and tertiary wastewater treatment, operation cost recovery, green space and three indicators concerning solid waste treatment. The geometric aggregation method has been selected because it emphasizes the need to improve the lowest scoring indicators. In conclusion, the improved CBF is more performance-oriented and therefore more suitable to assist cities in their transition towards water-wise cities.

3.1 URBAN WATER CHALLENGES

Rapid urbanization and climate change pose increasing pressures on Integrated Water Re- sources Management (IWRM), especially in cities (OECD 2015a). In 2014, about 4 billion people lived in cities, mostly situated along coasts and major rivers (accounting for 54 % of the world's population). IWRM becomes even more challenging as the global urban population is estimated to increase with 2.5 billion people by 2050 (UN 2014b).

Climate change amplifies urban water vulnerabilities such as flooding, heat stress, water scarcity and water pollution. Sea level rise and increased river discharges pose a projected 15 % of the global population at risk of flooding. This is mainly in cities including almost all worlds' megacities (Ligtvoet et al. 2014). Also, extreme rainfall and heat waves will become more severe due to global warming (Jongman et al. 2014). As urban surfaces are often largely sealed and lack green areas, the impact of drainage flooding and Urban Heat Islands (UHI) are even more exacerbated (Shuster et al. 2005; Gill et al. 2007). Water withdrawals are estimated to increase by 50 % in developing countries and by 18 % in developed countries by 2025 (WWDR 2006). This increased water demand will lead to an estimated 40 % fresh water shortage by 2030 (WRG 2009). Climate change will exacerbate these fresh water shortages (Iglesias et al. 2007) and amplify the spread of water-borne diseases (IPCC 2013). Pollution from combined sewer overflows and stormwater runoff will rise due to climate induced increase in extreme rainfall events (Nilsen et al. 2011). Rapid urbanization poses extra stresses, for example, wastewater treatment in Asia and Africa is already sparse, while nutrient emissions are projected to double or triple within 40 years. This will strongly enhance eutrophication, biodiversity loss, threaten drinking water, fisheries, aquaculture, and tourism (Ligtvoet et al. 2014). Moreover, cities produce massive amounts of solid waste, in particular plastics. Worldwide 280 million tons of plastics are produced annually (Sigler 2014). These plastics photodegrade into small particles that affect marine ecosystems (Derraik 2002).

The prospect of increased urban flooding, heat stress, water scarcity and pollution emphasizes the need for adaptive and reliable urban water infrastructures (Short et al. 2012). However, water infrastructures are often old and require refurbishment to meet current standards, whereas standards to withstand future conditions of increased storm events and urbanization are often not accounted for (OECD 2015a). An estimated US$ 41 trillion (41 × 1012) is needed to refurbish the urban infrastructure in the period 2005–2030. Over 50 % will be needed to refurbish the water systems (UNEP 2013). This is roughly 60 % more than is spent on infrastructure in the same period until now (McKinsey 2013). In developed countries water infrastructure investments amount to 1 % of the GDP every year. For developing countries this is even more substantial, i.e., about 3.5 % with extremes up to 6 % or more (Cashman and Ashley 2008). The costs of climate change related damages are expected to be large. In Europe this is estimated to be € 190 billion by 2080 (JRC 2014), especially flood damage is predicted to increase five-fold by 2050 (Jongman et al. 2014). Recent extreme weather events resulted in much damage. For example, in 2011 in Copenhagen a storm event caused a lot of damage of nearly € 1 billion (Leonardsen 2012). In the USA, hurricane Sandy (2012) caused 117 deaths and costs US$ 19 billion including US$ 2.6 billion to repair New York's drinking and wastewater infrastructure (Johnson 2013). These alarming events demonstrate the climate vulnerability of cities and the urgency to improve urban IWRM.

3.2 THE CITY BLUEPRINT

Approximately 80 % of the world's GDP is produced, and 75 % of the global energy and material flows are consumed in cities (UNEP 2013). This makes cities the major contributors of economic growth but also the major sources of environmental pressures. It also implies that cities have the highest potential to reduce these pressures. Urban water management is often locked-in to the large-scale, centralized infrastructure approaches limiting the adoption of more flexible and resilient technologies and approaches such as fit-for-purpose water use, nutrient and energy recovery from wastewater, and blue-green infrastructures (Brown et al. 2011). Hence, the main objective of the City Blueprint® action is to create awareness among decision makers and resource managers. It may help them envisioning, developing and implementing stepwise measures to transform towards water-wise or water sensitive cities (EC 2015a). Improving the implementation capacities of cities by sharing information can be described as city–to-city learning. The first step in the strategic planning process is that stakeholders are identified and information is provided for a baseline assessment. Hereafter, long-term goals and priorities are set resulting in follow-up actions leading to measures that promote sustainable IWRM (Philip et al. 2011; Van Leeuwen et al. 2015). The City Blueprint Framework (CBF) aims to be the first step in strategic planning and consists of 24 indicators divided over eight broad categories, i.e., 1) Water security, 2) Water quality, 3) Drinking water, 4) Sanitation, 5) Infrastructure, 6) Climate robustness, 7) Biodiversity and attractiveness, and 8) Governance. The output is a spider diagram and a Blue City Index® (BCI). The BCI is the arithmetic mean of the 24 indicators. The methodology and its application have been published in this journal (Van Leeuwen et al. 2012; Van Leeuwen 2013) and a detailed description of the calculation methods is provided in the City Blueprint questionnaire available on the website of the European Innovation Partnership on Water (EC 2015a).

This paper provides a critical revision of the CBF, based on the learning experiences obtained during the assessments in 45 cities in 27 countries. The aim of this revision is to:

- Provide a clear separation between indicators describing urban *trends and pressures* (on which local water managers have a negligible influence, e.g., current climatic conditions, demographic chances etc.) and indicators measuring IWRM performance in cities. The improved performance framework (CBF) will be more adequate in showing the potential for improvements and enhances city-to-city learning because emphasizes the city's own *IWRM performance*.

- Develop a separate framework describing the most important trends and pressures that may limit IWRM or, on the contrary, poses opportunity windows. This supplementary framework is important in providing context and may assist in the setting of priorities.
- Include solid waste indicators as important urban performers to decrease water pollution.
- Update existing indicators by including new developments in data accuracy and availability.
- Design a coherent framework in which indicators and categories make a balanced contribution to the overall score, i.e., the BCI.
- Select an aggregation method that penalizes unbalanced indicator scores in order to express the urgency to improve the lowest scoring indicators.
- Make sure that the indicator results are easy to understand, timely and relevant, and useful for the end-users, i.e., policy makers, decision makers, water managers and citizens in general.

3.3 METHOLOGY

The application of the CBF followed a learning by doing approach. Based on constructive feedback from stakeholders, we have performed a detailed revision of the indicator choice and framework, together with a revision of the indicator scaling and aggregation method (Koop and Van Leeuwen 2015c). The process is summarized in Fig. 3.1 and is based on data of 45 municipalities and regions, mainly in Europe (Koop and Van Leeuwen 2015a). In the rest of this paper these municipalities, regions and Malta will be referred to as cities. This review consists of three consecutive steps:

Step 1 Development of the Trends and Pressure Framework (TPF).
Step 2 Improvements of the City Blueprint indicators.
Step 3 Indicator rearrangements and aggregation methods. The application of the revised CBF and new TPF, the clustering and categorization of cities' IWRM performances, as well as comparisons with other city descriptors, have been published separately in this journal (Koop and Van Leeuwen 2015a).

3.3.1 STEP 1: DEVELOPMENT OF THE TRENDS AND PRESSURES FRAMEWORK

Every city has its own social, financial and environmental setting in which water managers have to operate. In order to promote city-to-city learning, it is essential to solely measure urban water management performances. For example, a city situated in an arid area may not necessarily experience water stress due to overconsumption, but simply due to the low natural availability of fresh water. In this case, water consumption or the use of water saving techniques are performance indicators, whereas the natural availability of fresh water is a descriptive indicator belonging to the TPF. A more performance-oriented set of indicators (CBF) is more adequate in showing the potential for improvements and sharing of knowledge, experiences and best practices between cities. A separate TPF may provide the context to obtain insight in the limitations and windows of opportunities for urban IWRM. Therefore, the first step in this review was the development of the TPF with the aim to provide an overview of the most important social, environmental and financial characteristics affecting urban IWRM.

3.3.2 STEP 2: IMPROVEMENTS OF THE CITY BLUEPRINT INDICATORS

All indicators of the CBF have been critically assessed on data reliability, scoring method and whether the used data are

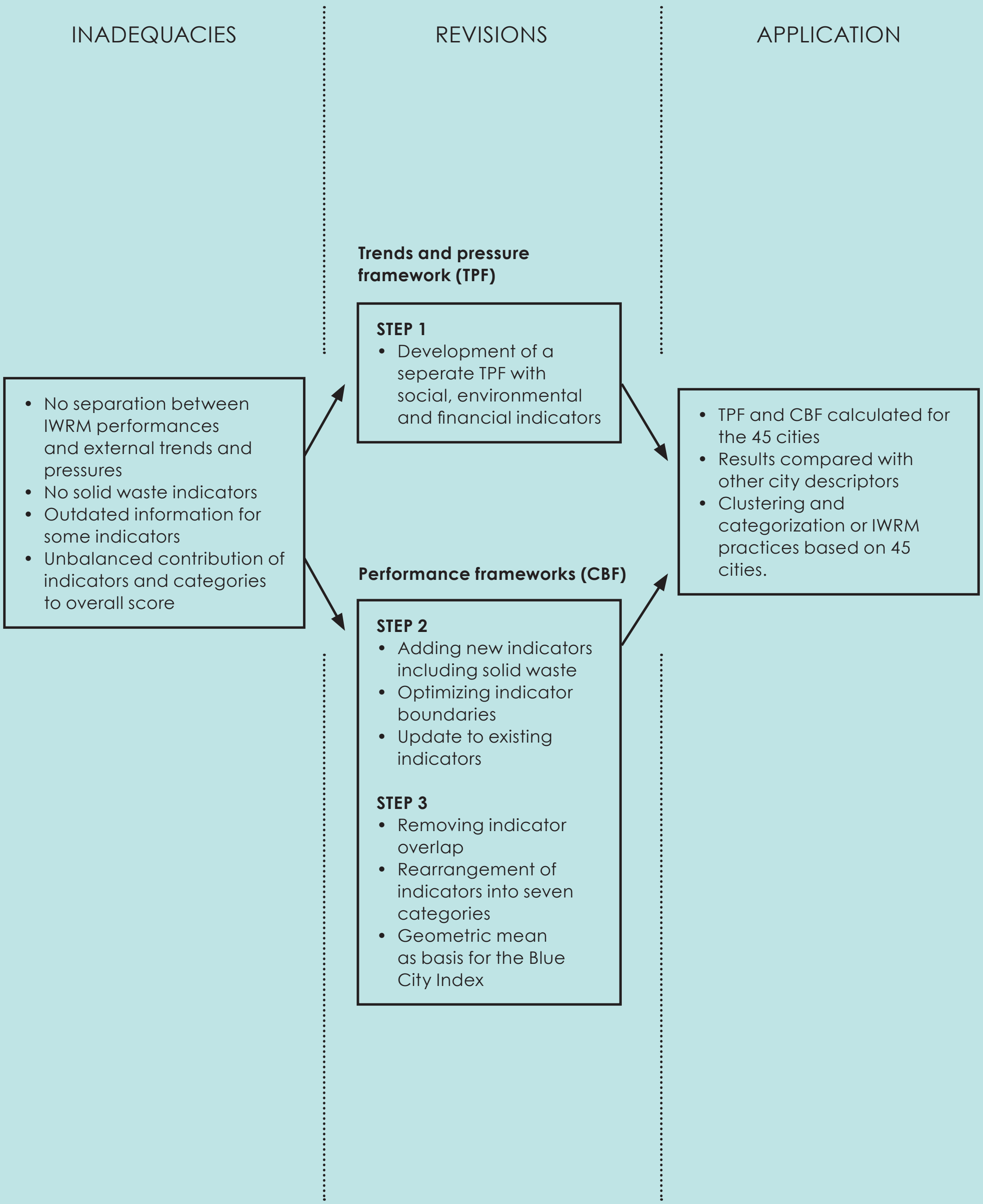

FIGURE 3.1 — Flow chart of the City Blueprint revision described in this paper using data of 45 cities divided over 27 countries. The applications of the Trends and Pressure Framework (TPF) and Performance framework (CBF) have been published in this journal (Koop and Van Leeuwen 2015a)

time-series in order to ensure that the indicators are up-to-date. At the same time new indicators are proposed to replace indicators with data problems. Also boundary issues are reviewed in order to adjust extreme indicator variances. Alternative scaling methods for a few indicators with sufficiently large data sets (n>100) are proposed as well. Only performance-oriented indicators have been selected in this step.

3.3.3 STEP 3: INDICATOR REARRANGEMENTS AND AGGREGATION METHOD

Finally, the revised performance-oriented indicators have been rearranged to arrive at a more coherent framework. The aim was to obtain intra-category correlations (correlations between indicators of the same category) that were higher than the inter-category correlations (correlations of the indicators belonging to different categories). Hence, high correlations between indicators suggest that these indicators should be united into one category. Finally, it is aimed to equalize the number of indicators per category, to make sure that all categories equally contribute to the BCI. Furthermore, an aggregation method has been selected that penalizes unbalanced scores in order to emphasize the need to improve the lowest indicator scores.

3.4 RESULTS

3.3.4 STEP 1: DEVELOPMENT OF THE TRENDS AND PRESSURES FRAMEWORK

Because the regenerative capacity and renewable resources on earth are limited (Hoekstra and Wiedman 2014), environmental pressures of cities need to be reduced provided that adequate living standards are maintained (Mori and Yamashita 2015). Hence, an equal number and weighing of indicators for social, environmental and financial classes has been strived for. Each indicator has been scaled from 0 to 4 points, where a higher score represents a higher urban pressure or concern. The following ordinal classes, expressed as 'degree of concern', have been used: 0–0.5 points (no concern), 0.5–1.5 (little concern), 1.5–2.5 (medium concern), 2.5–3.5 (concern), and 3.5–4 (great concern). In this way, a TPF is provided that depicts the most relevant topics that either hamper sustainable IWRM or, on the contrary, pose opportunity windows. Examples for three cities are shown in Section 4.4. For the social and financial categories, four well-known descriptive indicators have been selected, that are widely used to describe urban pressures. The environmental category is focussed on urban water and climate issues, i.e., flooding, water scarcity and heat risk (EEA 2012). Water quality is also included because cities are often situated at rivers and in deltas that receive pollution from upstream activities. Table 3.1 describes the scaling method and data sources of the indicators and

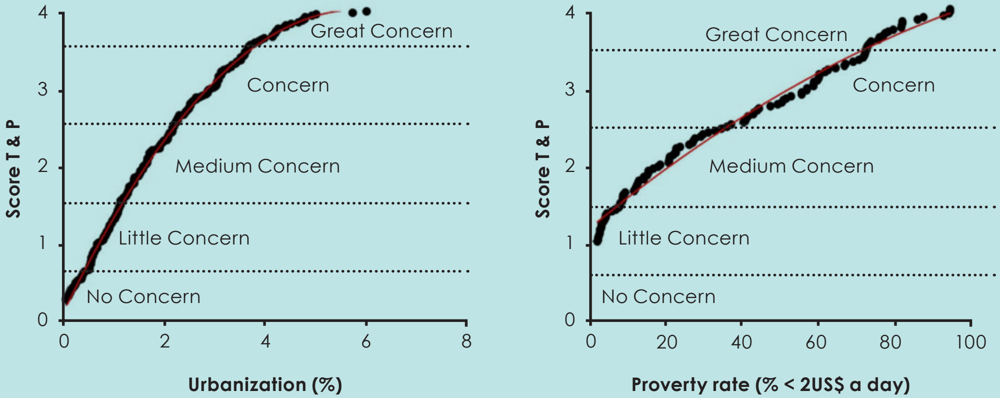

FIGURE 3.2 — Two examples of trends and pressure indicators developed in step 1 of this revision (Fig. 3.1). Left: urbanization rate (CIA 2014). Right: poverty rate (World Bank 2014). The urbanization and poverty rates of all available countries are ranked and subsequently linearly converted into scores of 0–4 (y-axis). Based on this score, ordinal classes, expressed as 'degree of concern', are used. Table 3.1 provides the calculation method

sub-indicators that are proposed. Most of these indicators are scaled according to existing scaling methods. Furthermore, sub-indicator 5.4 *(Land subsidence)* and 6.3 *(Salinization and seawater intrusion)* are scaled according to an ordinal self-assessment.

For seven indicators and sub-indicators we have proposed a scoring method as no international standards are available. The scores are determined using the ranking of the city amongst all available country scores (Fig. 3.2). The rankings are linearly standardized on a scale from 0 to 4 points (y-axis Fig. 3.2). Subsequently, an equation has been selected that best fits this ranking (lowest correlation coefficient: r=0.97; Table 3.1). Next, these equations are applied in order to determine the indicator scores for each city. The numbers are rounded and scores of 3 or 4 points are marked in red and communicated to the stakeholders because they are considered as a concern or great concern (see Table 3.3 in Section 4.4). These scores are not normative but only provide an indication of the urban pressures. Finally, the Trends and Pressure Index (TPI; the arithmetic mean of all twelve TPF indicators) can be calculated for each city.

3.4.2 STEP 2: IMPROVEMENTS OF THE CITY BLUEPRINT INDICATORS

3.4.2.1 The Use of Wastewater Treatment as Indicator for Surface Water Quality

Baseline assessments of IWRM in cities should preferably include *surface water quality* and biodiversity. Unfortunately, this appears problematic as a result of a lack of local data and questionable data reliability. In the current CBF, the indicator surface water quality uses data from the water quality index (WQI) of the environmental performance index (EPI 2010). The WQI is the only global database of water quality for inland waters. However, insufficient spatial and temporal coverage of measurements, poor reporting and inconsistent sampling design, all posed data reliability problems (Srebotnjak et al. 2012). Therefore, the EPI stopped using the WQI after the year 2010 (EPI 2012).

A similar concern is the current indicator *biodiversity*, for which information is provided for member states of the European Union (EU), but this information is not available for non-EU countries (EEA 2014a). As an estimate for non-EU countries, the EPI water (effects on ecosystems) index has been used (EPI 2010). However, data reliability and the use of different databases appeared to be problematic (Emerson et al. 2010; Koop and Van Leeuwen 2015c). Moreover, both indices are national averages which lead to overestimations of urban water quality and biodiversity because

TABLE 3.1 — Summary of calculation methods for the indicators of the Trends and Pressures Framework developed in step 1 of this revision (Fig. 3.1). Three indicator categories are distinguished: (a) social indicators (nrs. 1–4), (b) environmental indicators (nrs. 5–8), and (c) financial indicators (nrs. 9–12). All indicators are categorized into five concern scores varying from 0 to 4, i.e., 0–0.5 points (no concern), 0.5–1.5 (little concern), 1.5–2.5 (medium concern), 2.5–3.5 (concern), and 3.5–4 (great concern). The equations are based on publicly available data and the derived relations are all significant (p max<10-6). For a more detailed description of the data source and calculation method reference is made to the EIP City Blueprint website (EC 2015a)

INDICATOR	UNIT **X**	METHOD/EQUATION	SOURCE
1. Urbanization rate	% per year	Score = $-0.114\mathbf{X}^2 + 1.3275\mathbf{X} + 0.1611$ r=0.999	CIA 2014
2. Burden of disease	DALY's	Classification World health organization	WHO 2014
3. Education rate	% primary education	Score = $-10^{-5}\mathbf{X}^3 + 0.0012\mathbf{X}^2 - 0.0426\mathbf{X} + 4.3057$ r=0.974	World Bank 2012
4. Political instability	World Bank standardized	Classification of the World Bank	World Bank 2013A
5.1 Urban drainage flood	%flooded	Score = $6{\cdot}10^{-8}\,\mathbf{X} - 2.10^{-5}\mathbf{X}^{-4} + 0.0014\mathbf{X}^3 - 0.0526\mathbf{X}^2 + 0.8302\mathbf{X} - 3.8745$ r=0.992	EEA 2015B
5.2 River peak discharges	% flooded	Classification of the EEA (2012)	EEA 2015B
5.3 Sea level rise	% flooded	Classification of the EEA (2012)	EEA 2015B
5.4 Land subsidence	Self-assessment	0 = No infrastructure damage, no flood risk. 1 = Low infrastructure damage expected, no increase in flood risk expected. 2 = Infrastructure damage or <0.50m subsidence by 2100 in substantial urban area. 3 = Serious infrastructural damage or <1m subsidence substantial urban area by 2100. 4 = As 3 with Imminent flood risk.	Case studies Local reports
6.1 Freshwater scarcity	% use of renewable resource	Classification of the OECD (2004) and WRI (2013)	FAO 2015
6.2 Groundwater scarcity	% use of renewable resource	Classification of the IGRAC (2010)	FAO 2015
6.3 Salinization and seawater intrusion	Self-assessment	0 = Both not reported and city not vulnerable 1 = Both not reported but city is vulnerable in coming century 2 = one/both not reported but imminent threat 3 = one/both reported 4 = one/both reported seriously affecting the city	Case studies Local reports
7.1 Surface water quality	WQI	Score = [100 – WQI] / 25	EPI 2010
7.2 Biodiversity	- % - Water (effect on ecosystems) index	For EU: % water bodies less than good quality[A] For other: Score = 100 – [Water (effects on ecosystems)/25]	EEA 2015A EPI 2010
8 Heat island effect		Average of the following two scores: (1) Number of hot days >35 °C and nights > 20 °C[B]. (2) Green space coverage (%)[C]	EEA 2015B EEA 2012
9 Economic pressure	GDP $\text{capita}^{-1}\,\text{day}^{-1}$	Score = $-0.783\,\mathrm{LN}(\mathbf{X}) + 4.115$ r=0.995	IMF 2013a
10 Unemployment rate	%	Score = $0.0002\mathbf{X}^2 + 0.5077\mathbf{X} - 0.8356$ r=0.989 If <2% score is 0 points	World Bank 2014A
11 Poverty rate	% <2US$ day^{-1}	Score = $-0.0001\mathbf{X}^2 + 0.0404\mathbf{X} + 1.1686$ r=0.994	World Bank 2015a
12 Inflation rate	% year^{-1}	Score = $0.0025\mathbf{X}^3 - 0.0744\mathbf{X}^2 + 0.866\mathbf{X} + 0.0389$ r=0.996	World Bank 2013B

A Scores for the classification of water bodies (EEA 2015A) are as follows: 0-10% (0), 10-30% (1), 30-50% (2), 50-70% (3), > 70% (4).
B Annual number of hot days >35°C and nights >20 °C standardized in a 0-4 range (boundaries: min. 0; max. 50).
C Green space coverage (%) standardized in a 0-4 range (boundaries have been set at the upper and lower 10% of approximately 600 cities according to EEA (2012)).

cities are often large emitters of pollutants (Van Leeuwen 2013; Gessner et al. 2014).

Cities may have hardly any direct influence on the scores for surface water quality and biodiversity because of upstream pollution. Hence, the indicators *water quality and biodiversity* should focus on the city's own IWRM performance to prevent pollution. The coverage of secondary Waste Water Treatment (WWT) greatly determines the quality and biodiversity in urban waters because detrimental effects on aquatic species due to oxygen depletion are avoided. WWT removes at least 70 % of the biological and 75 % of the chemical oxygen demand (OECD 2013). Furthermore, the coverage of tertiary WWT avoids eutrophication by removing nitrogen and phosphorous, as well as other (microbiological) pollutants (OECD 2013). Secondary and tertiary WWT data are often available at the level of cities, frequently updated and widely used by international organizations (ISO 2014; UN-Water 2014; OECD 2013; Siemens 2015; SOPAC 2004).

The scores for indicators 10 *(nutrient recovery)*, 11 *(energy recovery)* and 12 *(sewage sludge recycling)* have been updated. These indicators reflect the reuse of wastewater as a fraction of the water that is passing the city's wastewater treatment plants; whereas the city's WWT service coverage is disregarded. Hence, a city that only treats a small fraction of its wastewater, but fully recycles the nutrients, sludge and applies full energy recovery from this small fraction, would receive a high score for these indicators while loads of potentially abstractable nutrients, sludge and energy actually flush away. In order to take all urban wastewater into account, the scores are therefore multiplied by the fraction of wastewater (F) that is actually treated at the WWT facilities (Eqs. 1, 2 and 3).

(1) Score for nutrient recovery = (nutrient recovery(%) * F) = 10

(1) Score for energy recovery = (energy recovery(%) * F) = 10

(3) Score for sewage sludge recycling = (sewage sludge recycling (%) * F) = 10

3.4.2.2 Public Participation

The Voluntary Participation Index (VPI) is used for indicator 23 *(public participation)* and represents the average number of memberships in voluntary organizations as measured for

EU-countries in 2003 (EFILWC 2006). We have updated this indicator by using the percentage of people involved in unpaid work (EFILWC 2012). For non-EU countries a best estimate is provided (Eq. 4) based on the high correlation with the World Bank indicator *Rule of Law* (n=27; r=0.84; p <0.0000001).

(4) Public participation core = 0.0657 * score for Rule of Law–2.2278

3.4.2.3 Indicator Boundaries

The indicators of the CBF are standardized according to the min-max method, by using percentages or by a self-assessment scoring method as explained in the City Blueprint questionnaire (EC 2015a). The min-max standardization method is sensitive for outliers that may result in unrealistic scores and therefore indicator boundaries have been reviewed. For instance, indicator 16 *(water system leakages)* measures the leakage rate of the drinking water distribution system. The indicator boundaries for leakage have been set at 0 and 100 %, respectively. Consequently, 0 % is equivalent to a completely leaking water distribution system which results in a low variance of this indicator. Therefore, the maximum boundary of water leakage has been arbitrarily reset at 50 %. The same holds for indicator 15 *(average age sewer system)*, where the maximum age of the urban sewers has been lowered from 100 to 60 year. For large datasets (n>100), the average of the lower and upper 10 % have been used as minimum and maximum. This is done for indicator 4 *(solid waste collected)*, 17 *(operation cost recovery)* and 18 *(green space)*.

3.4.2.4 Water Footprint Indicators

Based on constructive criticism from local water authorities concerning the use of the Water Footprint (WF) concept (used in the former category *water security*), it has been decided to discontinue their use. The WF describes the total volume of water over the full supply chain that is needed to produce a product or that is used by a country (Hoekstra et al. 2009). Water imports and exports of a country are highly dependent on many social-economic processes and national and global trends on which the local water authorities have a negligible influence. Moreover, the indicator *water scarcity* and *water self-sufficiency* are largely determined by the total renewable water resource which is abundant or not, regardless of the interventions by local water authorities. In fact, temperature, rainfall, soil type, river course, etc., largely determine the total renewable water resources.

3.4.2.5 Solid waste

Cities are prone to water pollution due to their highly efficient drainage systems that quickly collect and discharge polluted water. Cities are the largest source of plastic waste that enters the oceans via rivers and canals. About 280 million tonnes of plastics ends up in the oceans annually, where it photodegrades into small particles and affects marine ecosystems (Derraik 2002; Sigler 2014). The degradation of plastic waste in landfills is approximately 1 to 5 % during 100 years (Bez et al. 1998). Urban solid waste treatment is therefore a key performance- oriented aspect that determines the water quality in cities, rivers and oceans. According to the European Commission (EC 2008), the priority order for waste reduction is waste prevention, reuse, recycling, recovery and disposal. Hence, indicator 4 *(solid waste collected*), 5 *(solid waste recycled)* and 6 *(solid waste energy recovered)* have been included.

3.4.3 Step 3: Indicator Rearrangements and Aggregation Method

The contribution of the indicators and categories to the BCI are currently highly variable. Indicators with low variances contribute less to the BCI. Moreover, the variances differ strongly and the number of indicators per category are not equal (Koop and Van Leeuwen 2015b). However, an equal contribution of each category and indicator is strived for. The final rearrangement of the indicators and categories is shown in Table 3.2. Currently, no particular penalty for unbalanced scores is given, and therefore the need to improve the achievements for low scoring indicators needs to be addressed (JRC 2014).

3.4.3.1 Basic Water Services

An indicator intra-correlation analysis revealed that the indicators *safe sanitation*, *sufficient to drink* and *drinking water quality* strongly correlate (Koop and Van Leeuwen 2015b). Access to proper drinking water and improved sanitation are basic water services which are united into a new category, i.e., category III *(basic water services)*. The remaining indicators in the former category sanitation, all deal with wastewater treatment and the category has been renamed to '*wastewater treatment*' (category IV; Table 3.2). This is in accordance with the ISO37120, which is a much broader urban indicator framework that also includes a '*water and sanitation*' and '*wastewater*' category (ISO 2014).

3.4.3.2 Climate Robustness

The correlation coefficient between the indicators climate commitment and adaptation measures is high (r= 0.93).
Given the similar ordinal assessment method, it is most likely that these indicators overlap. Furthermore, given the high correlations with indicators 19, 20, 22 and 23 (r> 0.71), it is presumable that the indicator *climate commitment* is redundant and has therefore been removed (Koop and Van Leeuwen 2015c). Although climate change impacts are complex and ubiquitous, three climate vulnerabilities with particular reference to urban areas have been identified, i.e., UHI, water scarcity and flooding (EEA 2012). The UHI exacerbates heat waves in cities because the cooling effect of vegetation is replaced by surfaces sealed with concrete, asphalt and stone (EEA 2012). Green and blue areas store rainwater and evaporate this water, thereby mitigating heat waves and storm events. In addition, green and blue areas alleviate air pollution, increase the city's recreational value and reduce water polluted (Li et al. 2014; Jia et al. 2013; Jonker et al. 2014; Czemiel Berndtsson 2014). Therefore, the share of blue and green area (%) is added as a new indicator in category VI *(climate robustness)*, shown in Table 3.2. Climate change will also increase the urban vulnerability to water scarcity (EEA 2012). The domestic and industrial use of drinking water is an adequate indication of how cities combat water scarcity. Therefore indicator 20 *(drinking water consumption)* is also included in category VI *(climate robustness)* (Table 3.2).

3.4.3.3 Governance

At this stage of the framework rearrangement, the former category *biodiversity and attractiveness* only includes indicator 25 *(attractiveness)*, because the indicator biodiversity has previously been removed. Indicator 25 *(attractiveness)* measures the incorporation of blue- green areas which is mainly the result of urban planning by local authorities, the local community and private companies (shops, factories, restaurants, bars etc.) who want to shape an attractive place to live. The relation with governance is also indicated by the correlations with the indicator 22 *(management and action plans)* (r=0.53), 23 *(public participation)* (r=0.61) and 24 *(water efficiency measures)* (r=0.74). *Water efficiency measures* assesses to what extent water efficiency measures are applied. Because correlated indicators 22, 23, 24 and 25 all assess how local authorities manage water issues, these indicators have been united into category VII *(governance)*.

3.4.3.4 Infrastructure

The former category *infrastructure* is only poorly accounted for given the large maintenance cost and large global investment deficit in water infrastructure (AWWA 2001; Cashman and Ashley 2008). Therefore indicator 16 *(water system leakages)* has been added because it is suitable to represent the maintenance of the drinking water infrastructure. In contrast with data on total investments in water infrastructure, data of operation costs and revenues of drinking water and sanitary services is often available (IBNET 2015; OECD 2010). The ratio of the total yearly operating revenues divided by the operating costs of drinking water and

TABLE 3.2 — Overview of the performance indicators of the improved City Blueprint Framework (CBF) as described in step 2 and 3 of the revision (Fig. 3.1). Indicators in bold are new and indicators with adjusted scaling or new data bases are in italics. The other indicators have not been adjusted

I. WATER QUALITY	**1. Secondary WWT** **2. Tertiary WWT** 3. Groundwater quality
II. SOLID WASTE TREATMENT	**4. Solid waste collected** **5. Solid waste recycled** **6. Solid waste energy recovered**
III. BASIC WATER SERVICES	7. Access to drinking water 8. Access to sanitation 9. Drinking water quality
IV. WASTEWATER TREATMENT	*10. Nutrient recovery* *11. Energy recovery* *12. Sewage sludge recycling* 13. WWT energy efficiency
V. INFRASTRUCTURE	14. Stormwater separation *15. Average age sewer* *16. Water system leakages* **17. Operation cost recovery**
VI. CLIMATE ROBUSTNESS	**18. Green space** 19. Climate adaptation 20. Drinking water consumption 21. Climate-robust buildings
VII. GOVERNANCE	22. Management and action plans *23. Public participation* 24. Water efficiency measures 25. Attractiveness

sanitation services is an important indicator of the financial state of the local water authorities and their ability to make the necessary investments in infrastructure (OECD 2015a). Hence, indicator 17 *(operation cost recovery)* is added to strengthen category V *(infrastructure)*, given in Table 3.2.

3.4.3.5 Aggregation Method

For composite indices, issues of weighting and aggregation are sensitive and subjective (EPI 2010). It should be recognized that assigning explicit weightings, by definition, represents only one viewpoint. Therefore, no indicator or category weightings are applied. Moreover, the implicit weighting, due to correlations and/or differences in variances are addressed before the indicators are aggregated.

Most frequently used aggregation methods are the arithmetic and geometric mean. The arithmetic mean gives no particular penalty for unbalanced scores, and consequently does not address the urgent need to improve achievements for the lowest scores (JRC 2014). However, it is essential to regard water management in an integrative way, e.g., increasing access to sanitation greatly improves human hygiene but without adequate investments in WWT, this leads to a strong emission increase in hazardous pollutants and nutrients. Hence, a high score for access to sanitation should not fully compensate a low score for WWT coverage (Ligtvoet et al. 2014).

Since a geometric mean can be defined as the nth root of the product of n numbers or as the anti-log of the sum of logs divided by the number of samples and the log zero (0) is not defined, the calculation of the geometric mean method requires strictly positive values. It is therefore chosen to re-standardize the indicators to a 1–11 score, aggregate the indicators with the geometric mean and finally subtract 1 point from this score. In this way, balanced indicator performances are rewarded.

3.4.4 EXAMPLES

For all 45 cities data have been gathered for the analyses of their TPF and improved CBF. In this section examples of only three cities are presented, i.e., Dar es Salaam, Melbourne and Amsterdam. The TPF is shown in Table 3.3. The overall Trends and Pressure Index (TPI) for Dar es Salaam, Melbourne and Amsterdam are 2.7, 1.1 and 1.2 respectively. The improved City Blueprints for these cities are shown in Fig. 3.3. The new BCI for Dar es Salaam, Melbourne and Amsterdam are 1.3, 5.4 and 8.3 respectively. The performance ranking of these cities is shown for each category (Fig. 3.4).

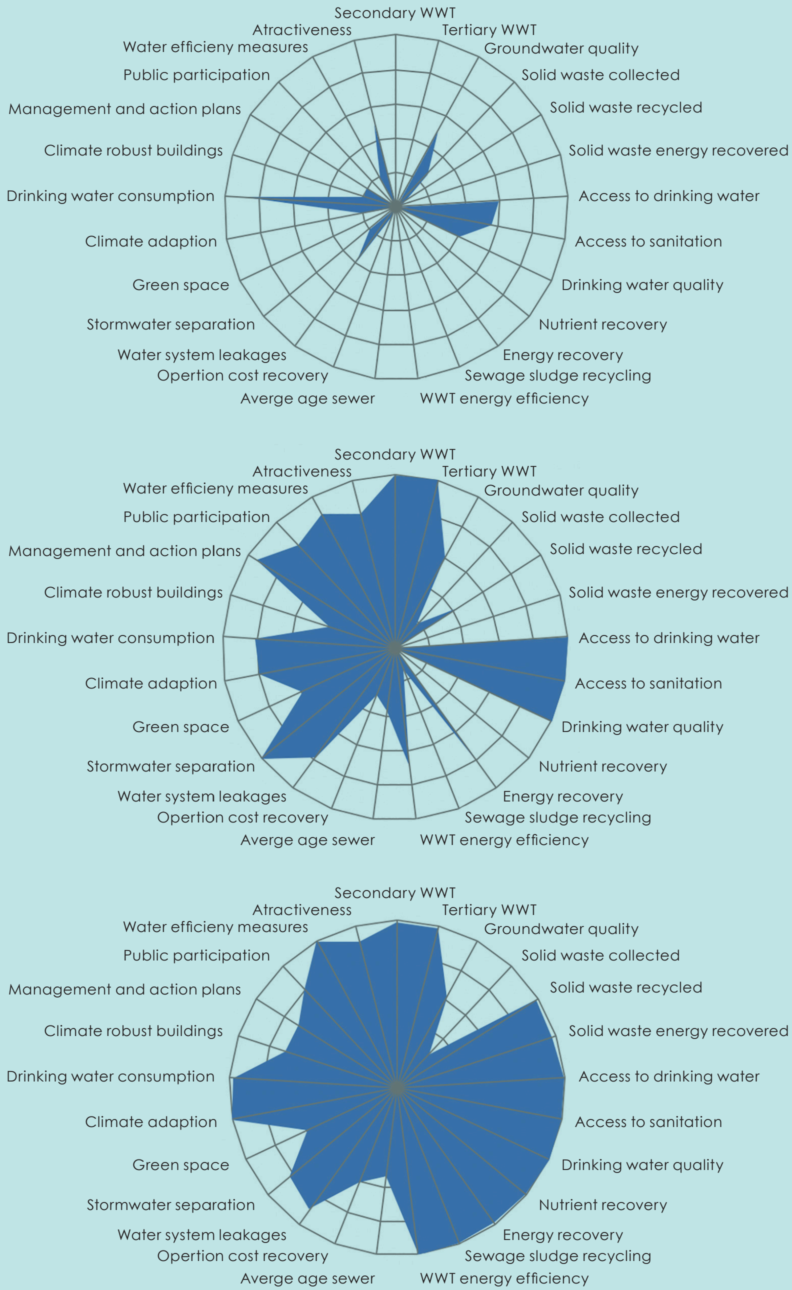

FIGURE 3.3 — Spider diagram application of the improved performance framework (Fig. 3.1). Examples of three spider diagrams based on 25 performance indicators for Dar es Salaam (top), Melbourne (centre) and Amsterdam (bottom). The geometric mean of the indicators, i.e., the BCI, is 1.3, 5.4 and 8.3, respectively

TABLE 3.3 — Trends and Pressures Framework (TPF) of Dar es Salaam, Melbourne and Amsterdam with their concern scores: 0 (no concern), 1 (little concern), 2 (medium concern), 3 (concern), and 4 (great concern)

TRENDS AND			Dar es Salaam	Melbourne	Amsterdam
	SOCIAL	1. Urbanization rate	**4**	1	1
		2. Burden of disease	**3**	1	0
		3. Education rate	**3**	0	1
		4. Political instability	2	1	1
	ENVIRONMENTAL	5. Water scarcity	2	1	1
		6. Flood risk	**3**	2	**3**
		7. Water quality	1	2	2
		8. Heat risk	**3**	**4**	1
	FINANCIAL	9. Economic pressure	**4**	0	1
		10. Unemployment rate	1	1	1
		11. Poverty rate	**4**	0	0
		12. Inflation rate	**3**	2	1

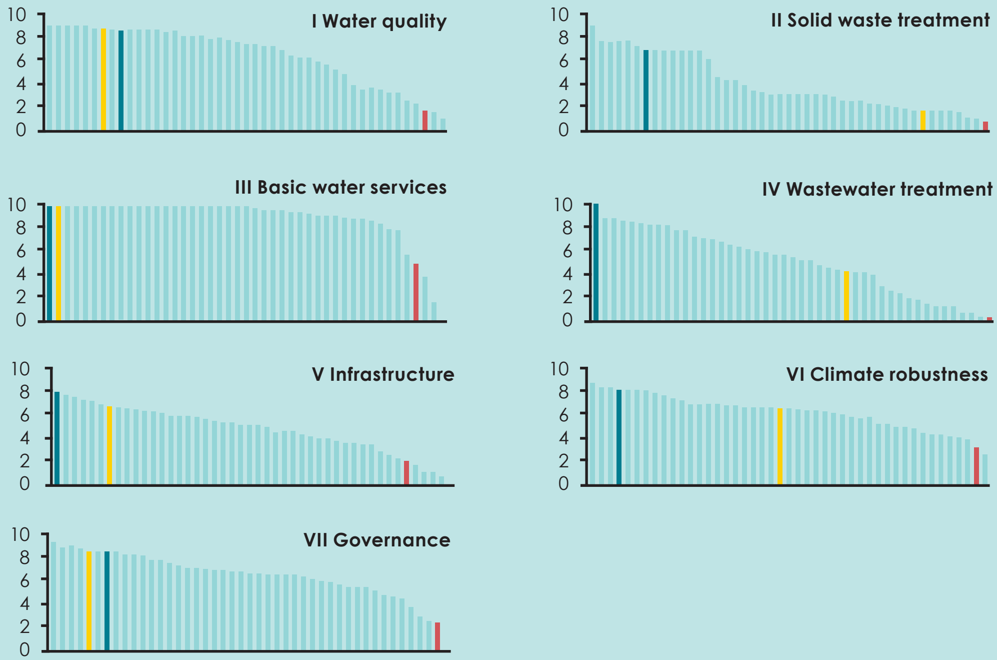

FIGURE 3.4 — Category ranking of the City Blueprints of Dar es Salaam (red), Melbourne (orange) and Amsterdam (green). The arithmetic average of the indicator scores for each of the seven categories (Table 3.2) is ranked from high too low for each of the 45 municipalities and regions. This ranking is part of the application of the performance framework (Fig. 3.1).

3.5 DISCUSSION

3.5.1 CITY BLUEPRINT IMPROVEMENTS

We have developed two separated indicator frameworks that embody the distinction between trends and pressures (TPF) and IWRM performance of a city (CBF). In the TPF only indicators that are of concern or great concern (3 or 4 points) are explicitly communicated to the stakeholders (Table 3.3). The CBF is essential to show the potential gain possible by sharing knowledge, experiences and best practices amongst cities. Moreover, it more accurately depicts the own activities and efforts of cities to improve the sustainability of their IWRM and how they can alleviate environmental pressures such as emissions of poorly treated wastewater and solid waste. The TPF provides a wider context, which is important in obtaining insight into the limitations and windows of opportunities to improve urban IWRM. Finally, the categories of the 45 cities are averaged and ranked in order to provide a quick overview of potential improvements compared to other cities (Fig. 3.4). These simple graphical representations allow for a quick overview of cities on their path to become water-wise and climate prove.

3.5.2 LIMITATIONS

Only publicly available data is added to this improved CBF in order to promote transparency, and to reduce time and costs. City scale data concerning urban IWRM appeared to be particularly scarce. In fact, this information is often available, but publicly inaccessible which hampers city-to-city learning (EEA 2014b). Moreover, most urban water-related indicators are often not standardized, consistent, or com- parable over time and between cities (ISO 2014). For a considerable number of indicators national data are used because local data is not publicly available for all cities. This limits the accuracy of city assessments, especially in large countries with high regional variety.

Basic statistics obtained from the 45 cities have been used to reconstruct the CBF and to arrive at an approximately proportional contribution of all indicators and categories. However, the 45 cities that are used for this statistical analysis have a distribution bias as most cities are located in North-West Europe and are therefore not representative for the global urban challenges. This is a limitation of our work. Hence, it should be taken into account that the actual variance of the indicators may differ from the output of cities that have been analysed. For instance, the variance of category 3 (basic water services) and 7 (governance) is expected to be larger if the cities would really represent a global sample, i.e., if cities from developing countries would not be underrepresented.

3.5.2.1 Indicator Limitations

The data for the baseline assessment proposed in this paper is gathered by means of a questionnaire (EC 2015a) and by using publicly available data. In order to include a large number of cities of different size and geography, the indicator framework is limited by the information that was available. Hence, the set of indicators can and should be extended for some cities. Public data concerning flood risks appeared to be particularly sparse. Information on urban flood vulnerability is available, i.e., vulnerability to river peaks and sea level rise (Jongman et al. 2014; EEA 2012). However, these data do not represent flood protection performances. Hence, these indicators are included in the TPF. Ideally, a flood return interval is used to quantify the performance of flood defence. However, flood return intervals are not consistently reported worldwide, let alone, calculated in comparable manner.

The percentage of uncollected solid waste is inconsistently reported. Only for a very few cities, it was more than zero, preventing it to become a suitable comparative indicator. However, uncollected solid waste can strongly contribute to the release of a variety of pollutants such as heavy metals, persistent bio-accumulative chemicals, pesticides, pharmaceuticals and plastic (Katsanevakis 2011). However, efforts to reduce water polluting activities such as landfilling and solid waste production are explicitly included.

Another major cause of urban water pollution is stormwater runoff. This pollution pathway is related to traffic intensity and uncollected solid waste (Czemiel Berndtsson 2014; Revitt et al. 2014). Urban soil permeability or the use of best practices to reduce or filter stormwater runoff, e.g., by biofilters, infiltration ponds or bioswales, may be insufficiently addressed in the CBF due to limited data availability on soil permeability. Only indicator 18 *(green space)* and 19 *(climate adaptation)* implicitly address these issues. Hence, a supplementary indicator that assesses the application of measures to decrease and filter stormwater runoff could be added.

The min-max method can be sensitive for extreme outliers that may disrupt the scoring. Therefore the average of the lower and upper 10 % from a large data set (n>100) is taken as the minimum and maximum for indicators 4 *(solid waste collection)*, 17 *(operation cost recovery)* and 18 *(green space)*. However, for drinking water consumption this was hindered because there was no large dataset that included residential, commercial, industrial and public purposes. Often only domestic water consumption data is provided which represents only 10 % of the total drinking water consumption in the EU (ISO 2014). Likewise, indicator 15 *(average age sewer)* is prone for outliers because minimum and maximum numbers are taken from a limited dataset.

Data coverage of the selected set of indicators is high. Only the operation cost recovery (ratio) of Helsinki and data according to the EEA (2012) assessment method for indicator 18 *(green space)* were not available for non-EU cities. In most cases a realistic default value of 20 % green space is taken (e.g., for Ho Chi Minh City and Istanbul) and only for Melbourne we arbitrarily set this score equal to that of Amsterdam. Finally, the operation cost recovery for Helsinki has been arbitrarily set at 1, as data have not been provided.

3.5.2.2 Water Infrastructure Investment Deficit

Upgrading of water infrastructure is crucial for water security in cities (OECD 2015a). Water infrastructure investment requirements are already high in developed countries (yearly 0.35–1.2 % of GDP) and even higher for developing countries (yearly 0.71–6.30 % of GDP) (Cashman and Ashley 2008). Hence, the state of the water infrastructure network (indicator 15 *average age sewer*) is decisive for the city's financial performance.

As an indication of the maintenance of the sewer system in a city, we have divided the average by an assumed sewer lifespan. This is an inaccurate approximation since local circumstances that determine the sewer lifespan are not incorporated. A first improvement could be to determine a site-specific maximum sewer lifespan and compare this with the current site-specific average age. A more advanced approach would be to calculate the yearly sewer maintenance investment requirement (Equation 5) as proposed by Prof. Dr. Bosseler (personal communication). The infrastructure lifespan and system asset value should be calculated for each city. By using equation (5), an annual investment can be calculated that should be reserved for long-term infrastructure maintenance. The actual investment in infra- structure can be scored as a fraction of this annual investment requirement.

$$(5)\ \text{Investment requirements } (€\ \text{year}^{-1}) = \frac{\text{System Asset Value } (€)}{\text{Lifespan (years)}}$$

3.6 CONCLUSIONS

The goal of this study is a methodological review of the City Blueprint indicator framework to improve the assessment of the sustainability of IWRM in cities (Fig. 3.1). The results of the application of this improved method have been reported in this journal (Koop and Van Leeuwen 2015a). This revision was necessary to better emphasize cities' opportunities to envision, develop and implement stepwise measures to transform towards water-wise or water sensitive cities. The following changes have been made:

1. A distinction between descriptive and performance-oriented indicators has been made by developing a Trends and Pressures Framework (TPF; on which the city's IWRM has a negligible influence) and improving the city-level IWRM performance framework, i.e., the City Blueprint Framework (CBF).
2. The TPF includes the following social, environmental and financial indicators: urbanization rate, burden of disease, education rate, political instability, water scarcity, flood risk, water quality, heat risk, economic pressure, unemployment rate, poverty rate and inflation rate. The data are publicly available (Table 3.1).
3. We distinguish 5 ordinal classes, varying from no concern to great concern, for each of these 12 TPF indicators.
4. In the revised CBF, seven indicators have been added, i.e., secondary and tertiary wastewater treatment, operation cost recovery, green space and three indicators concerning *solid waste treatment* (Table 3.2).
5. Adjusted scaling or new databases are used for the following CBF indicators: nutrient recovery, energy recovery, sewage sludge recycling, average age sewer, water system leakages and public participation (Table 3.2).
6. The geometric aggregation method has been chosen to calculate the Blue City Index for the 25 indicators of the CBF.
7. We have applied this new CBF, TPF and BCI to 45 cities in 27 countries (Koop and Van Leeuwen 2015a).
8. The focus on performance will enhance city-to-city learning, i.e., sharing of knowledge, experiences and best practices between cities. This is the ultimate goal of our EIP Water Action Group (EC 2015a) as the need to improve IWRM in cities is crucial and the time window to do this, is closing rapidly (OECD 2015; Van Leeuwen 2013).

ACKNOW-LEDGMENTS

We would like to thank Prof. Dr. Bosseler (Institute for Underground Infrastructure, Gelsenkirchen, Germany) for his advice on water infrastructure investment deficits. The City Blueprint Action Group is part of the governance activity of the European Innovation Partnership on Water of the European Commission, coordinated by both Dr. Richard Elelman of Fundació CTM Centre Tecnològic and NETWERC H2O (Manresa, Spain) and Prof. Dr. Kees Van Leeuwen of KWR Watercycle Research Institute. The European Commission is acknowledged for the support of our City Blueprint action and for the BlueSCities project in H^{2}0^{2}0-Water under Grant Agreement No. 642354.

CHAPTER 4

APPLICATION OF THE IMPROVED CITY BLUEPRINT FRAMEWORK IN 45 MUNICIPALITIES AND REGIONS

This chapter is published as: Koop S.H.A. and Van Leeuwen C.J. (2015) Application of the Improved City Blueprint Framework in 45 Municipalities and Regions. Water Resources management. 29(13), 4629-4647

ABSTRACT

This chapter addresses research 2: What levels of water-wisdom can be identified based on empirical urban water cycle management assessments?

Rapid urbanization, water pollution, climate change and inadequate maintenance of water and wastewater infrastructures in cities may lead to flooding, water scarcity, adverse health effects, and rehabilitation costs that may overwhelm the resilience of cities. Further- more, Integrated Water Resources Management (IWRM) is hindered by water governance gaps. We have analysed IWRM in 45 municipalities and regions divided over 27 countries using the improved City Blueprint® Framework (CBF). The CBF incorporates solely performance-oriented indicators that more accurately measure the city's own efforts and performances to improve its IWRM. We have also analysed the trends and pressures (on which the city's IWRM has a negligible influence). The Trends and Pressure Framework (TPF) creates awareness of the most stressing topics that either hamper or, on the contrary, pose opportunity windows for IWRM. The improved Blue City Index (BCI*) and the Trends and Pressures Index (TPI; the arithmetic mean of all TPF indicators) have been compared with other city descriptors. The BCI* and TPI showed a significant and negative Pearson correlation ($r=-0.83$). This implies that cities with pressing needs to improve their IWRM also face the highest environmental, financial and/or social limitations. The BCI* and TPI correlate significantly with the ND-GAIN climate readiness index ($r=0.86$; $r=-0.94$), the environmental awareness index ($r=0.85$; $r=-0.85$), the European green city index ($r=0.86$; $r=-0.85$) and various World Bank governance indicators. Based on a hierarchical clustering of the 45 municipalities and regions, 5 different levels of sustainability of urban IWRM could be distinguished, i.e., (1) cities lacking basic water services, (2) wasteful cities, (3) water efficient cities, (4) resource efficient and adaptive cities, and (5) water wise cities. This categorization, as well as the CBF and TPF are heuristic approaches to speed up the transition towards water wise cities.

4.1 INTRODUCTION

4.1.1 THE CHALLENGES OF URBAN WATER GOVERNANCE

Management of fresh water resources is of critical importance to the healthy social, economic and political well-being of a society. Stresses exerted on the world's water resources by the increasing demand from growing populations with changing consumption patterns, the detoriation of water quality by pollution and climate change are placing water increasingly higher on the international agenda (UNEP 2012; EC 2012; Hoekstra and Wiedman 2014; World Economic Forum 2014). These megatrends pose urgent water challenges, particularly in cities (Engel et al. 2011; SIWI 2012; Van Leeuwen 2013; Chong 2014; MacDonald et al. 2014; Koop and Van Leeuwen 2015a).

Conventional urban water management is often fragmented and relies on traditional, technical and linear management approaches (Brown and Farrelly 2009; Ferguson et al. 2013). Furthermore, it is often inflexible, energy intensive and tends to focus on short-term solutions disregarding long-term cost-effectiveness or sustainability (Philip et al. 2011). Despite significant progression in technical solutions such as advancements in water, wastewater and stormwater treatment technologies, the transition from conventional to more sustainable Integrated Water Resources Management (IWRM) is slow (Van de Meene et al. 2011).

About two-thirds of the OECD countries experienced a mismatch between the administrative responsibilities and available funding. Also insufficient scientific, technical and infrastructural capacity of local actors was reported in two-thirds of the countries. Many countries face a policy gap due to fragmentation of responsibilities and a lack of coordination between different policy fields. Finally, administration, information and accountability gaps were found for more than half of the OECD countries. These barriers are mostly intra- and inter-organizational, implying that knowledge and technology often form no limitation. Unfortunately, often, a joint vision and effective cooperation amongst institutions and communities is lacking. Hence, there is a need for an integrated long-term vision and planning, including adequate allocation of responsibilities and funding, in which all relevant stakeholders are involved already at an early stage (EC 2015a). This is a highly difficult task since urban water managers are being confronted with increasingly complex and multi-faceted challenges due to climate change, urban growth, resource limitations and societal expectations (Brown and Farrelly 2009; OECD 2011a; EEA 2014c; OECD 2015a). For the non-OECD countries it can be assumed that the water governance gaps as shown in Table 4.1, are even greater.

4.1.2 PROMOTING A TRANSITION TOWARDS SUSTAINABLE IWRM

Although there is a general recognition of the urban water challenges and water governance gaps, attempts to develop tools to overcome these barriers by stimulating the implementation of IWRM are often lacking (Van de Meene et al. 2011; Brown and Farrelly 2009). Because a significant proportion of IWRM practices are locally implemented, local decision-making processes provide important pathways for long-term planning (Floyd et al. 2014; Brown and Farrelly 2009). Globally, approximately 80 % of the GDP is produced in cities, and also 75 % of the energy and materials are consumed in cities (UNEP 2013). Therefore, global environ- mental pressures and long-term preservation of quality of life are largely determined by urban systems. Hence, the fostering of sustainable IWRM is most effective in cities.

TABLE 4.1 — The OECD multi-level governance framework: key co-ordination gaps in water policy (OECD 2011a)

1. ADMINISTRATIVE GAP	Geographical 'mismatch' betwen hydrological and administrative boundaries. This can be at the origin of resource and supply gaps.
2. INFORMATION GAP	Asymmetries of information (quantity, quality, type) between different stakeholders involved in water policy, either voluntary or not.
3. POLICY GAP	Sectoral fragmentation of water-related tasks across ministries and agencies.
4. CAPACITY GAP	Insufficient scientific, technical, infrastructrural capacity of local actors to design and implement water policies (size and quality of infrastructure, etc.) as well as relevant strategies.
5. FUNDING GAP	Unstable or insufficient revenues undermining effective implementation of water responsibilities at subnational level, cross-sectoral policies, and investments requested.
6. OBJECTIVE GAP	Different rationals creating obstacles for adopting convergent targets, especially in case of motivational gap (referring to the problems of reduced political will to engage substantially in organizing the water sector).
7. ACCOUNTABILITY GAP	Difficulty in ensuring the transparency of practices across the different constituencies, mainly due to insufficient users' commitment, lack of concern, awareness and participation.

First step in fostering sustainable IWRM is a description of the current state, thereby creating awareness, and identifying the most viable opportunities (Philip et al. 2011). Wong and Brown (2009) identified three pillars that should be integrated in IWRM to attain water wise or water sensitive cities: (I) cities as water supply catchments, using diverse centralized and decentralized water sources; (II) cities as providers of ecosystem services that prevent the surrounding environment for degradation and depletion as well as promoting urban biodiversity; (III) cities hosting water sensitive communities that promote sustainable decision making and behaviour. Their three pillar approach aspires: (I) integration between water planning and urban planning; (II) (climate) adaptive and multi-functional infrastructure; and (III) collaboration between science, policy, practice and community. No water wise or water sensitive city is until yet realized and there is no accepted set of attributes and indicators that define it (Ferguson et al. 2013). However, since indicators are values or parameters that are able to point to, provide information about, and describe the current state, with a significance that extends beyond that directly associated with the parameter value, a balanced indicator framework can provide an important first step in promoting IWRM (OECD 2003; Van Leeuwen et al. 2012). Most existing indicators are not standardized, consistent, or comparable over time or between cities (ISO 2014). This hampers the exchange of knowledge, experiences, and best practices between cities and thereby the transition of cities towards water wise or water sensitive cities. This needs to change as the urban water challenges become increasingly urgent (Van Leeuwen 2013; EC 2015a). We have highlighted these IWRM challenges and performances in detailed reports for the cities of Rotterdam (Van Leeuwen et al. 2012), Dar es Salaam (Van Leeuwen and Chandy 2013), Hamburg (Van Leeuwen and Bertram 2013), Amsterdam (Van Leeuwen and Sjerps 2015a), Istanbul (Van Leeuwen and Sjerps 2015b), Ho Chi Minh City (Van Leeuwen et al. 2015) and Melbourne.

4.2 METHODOLOGY

The City Blueprint Framework (CBF) is a first attempt to perform a baseline assessment of IWRM (Van Leeuwen et al. 2012) and the baseline assessment has been applied on 11 cities (Van Leeuwen 2013) and recently on 45 municipalities and regions, mainly in Europe (Koop and Van Leeuwen 2015b; EC 2015a). The City Blueprint® is a baseline assessment or quick scan that evaluates the actual state of a city's IWRM and shows the indicator results in a spider diagram. It is a first step in the strategic planning process of IWRM in cities (Philip et al. 2011).The City Blueprint allows for comparison with other leading cities and, thereby can promote city-to-city learning (EC 2015a). The City Blueprint process is an interactive approach that involves all stakeholders early on in the process. It is a first step in the strategic understanding and long-term planning of IWRM in cities. Major stakeholders include water utilities, water boards, city councils, companies, Non-Governmental Organizations etcetera.

Based on constructive feedback from cities we have recently revised the CBF and the results will be published in this journal (Koop and Van Leeuwen 2015a). We now distinguish two separate frameworks, i.e., a Trends and Pressures Framework (TPF; Table 4.2) and a performance-oriented CBF (Table 4.3). The TPF provides a wider context that is supplementary to the CBF. The TPF is composed of 12 descriptive indicators that are equally distributed according to the triple bottom line approach (Elkington 1998; Mori and Yamashita 2015). In this way, the TPF may create awareness of the most stressing topics that either hamper or, on the contrary, pose opportunity windows for IWRM. The CBF has been updated to incorporate solely performance-oriented indicators that more accurately measure the city's own efforts, performances and possibilities to improve IWRM. A detailed description of the data sources and scoring methods are described elsewhere (EC 2015a; Koop and Van Leeuwen 2015b). In this paper we review IWRM in the following 45 municipalities and regions, mainly in Europe. In the rest of this paper these municipalities and regions will be referred to as cities.

The paper summarizes the most important results of the improved CBF (CBF*) and TPF and compares this with the previous CBF by using the assessments of 45 cities, mainly in Europe. Next the overall score of the improved Blue City Index® (BCI*) and the TPI (the arithmetic mean of the 12 TPF indicators) are compared with other indices and city descriptors. All city descriptors and the BCI* are tested to meet the requirements for Pearson correlations, i.e., being an interval or ratio level, the assumption of linearity and normality by applying the Shapiro-Wilk test using SPSS software. Finally, based on a hierarchical clustering analyses, BCI* scores and key indicator results, a heuristic categorization of different levels of sustainability of urban IWRM is proposed.

45 CITIES ASSESSED BY THE CITY BLUEPRINT

Algarve (Portugal)	Amsterdam (The Netherlands)	Ankara (Turkey)
Athens (Greece)	Belém (Brazil)	Berlin (Germany)
Bologna (Italy)	Bucharest (Romania)	Budapest (Hungary)
Copenhagen (Denmark)	Dar es Salaam (Tanzania)	Dordrecht (The Netherlands)
Eindhoven (The Netherlands)	Eslov (Sweden)	Galati (Romania)
Genova (Italy)	Hamburg (Germany)	Helsingborg (Sweden)
Helsinki (Finland)	Ho Chi Minh City (Vietnam)	Istanbul (Turkey)
Jerusalem (Israel)	Kilamba Kiaxi (Angola)	Kristianstad (Sweden)
Ljubljana (Slovenia)	Lodz (Poland)	London (UK)
Lyon (France)	Maastricht (The Netherlands)	Malmö (Sweden)
Malta (Malta)	Manresa (Spain)	Melbourne (Australia)
New York (USA)	Nieuwegein (The Netherlands)	Oslo (Norway)
Reggio Emilia (Italy)	Reykjavic (Iceland)	Rotterdam (The Netherlands)
Scotland (UK)	Stockholm (Sweden)	Varna (Bulgaria)
Venlo (The Netherlands)	Wroclaw (Poland)	Zaragoza (Spain)

TABLE 4.2 — Basic method and features of the Trends and Pressures Framework (TPF)

GOAL	Baseline performance assessment of the sustainability of urban IWRM	
FRAMEWORK	Social pressures	1. Urbanization rate 2. Burden of disease 3. Education rate 4. Political instability
	Environmental pressures	5. Flooding 6. Water scarcity 7. Water quality 8. Heat risk
	Financial pressures	9. Economic pressure 10. Unemployment rate 11. Poverty rate 12. Inflation rate
DATA	Public data or data provided by the water utilities	
SCORES	0: no concern, 1: little concern, 2: medium concern, 3: concern and, 4: great concern	
OVERALL SCORE	Trends and Pressures Index (TPI), the arithmetic mean of 12 indicatiors. Indicators scoring a concern or great concern (3 or 4 points) are marked and communicated to the stakeholders.	

4.3 RESULTS

4.3.1 TRENDS AND PRESSURES

The social, financial and environmental setting of every city is unique. This context may result in different priorities per city and their ability to attain sustainable IWRM. Indicators aimed to foster sustainable IWRM, should measure solely IWRM performances. A typical example is the limited natural availability of fresh water which may cause water stress for cities in (semi)arid regions. In this case, descriptive indicators measuring water availability would score low while the city may be a frontrunner in water efficiency practices precisely because they have to cope with limited water resources. Solely measuring urban performance to reduce water consumption allows for a fair comparison between cities and, more importantly, fosters sustainable practices in all cities participating in a city-to-city learning alliance. The main task of the TPF here is to identify priorities. In this case priorities may be the application of water saving measures by consumers, as well as infrastructure leakage reduction by water utilities. Hence, the TPF provides a wider context and allows for a quick overview of the most important limitations and windows of opportunity for IWRM.

Urban environmental pressures need to be reduced while social and financial living standards have to be sufficient to enable a good quality of life (Mori and Yamashita 2015). Hence, social, environmental and financial aspects are considered as equally important and are therefore covered by an equal number of indicators. All 12 indicators (Table 4.2) are scaled from 0 to 4 points, and the following classes have been used: 0–0.5 points (no concern), 0.5–1.5 (little concern), 1.5–2.5 (medium concern), 2.5–3.5 (concern), and 3.5–4 (great concern). Figure 4.1 shows the result of the aggregated score, i.e., the TPI for the 45 cities. The overall TPI provides a basic overview of the social, environmental and financial pressures. All cities in north western Europe have low TPIs. Mediterranean and eastern European cities already experience moderate pressures, while big cities such as Belém, Ho Chi Minh City, Istanbul, Dar es Salaam and Kilamba Kiaxi have high TPIs.

4.3.2. THE IMPROVED CITY BLUEPRINT FRAMEWORK

The CBF has been modified to obtain an approximately proportional contribution of all indicators and categories to the overall score, i.e., the improved BCI (BCI*). This was done by analysing correlations and variances, as well as by balancing and regrouping the different indicators. Six indicators have been removed because of data inaccuracy, overlap / redundancy, or

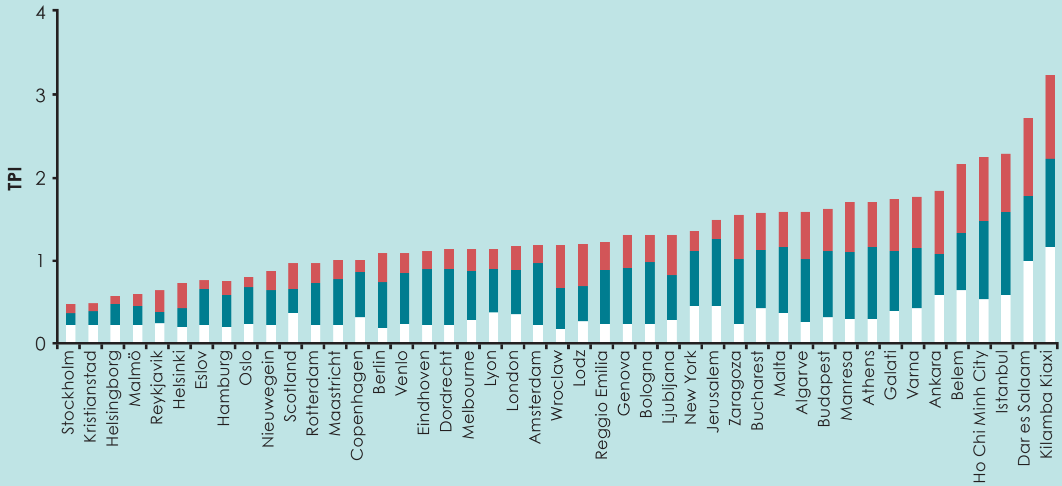

FIGURE 4.1 — The Trends and Pressures Index (TPI; the arithmetic average of all 12 indicators). Green, red and blue represent the share of the environmental, financial and social indicators, respectively to the overall TPI of each of the 45 cities

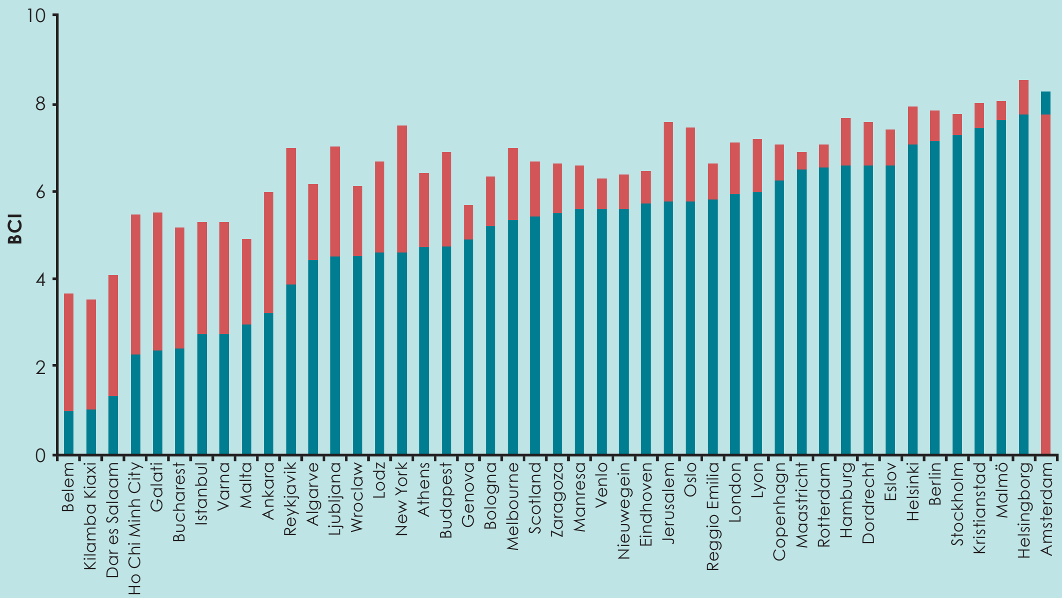

FIGURE 4.1 — The old Blue City Index (BCI; in red) compared to improved BCI (BCI* in blue). In general the BCI* is lower because of the more performance-oriented indicators and geometric aggregation method. Only the city of Amsterdam has a slightly higher BCI*

lack of focus on IWRM. Seven indicators have been added, i.e., secondary and tertiary wastewater treatment (WWT), operation cost recovery, green space and three indicators belonging to the category ‘solid waste treatment’. Furthermore, the geometric aggregation method has been selected for the calculation of the BCI* because it emphasizes the integrative nature of IWRM by penalizing unbalanced indicator scores (Koop and Van Leeuwen 2015a). The BCI (arithmetic average of the old 24 indicators) and the BCI* have been calculated for the same 45 cities. The BCI* shows more distinctiveness compared to BCI, since the variance is 2.5 times larger. The BCI ranges from 3.6 for the city of Belém (Brazil) to 8.5 for the city of Helsingborg (Sweden) which is a difference of 5.1 points. The BCI* ranges from 1.1 for the city of Belém (Brazil) to 8.3 for the city of Amsterdam (Netherlands) which is a difference of 7.2 points. The differences in the BCI and the BCI* are shown in Fig. 4.2.

Cities that already received a low BCI got even lower BCI* scores. On the contrary, cities that already had high BCIs, received slightly lower BCIs*. The city of Amsterdam is an exception (Fig. 4.2). The lower scoring cities showed the largest decrease in the overall BCI* compared to their old BCI, which is the result of the geometric aggregated mean as this method penalizes unbalanced scores. The ranking of the cities has not changed considerably and the BCI and BCI* correlate strongly with a Pearson correlation coefficient (r) of 0.92 (Fig. 4.3). The BCI* is negatively correlated with the overall TPI (*r*=-0.83; Fig. 4.3). Cities that experience high social, environmental and/or financial pressures, generally perform low on IWRM.

The BCI* and TPI have been compared with other indices and parameters that describe the state of cities and countries. It should be emphasized that correlations are not cause-effect relations. The BCI* correlated remarkably well with the Notre Dame Global Adaptation Index (ND-GAIN) climate readiness index (*r*=0.86). This index measures the country’s ability to absorb financial resources and mobilize them efficiently to adapt to climate change by taking into account economic, governance and social factors that contribute with 50, 25 and 25 %, respectively (ND-GAIN 2013). The ND-GAIN climate readiness index correlated highly with the BCI* (Fig. 4.4) and even better, but negatively, with the TPI (*r*=-0.94; Table 4.4). It means that cities that perform well on IWRM are cities that are also climate-ready.

Other correlations between the BCI* and TPI show the same pattern and are summarized in Table 4.4. Interestingly, the BCI* is also strongly correlated with the Environmental Awareness Index (EAI; Harju-Autti and Kokkinen 2014). Furthermore, correlations with public participation, measured by the involvement in voluntary work are high (EFILWC 2012). The BCI* and TPI correlate very well with all World Bank governance indicators (World Bank 2015), in particular with government effectiveness.

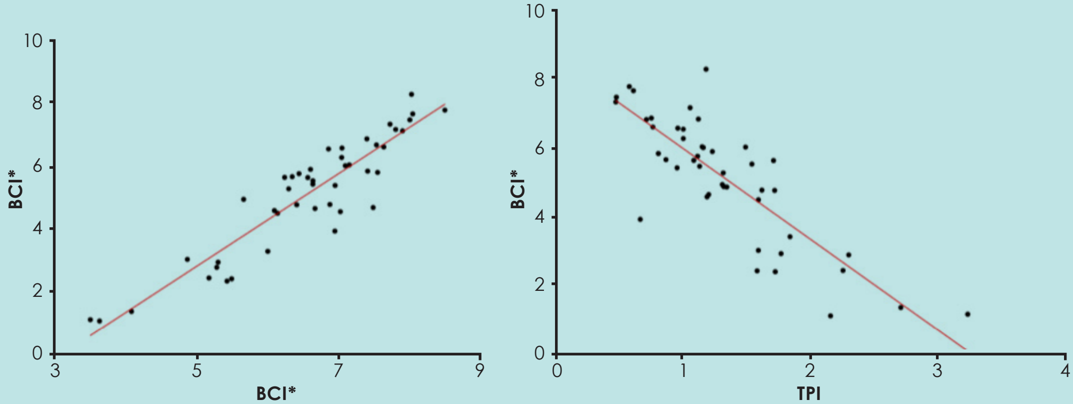

FIGURE 4.3 — The BCI of the current CBF and improved CBF are highly correlated (*left; r*=0.92). The BCI* shows a negative correlation with the TPI showing that cities experiencing high environmental, financial and/or social pressures also have low BCI* scores (*right; r*=-0.83)

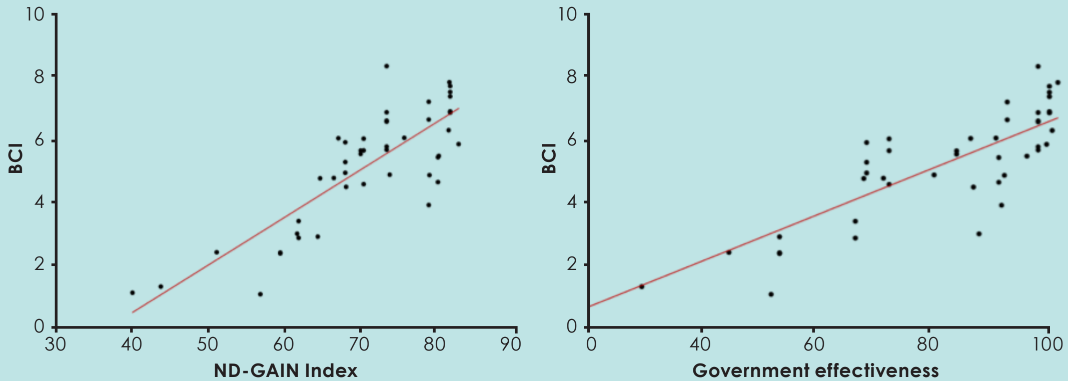

FIGURE 4.4 — The BCI* is highly correlated with the ND-GAIN climate readiness index and the Government effectiveness index (ND-GAIN 2013; World Bank 2015)

4.3.3 PERFORMANCE OF CITIES: MAIN RESULTS

It is impossible to address the detailed results of each and every City Blueprint and TPF of the 45 cities, but examples for cities have been provided by Koop and Van Leeuwen (2015a, 2015b). In this paper we summarize the main findings.

The lack of basic water services and the absence of environmental protection measures in cities in developing and transition countries, such as Dar es Salaam, Ho Chi Minh City, Belém and Istanbul are staggering. These cities have a secondary WWT coverage of less than 30 %. Overall, still 11 of the 45 cities have secondary WWT coverage of less than 50 %. These low coverage's pose serious threats to ecosystem and human health. For 19 of the 45 cities and regions, tertiary WWT is below 50 % coverage. This includes all eastern European cities, whereas most cities in western Europe have high coverage's.

Nutrient recovery from wastewater is important to decrease surface water pollution as well as to reduce our dependency on non-renewable resources. This holds especially for phosphorous and potassium as these resources will become increasingly expensive as they are difficult to obtain (Cordell and White 2011; EC 2014). About half of the cities do not apply any form of nutrient recovery. The reuse of nutrients can either be done directly by applying sewage sludge on agricultural land or indirectly by producing struvite ($MgNH^4PO^4.6H^2O$) from wastewater.

TABLE 4.4 — Correlations of the BCI* and TPI with various indices and city descriptors. All correlation coefficient are highly significant (maximum $p<10^{-5}$).

	BCI*	TPI	SOURCE
ND-GAIN climate readiness	0.86	- 0.94	ND-GAIN 2013
Green city index	0.86	- 0.85	Siemens 2015
Involvement in voluntary work	0.86	- 0.81	EFILWC 2012
Environmental awareness index	0.85	- 0.84	Harju-Autti and Kokkinen 2014
Government effectiveness	0.84	- 0.88	World Bank 2015
Regulatory quality	0.83	- 0.90	World Bank 2015
Rule of law	0.82	- 0.89	World Bank 2015
Voice & accountability	0.81	- 0.90	World Bank 2015
Control of corruption	0.80	- 0.89	World Bank 2015
GDP per capita	0.72	- 0.75	IMF 2013b
IWRM ambitions[A]	0.59	- 0.55	EC 2015a

[A] Because, IWRM ambitions is a CBF indicator, the shown correlation has been calculated with the BCI* calculated without this indicator (i.e. based on 24 instead of 25 indicators)

Struvite can be used as a fertilizer, e.g. in parks or sport fields as is done in Amsterdam (Van Leeuwen and Sjerps 2015a). The production of struvite is a good alternative if direct application of sewage sludge is legally restricted or banned as a result of health or economic concerns. Currently, many cities do not apply nutrient recovery because they are either not aware or a market to apply struvite is lacking.

Eleven cities do not apply any form of energy recovery techniques at the wastewater treatment plants while this can be considered as a CO2-neutral way of energy generation. Moreover, 30 cities used less than 50 % of their potential to apply energy recovery from their solid waste. German cities even burn 21 % of their total solid waste without energy recovery (OECD 2013). On average 47 % of the solid waste ends up in landfills where it produces large amounts of greenhouse gasses and may lead to water pollution, especially when the site management is insufficient (Rosik-Dulewska et al. 2007; Lazarevic et al. 2010).

The average infrastructure leakage rate for 45 cities and regions is considerable, i.e., 21 %. Seven cities had leakage rates that exceeded 40 %. Stormwater separation is applied in 49 % of the water infrastructures in the cities in this study. It is remarkable that Copenhagen and almost all Dutch cities have high BCIs* but low separation rates (less than 12 %). As a consequence, combined sewage overflows, urban drainage flooding, both exacerbated by climate change, may seriously affect water quality and biodiversity. This may lead to damages from extreme weather events that are projected to increase significantly (Jongman et al. 2014).

Green space coverage's (%) differed largely per city with 40 % or more for most Scandinavian cities and on the other hand less than 15 % for Athens, Bucharest and all developing cities. A low share of green area increases the vulnerability to urban drainage floods and heat waves (EEA 2012). Increasing green space in cities is important and may result in multiple co-benefits for health, the economy, society and the environment. Hence, this nature-based measure often represents a more efficient and cost-effective solution than more traditional approaches (EC 2015c). Furthermore, the future damage as a result of inaction is often more costly than the necessary investments (EEA 2012; Klein Tank and Lenderink 2009).

4.3.4 COMPARING CITIES

The focus of this paper has been on the performance of IWRM in European cities. Nevertheless, we have tried to include also other geographical regions. The selection of cities is therefore not random at all, but regionally biased towards western Europe. With these limitations in mind we have clustered cities into distinct categories of sustainability regarding their IWRM. The categorization is based on the BCI* scores and the CBF indicators for 45 cities in 27 different countries. The suggested categorization is supported by the results of a hierarchical clustering analysis (Fig. 4.5). Three broad categories can be identified (Fig. 4.5 with squared Euclidean distance > 12). One category includes most Scandinavian and Dutch cities which typically have high BCI* values varying from 6 to 8. Next, a category including a variety of cities with average BCI* values between 4 and 6. Finally, a third category is identified that includes cities in developing and transition countries and many cities from eastern Europe. The BCI* values range from 0 to 4. However, the developing cities (Dar es Salaam, Kilamba Kiaxi, Belém and Ho Chi Minh city) appear to be substantially different from the other cities in this category. These cities also have the lowest BCI* values with values in the range of 0 to 2. Moreover, these cities do not meet their basic water services such as access to drinking water and sanitation, whereas cities in the BCI* range of 2 to 4 have almost full coverage of basic water services (Fig. 4.6). As basic water services are essential for human life, cities which lack basic services are categorized separately. Based on Fig. 4.5 and the indicator scores of 45 cities, and in particular some key indicators as shown in Fig. 4.6, we propose a simple categorization of the different levels of sustainability for IWRM in cities (Table 4.5; Fig. 4.7).

4.4 DISCUSSION

4.4.1 IWRM PERFORMANCE OF CITIES

A performance-oriented set of indicators more accurately measures cities own activities and efforts to improve their IWRM. The BCI* shows a larger variation than the previous BCI, thereby better emphasizing the potential gain that is possible by sharing knowledge, experiences and best practices amongst cities (Fig. 4.2). The correlations between the BCI* and IWRM ambitions, public participation, government effectiveness and GDP for 11 cities (Van Leeuwen 2013) have been confirmed in this paper for 45 cities (Table 4.4). Moreover, strong correlations with ND-GAIN climate readiness (r=0.86), green city index (r=0.86), environmental aware- ness index (r=0.86), and various World Bank governance indicators have been found (ND- GAIN 2013; Siemens 2015; EFILWC 2012; Harju-Autti and Kokkinen 2014; World Bank 2015). This may emphasize the importance of IWRM ambitions, effective governance, community involvement and financial resources for sustainable urban IWRM.

CBF indicators scores differed largely, even between western European cities. Especially, differences in solid waste treatment appeared to be large. Only the best performing cities applied recycling and energy recovery for most of their solid waste while, unlike water consumption, solid waste production was still high. The application of energy and nutrient recovering techniques was also highly variable with a lot of potential for improvements in many cities.

Cities appeared to be particularly vulnerable for flooding, heat island effects and water scarcity. Urbanization and climate change will only amplify these trends (EEA 2012) and delaying climate adaptation often results in much more expensive adaptation measures and damage costs in the long term (EEA 2007). Hence, the cost of political inaction will increase while the danger to citizens and the economy rises. For example, riverine flood losses in Europe could more than double in frequency by 2050. However, it is estimated that by raising the flood protection standard to 1 per 100 years for all European river basins, an annual flood loss of around €7 billion is avoided whereas the associated cost to avoid this are estimated at €1.75 billion (Jongman et al. 2014). Also stormwater separation and increase in soil permeability (e.g. green space) could greatly reduce damage as a result of extreme precipitation, water pollution, water scarcity and heat waves (EEA 2012; Gill et al. 2007). Only 49 % of the water infrastructures in the cities and regions in this study separated stormwater and many cities have a green space coverage of less than 15 %. Hence, many cities urgently

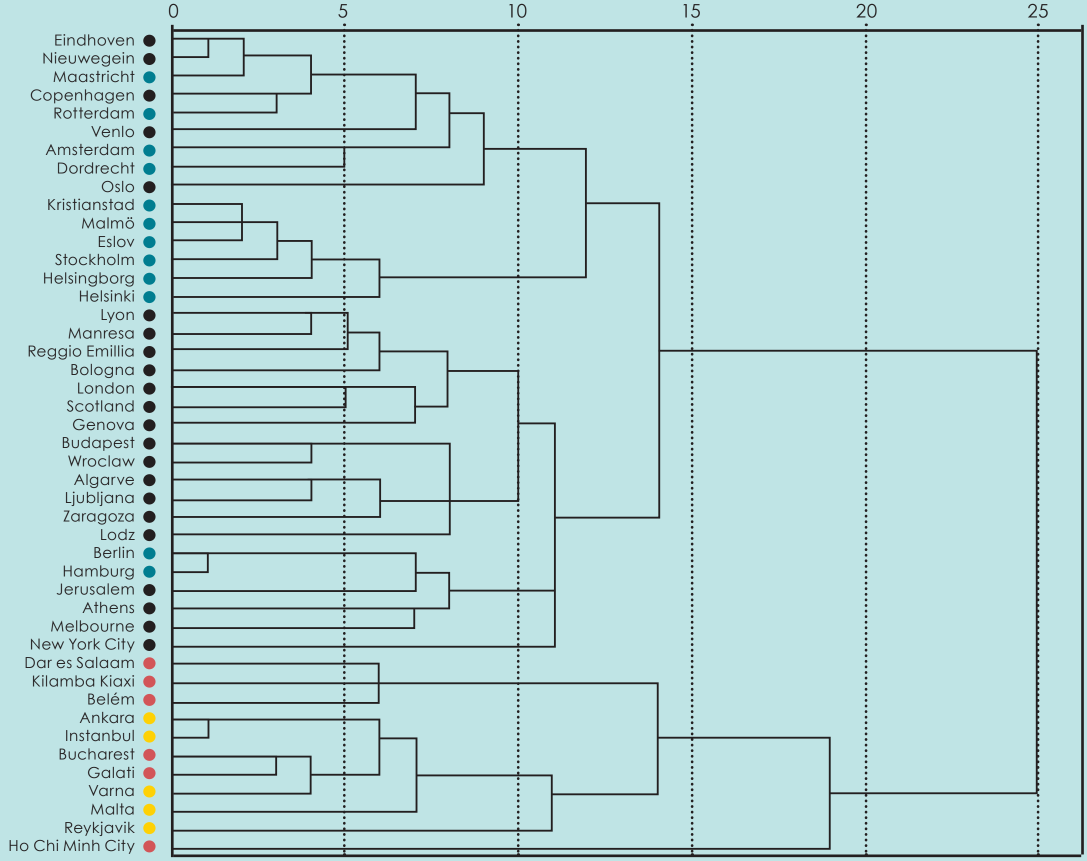

FIGURE 4.5 — Dendrogram of the City Blueprints using hierarchical clustering with the squared Euclidean distances for all 25 indicators. The cities marked red, orange, black or blue have a BCI* between 0–2, 2–4, 4–6 and 6–8, respectively. Three broad categories with squared Euclidean distance > 10, can be identified

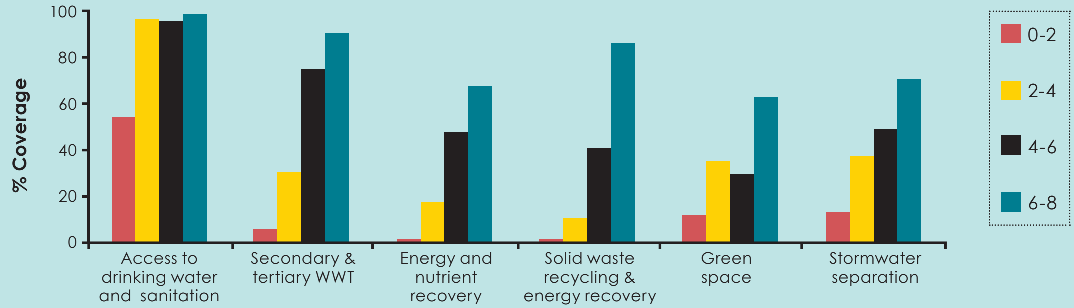

FIGURE 4.6 — Key indicators of the improved CBF. Bars represent the averages (%) of the data for the 45 cities and regions. The columns marked red, orange, black or blue are cities with a BCI* between 0–2, 2–4, 4–6 and 6–8, respectively

need to invest in adaptation measures to decrease their climate vulnerability (EEA 2012).

About 50 % of the required infrastructure investments up till 2025 are on water distribution and sewer systems (UNEP 2013) which is about 60 % more than is spent in the same period until now (McKinsey 2013). Water infrastructure investment requirements are already 0.35–1.2 % of the annual GDP in developed countries and much higher for developing countries (0.71–6.30 % of their annual GDP; Cashman and Ashley 2008). The infrastructure investment deficits in the assessed cities can be demonstrated clearly, for example by an average leakage rate of 21 % with 7 cities exceeding 40 %. Importantly, infrastructure investments are not only insufficient according to current standards but investments need to be increased significantly to make the necessary climate adaptations for an, in many cases, strongly rising urban population.

4.4.2 CATEGORIZATION OF CITIES

For the categorization of cities, BCI* scores have been rounded. Consequently, the lowest and highest category is less frequently represented. Furthermore, our selection of cities is regionally biased towards western Europe. Nevertheless, the results allow for a simple heuristic categorization of the different levels of sustainability for urban IWRM (Table 4.5; Fig. 4.7). IWRM categorization in literature is scarce and the categorization proposed in this paper is the first that relies on an indicator analysis of a substantial number of cities in different countries.

Based on detailed historical, temporary and future research, Brown et al. (2009) described six hydro-social contracts concerning urban water management transitions in Australia. Furthermore, Lundin and Morrison (2002) identified four levels of environmental sustainability for the urban water infrastructure based on two case studies. Finally, based on several urban water characteristics, Van der Steen (2011) distinguished three types of cities, e.g., water management driven by; (1) basic service issues, (2) water scarcity, and (3) by climate change effects.

The first proposed category '*Cities lacking basic water service*' resembles the '*Water supply city*' and '*Sewered City*' transition described by Brown et al. (2009), and coincides with the type 1 '*Water management driven by basic service issues*' (Van der Steen 2011) and level D described by Lundin and Morrison (2002). '*Wasteful cities*' typically do not meet minimum standards for environmental protection and are therefore not described by Lundin and Morrison (2002). '*Water efficient cities*' is

TABLE 4.5 — Proposed categorization of different levels of sustainable IWRM in cities

BCI SCORE	CATEGORIES OF IWRM IN CITIES
0 - 2	**Cities lacking basic water services** Access to potable drinking water of sufficient quality and access to sanitation facilities are insufficient. Typically, water pollution is high due to a lack of WWT. Solid waste production is relatively low but is only partially collected and, if collected, almost exclusively put in landfills. Water consumption is low but water system leakages are high due to serious infrastructure investment deficits. Basic water services cannot be expanded or improved due to rapid urbanization. Improvements are hindered due to governance capacity and funding gaps (Table 4.2).
2 - 4	**Wasteful cities** Basic water services are largely met but flood risk can be high and WWT is poorly covered. Often, only primary and a small portion of secondary WWT is applied, leading to large scale pollution. Water consumption and infrastructure leakages are high due to the lack of environmental awareness and infrastructure maintenance. Solid waste production is high and waste is almost completely dumped in landfills. Governance is reactive and community involvement is low.
4 - 6	**Water efficient cities** Cities implementing centralized, well-known, technological solutions to increase water efficiency and to control pollution. Secondary WWT coverage is high and the share of tertiary WWT is rising. Water efficient technologies are partially applied, infrastructure leakages are substantially reduced but water consumption is still high. Energy recovery from WWT is relatively high while nutrient recovery is limited. Both solid waste recycling and energy recovery are partially applied. These cities are often vulnerable to climate change, e.g. urban heat islands and drainage flooding, due to poor adaptation strategies, limited stormwater separation and low green surface ratios. Governance and community involvement has improved.
6 - 8	**Resource efficient and adaptive cities** WWT techniques to recover energy and nutrients are often applied. Solid waste recycling and energy recovery are largely covered whereas solid waste production has not yet been reduced. Water efficient techniques are widely applied and water consumption has been reduced. Climate adaptation in urban planning is applied e.g. incorporation of green infrastructures and stormwater separation. Integrative, centralized and decentralized as well as long-term planning, community involvement, and sustainability initiatives are established to cope with limited resources and climate change.
8 - 10	**Water wise cities** There is no BCI* score that is within this category so far. These cities apply full resource and energy recovery in their WWT and solid waste treatment, fully integrate water into urban planning, have multi-functional and adaptive infrastructures, and local communities promote sustainable integrated decision making and behaviour. Cities are largely water self-sufficient, attractive, innovative and circular by applying multiple (de)centralized solutions.

a combination of level B and C described by Lundin and Morrison (2002). This category shows a high similarity with the '*Waterways City*' because environmental protection and awareness are increasing while centralized water system approaches are still largely dominant (Brown et al. 2009). '*Resource efficient and adaptive cities*' emphasize the integrative nature of the urban watercycle that deals with climate change and resource scarcity. This category is comparable with '*Water cycle cities*' described by Brown et al. (2009) and level A described by Lundin and Morrison (2002). Unfortunately, it appeared to be difficult to find data to include the advancements in fit-for- purpose water supply systems whereas this is an important component of IWRM and characteristic for this category (Brown et al. 2009). None of the 45 cities had a BCI* categorized as '*Water wise cities*' and it is unlikely that such a city will be found easily because the geometric aggregation method penalizes unbalanced indicator scores. This is in accordance with literature where a water wise or sensitive city is often assumed to be currently non-existing (Ferguson et al. 2013). However, new city quarters or future cities may realize water wise management.

There is not an accepted set of attributes and indicators that define water wise or water sensitive cities (Ferguson et al. 2013) and it is unlikely that this will be developed soon, since water wise solutions are divergent, redundant and applied on different scales. Hence, the City Blueprint is not an attempt to do this. Instead, the City Blueprint is a quick scan of the current IWRM state of cities that enables a basic comparison between cities. Consequently, high scoring cities are on the frontline of the urban transition towards water wise cities. However, this does not imply that these cities are water and climate robust. For example, extreme weather events such as in Copenhagen (EEA 2012) may still seriously affect high scoring cities that apply effective water management. Furthermore, the CBF and TPF may serve as a start for more in-depth studies in their urban strategic planning and implementation process towards water wise cities.

4.4.3 THE URGENCY TO IMPROVE DEVELOPING AND TRANSITIONING CITIES

The TPF provides a basic overview of the differences in social, environmental and financial situation of the 45 cities assessed (Fig. 4.1). The BCI* and TPI are negatively correlated ($r = -0.83$) implying that cities that experience many pressures also have low BCIs. Hence, the need to transform IWRM is urgent and extremely challenging. Currently, Belém, Dar es Salaam, Ho Chi Minh City, Istanbul and Kilamba Kiaxi experience many pressures that may seriously hamper even the first steps towards water wise cities. This is also pointed out by the highly negative correlation between TPI and the ND-GAIN climate readiness index (*r*=-0.94). Hence, cities in countries that have low ability to absorb financial resources and mobilize them efficiently to adapt to climate change (ND-GAIN 2013) are often cities that also experience social, environmental and financial pressures according to the TPF. Accordingly, these cities typically score low on e.g. environmental awareness (*r*=-0.84), public participation (*r*=-0.81), green city index (*r*=-0.85), government effectiveness (*r*=-0.88), as well as other World Bank governance indicators such as regulatory quality (*r*=-0.90), voice and accountability (*r*=-0.90) and control of corruption (*r*=-0.89) (World Bank 2015; Harju-Autti and Kokkinen 2014; EFILWC 2012). Fast urbanization and climate change may further worsen access to basic urban services and affect quality of life in cities. The urban poor— the slum dwellers in developing countries will be most affected (UN-Habitat 2010b).

Although the City Blueprint dataset is regionally biased with only a few cities in developing and transition countries (Fig. 4.7), the high similarity between the BCI* and the green city index scores available for many developing and transition cities

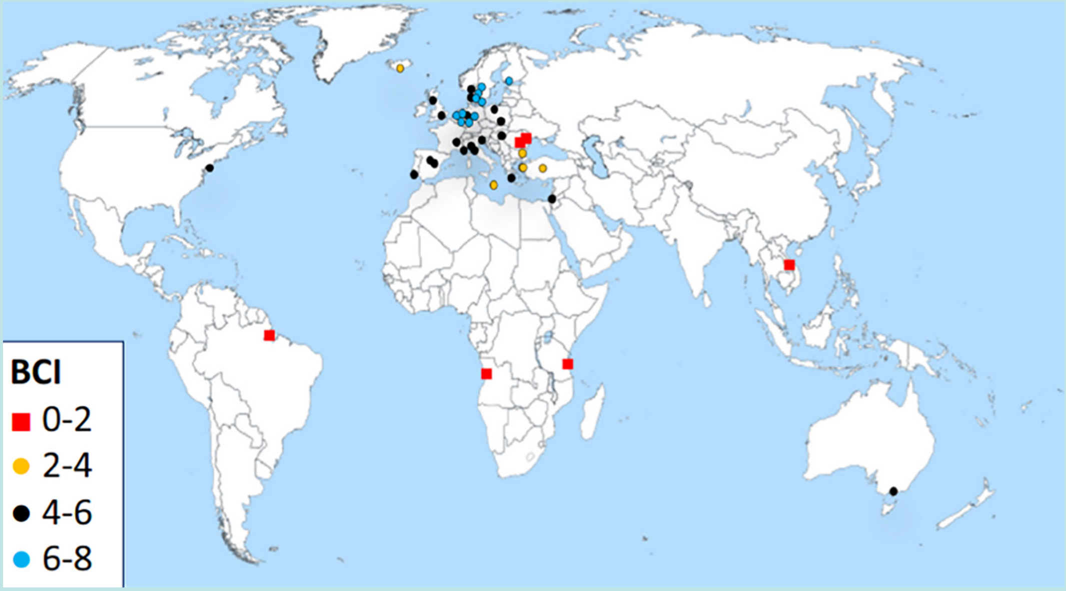

FIGURE 4.7 — Municipalities and regions that have been analysed. Red, orange, black and blue represent municipalities and regions with an improved BCI between 0–2, 2–4, 4–6 and 6–8, respectivelycities

(Siemens 2015), allows for broader extrapolation of our findings (Table 4.4). In general, the environmental, financial and social pressures in developing and transitioning cities may seriously limit their ability to improve their IWRM, whereas the priorities to do so are both high and urgent. Our results support the findings of the OECD (2011) that bridging of the multi-level governance gaps as shown in Table 4.1, may greatly enhance global IWRM and strongly decrease pressures on ecosystems, on which cities strongly depend. It also supports the view put forward by UN Secretary-General Ban Ki-moon on World Water Day 2015: 'The onset of climate change, growing demand on finite water resources from agriculture, industry and cities, and increasing pollution in many areas are hastening a water crisis that can only be addressed by cross-sectorial, holistic planning and policies—internationally, regionally and globally.

4.4.4 NEXT STEPS

Cities may play a leading role to meet the global water challenges. Cities need to be aware that inaction is often more costly than the development of a long-term coherent strategy and implementation plan to improve their sustainability. Climate change mitigation and adaptation, water and waste are important aspects of such a coherent long-term plan. Coupling of these water-related challenges in cities can also create many win-win's or co-benefits which can bridge the funding gap (Table 4.1). This is what is needed in smarter cities (EC 2015a). Local authorities need simple and practical tools to improve their IWRM (EEA 2007; EEA 2014d; Gleik 2003). Cities can benefit from the experiences of other cities. Therefore, city-to-city learning (city learning alliances) and urban-rural co-operation are needed (EC 2015a; OECD 2015a). Learning alliances can be used to improve awareness, communication, community involvement, governance (Table 4.1), and accelerate the transition towards water wise cities. Our baseline assessment is therefore important in order to create awareness and can serve as a first step for decisions makers to envision, implement and evaluate sustainable IWRM strategies. Our next steps in the City Blueprint action group will be the development of a compendium of best practices in cities and, if possible, the development of simple models that can help cities to calculate the costs and benefits of implementation measures to improve their IWRM. We would like to extend our assessments beyond Europe as the challenges for adaptive urban IWRM in other continents such as Africa and Asia are very pressing (Van Leeuwen 2013).

4.5 CONCLUSION

The urgency for sustainable urban IWRM is increasingly high due to global infrastructure deficits, lack of climate change adaptation and vast urbanization. In fact, the longer investments are postponed, the more expensive it will become while the danger for citizens and the economy only increases. The proposed improved CBF is more performance-oriented and therefore more accurately measures the cities' own efforts to improve their IWRM, thereby better emphasizing the potential gain that is possible by city-to-city learning. By showing key social, financial and environmental pressures, the TPF provides an overview of the most important opportunities and limitations for IWRM and may assist in prioritizing city-specific water issues. The BCI* showed highly positive and the TPI showed highly negative correlations with, e.g. the World Bank governance indicators, the ND-GAIN climate readiness index, the environmental awareness index, green city index and public participation (Table 4.4). This may imply that effective governance, environmental awareness and community involvement are important for sustainable urban IWRM. The BCI* and the TPI correlated negatively ($r=-0.83$) implying that cities that experience many social, environmental and/or financial pressures are associated with a low IWRM performance. These cities urgently need to improve their IWRM but face many challenges such as fast urbanization, climate change and institutional and financial barriers (Table 4.1). Based on the overall BCI* and key indicators, a simple categorization is proposed (Table 4.5). This categorization scheme may provide a heuristic tool aimed at informing decision makers and accelerating transitions towards water wise cities.

ACKNOW-LEDGMENTS

We would like to thank all city representatives for their participation in this study. In particular we would like to thank Misagh Mottaghi (Lund University in Sweden), for her work to contact and assess cities in Sweden. We would also like to thank Ciprian Nanu (EIP Water Secretariat) for his efforts to contact cities in Central and Eastern Europe. We would also like to thank Zsóka Ardai (Budapest, Hungary) for her involvement in the assessments of both Budapest and Wroclaw, and Professor Zalewski (European Regional Centre for Ecohydrology in Lodz for the assessment of Lodz. This report is a summary of activities that has been carried out over a period of more than 4 years. The City Blueprint activities started in 2011 as institutional research of KWR Watercycle Research Institute in the context of Watershare®: sharing knowledge in the water sector (http://www.watershare.eu/). The methodology has been applied in the context of the EU Research Project TRUST (Transitions to the Urban Water Services of Tomorrow) and further received funding from the Netherlands TKI Water Technology Program (Project T550004). The City Blueprint Action Group is part of the governance activity of the European Innovation Partnership on Water of the European Commission (http:// www.eip-water.eu/City_Blueprints), coordinated by both Dr. Richard Elelman of Fundació CTM Centre Tecnològic and NETWERC H2O (Manresa, Spain) and Prof. Dr. Kees Van Leeuwen of KWR Watercycle Research Institute. The European Commission is acknowledged for funding TRUST in the 7th Framework Programme under Grant Agreement No. 265122 and for BlueSCities in H2020-Water under Grant Agreement No. 642354.

GOVERNANCE CAPACITY OF CITIES & THEIR CHALLENGES

Chapter 5
Assessing the governance capacity of cities to address challenges of water, waste, and climate change

Chapter 6
Assessing the capacity to govern flood risk in cities and the role of contextual factors

Chapter 7
Relating water management performance to governance capacity: what are the capacity-development needs?

CHAPTER 5

ASSESSING THE GOVERNANCE CAPACITY OF CITIES TO ADDRESS CHALLENGES OF WATER, WASTE, AND CLIMATE CHANGE

This chapter is published as: 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

ABSTRACT

This chapter addresses research 3: What are the characteristics of a comprehensive framework for assessing water governance capacities in cities around the world?

The challenges of water, waste, and climate change in cities are overwhelming and underpin the importance of overcoming governance issues impeding adaptation. These “governance challenges” typically have fragmented ¬scopes, viewpoints, and responsibilities. As there are many causes leading to this uncertainty and disagreement, there is no single best approach to solve these governance challenges. In fact, what is necessary is iterative and requires governance capacity to find dynamic long-term solutions that are supported by flexible interim targets, so as to anticipate emerging barriers and changing situations. The literature contains a plethora of governance gaps, barriers, and capacities, which sometimes overlap, are contradictory and case-specific, and reflect disciplinary scopes. We argue that a balanced set of well-developed conditions is needed, to obtain the governance capacity that enables effective change. Therefore, we aim to obtain deeper understanding of the key conditions determining the urban water governance capacity, by developing an integrated empirical-based approach that enables consistent city comparisons and facilitates decision-making. We propose a governance capacity framework focusing on five governance challenges: 1) water scarcity, 2) flood risk, 3) wastewater treatment, 4) solid waste treatment and 5) urban heat islands. Nine governance conditions, each with three indicators, are identified and empirically assessed using a Likert-type scoring method. The framework is illustrated by a case study on Amsterdam, the Netherlands. We conclude our approach shows great potential to improve our understanding of the key conditions determining the governance capacity to find solutions to the urban challenges of water, waste, and climate change.

5.1 INTRODUCTION

Governance challenges

Cities across the globe face huge challenges of water, waste and climate change in a rapidly urbanizing world (World Economic Forum 2016; Koop and Van Leeuwen 2016). By 2030, the world will be experiencing an estimated 40% freshwater shortage (WRG 2009). Sea-level rise, soil subsidence, and extreme river discharges pose risks to around 15% of the global population, mostly in urban areas, including almost all the world's mega-cities (Ligtvoet et al. 2014). Cities are particularly vulnerable to flooding by storm events, which are increasing in magnitude and frequency (EEA 2012). Furthermore, streams, rivers, and oceans are heavily polluted by insufficiently treated wastewater and solid waste (Derraik 2002; Ligtvoet et al. 2014), which is leading to losses of valuable resources such as phosphate (EC 2015b). Finally, global warming is exacerbating heatwaves that pose serious health risks to people living in Urban Heat Islands (UHI): for example, it is estimated that in 2003 heatwaves were responsible for 70,000 deaths in Europe (Baccini et al. 2008). In order to combat UHI, vegetation and water bodies need to be intertwined in the urban infrastructure.

Altogether, urban areas face five main interrelated water challenges: 1) water scarcity, 2) flood risk, 3) wastewater treatment, 4) solid waste treatment, and 5) urban heat islands (EEA 2012, 2016; UCCRN 2011). Meeting these challenges requires good governance, because it entails managing long-term, complex, uncertain, and imperfectly known risks that can have large impacts. Typically, multiple governance layers (OECD 2011a) and a variety of stakeholders, sectors, and policies are involved, each with different time horizons and agendas (Segrave et al. 2013). Because there are many causes that can lead to the complexity, uncertainty, and disagreement, there is no single best approach to address these governance challenges. In fact, what is necessary is an iterative process that requires governance capacity to find integrated long-term solutions that are supported by flexible intermittent targets to anticipate changing situations and adapt to emerging barriers. Hence, it is essential to manage governance challenges in an integrative long-term approach (Patterson et al. 2013).

Knowledge gap

The need for integrated approaches is reflected in two main concepts: 1) Integrated Water Resources Management (IWRM), and 2) Adaptive Management (AM). IWRM aims to reshape institutional structures and redefine problems, to broaden scope. AM focuses on changing the way responsible authorities perceive and act, by emphasizing experimentation and the value of learning to adapt to changing and uncertain challenges such as climate change (Medema et al. 2008). Despite their important contributions, both approaches appear to be difficult to implement, as they are not very concrete and their explanations differ as they refer to largely undefined, complex and unpredictable processes. Moreover, they tend to be focused on more technical solutions with lesser attention to governance processes (Medema et al. 2008; Rahaman and Varis 2005; Gregory et al. 2006). Therefore, these approaches sometimes fail to provide clear and effective guidelines for their concrete application (Gregory et al. 2006).

With respect to water management, the City Blueprint Trends and Pressure Framework and the City Blueprint Performance Framework provide integrated and strategic insights into the management performance of local authorities (Koop and Van Leeuwen 2015a, b). Furthermore, the OECD (2015a) principles of good water governance provide for an integrated network analysis of the fragmented water sector. They include analyses of international, national, and sub-national indicators and learning practices but do not focus on urban water governance.

A few worthy attempts have been made to compare organizations and institutions (Gupta et al. 2010; Ballard 2008; Engle and Lemos 2010). However, the rich literature on governance and transformation processes has a theoretical nature and only a few approach have been reported as providing tangible results to facilitate decision-making (Kersberger and Waarden 2004). At the same time, there is a seemingly endless list of social factors and conditions that impede or enhance our ability to respond proactively to future changes (Biesbroek et al. 2013). They often reflect a disciplinary scope and focus on specific case studies, which limit their usefulness and learning value (Measham et al. 2011; Plummer et al. 2012). Hence how socioeconomic factors actually influence urban governance processes largely remains an open question (Biesbroek et al. 2013) that can only be explored by applying a coherent framework that assesses different contexts consistently, provides empirical-based understanding of underlying governance processes, and searches for transferable lessons that enhance overall governance effectiveness.

Research aim

In many cases, organizations or institutions are taken as the point of departure for governance assessment, whereas in practice, organizations often tend to focus on sub-tasks, lacking a full notion of their interdependencies, and underestimating the need for cooperation in addressing shared goals (Emerson et al. 2012). We argue that this is a missed opportunity, because interaction and collaboration between all relevant actors is critical. On the contrary, overly comprehensive, multi-layer governance structures that address multiple issues across different jurisdictions, proof to be difficult to analyse (Medema et al. 2008). Interestingly, the urban scale is increasingly recognized as having a crucial role in finding the most suitable solutions to address context-specific climate vulnerabilities (Measham et al. 2011; OECD 2015a). So far, little effort has been made to consistently assess the urban water governance capacity. However, such an assessment creates great potential to understand specific (local) issues and underlying processes, can provide recommendations for stakeholders, and shape learning alliances in and between cities. Here we aim to provide a deeper, integrated, and empirically-based understanding of the most important enabling conditions that determine the governance capacity needed to continuously solve governance challenges of water, waste, and climate change in urban networks. To do so, we develop a cohesive, comprehensive, and applicable Governance Capacity Framework (GCF) for cities, which can:

1. compare cities in order to develop a deeper empirical-based understanding of the key enabling governance conditions and identify transferable lessons.

reveal the limiting conditions and thereby formulate pathways for effective and efficient increase in the local governance capacity. The paper is structured as follows. Section 2 provides a literature-based overview that frames and defines governance capacity. This definition is operationalized into a comprehensive framework in section 3. In section 4 a Likert-type method to score governance capacity is described. Section 5 provides an illustration of the first GCF pilot study in the city of Amsterdam, the Netherlands. Finally, section 6 presents the major discussion points and conclusions about the framework.

5.2 FRAMING GOVERNANCE CAPACITY

Governance capacity has a rich literature in the fields of environmental governance, climate adaptation, capacity building, public administration, and water governance. An important component of governance capacity is institutional capacity: this generally focuses on how institutional setting, rules, and regulations enable actors to collaborate and address shared problems (UNDP 2008; Dang et al. 2016). Governance capacity is broader, also including resources and the role of discourses (Engle and Lemos 2010; Pahl-Wostl 2009). As it is widely recognized that governance capacity is context-dependent, definitions diverge considerably. Some emphasize integration (Emerson et al. 2012), others cooperation (Dang et al. 2016), yet others focus on flexibility (Termeer et al. 2015). We take the position that governance capacity is about enabling effective change.

The kind of change that is effective is context-dependent. For example, integration is needed whenever scopes are fragmented, whereas adaptive approaches are needed to address inflexibility, and anticipatory governance is required when responses are reactive (Segrave et al. 2016). Nevertheless, a few communalities regarding governance capacity can be identified. First, this capacity is about the ability of actors to continuously identify and jointly act on collective problems (Dang et al. 2016). Second, the capacity is determined by actors' interactions formed by social-institutional settings and allocation of resources (Pahl-Wostl 2009). Third, actors' frame of reference, including their interests, values, and culture, shape interactions and influence collective problem-solving (Adger et al. 2009). Therefore, no single governance condition is decisive. On the contrary, governance capacity is determined by a balanced set of conditions that need to be well developed. Importantly, the nature of actors' interactions is complex, unpredictable, and susceptible to external social-ecological developments. Hence, governance capacity per see does not lead to efficacious change, but rather is a precondition or enabler for effective change. Accordingly, we define water governance capacity as *"the key set of governance conditions that should be developed to enable change that will be effective in finding dynamic solutions for governance challenges of water, waste, and climate change in cities".*

5.3 CONSTRUCTING THE GOVERNANCE CAPACITY FRAMEWORK

Policy actions often appear to be ineffective and a wide range of governance gaps or barriers have been suggested as reasons for this (e.g. Biesbroek et al. 2013; Eisenack et al. 2014). The literature has identified normative principles (e.g. OECD 2015b) and enabling or adaptive capacities to overcome barriers (e.g. UNDP 2008; Ford and King 2015). We make use of this rich knowledge base by selecting and redefining key conditions and their indicators that enable effective change, exploring their interrelations, assessing their relevance for urban water governance, and reformulating them into a well-balanced framework. We have also studied existing frameworks that analyze social processes that have inhibited or stimulated effective change in the field of urban water governance (Brown and Farralley 2009), river basins (Engle and Lemos 2010), water systems (Van Rijswick et al. 2014), or have a multi-level perspective (OECD 2011a, 2015a; Pahl-Wostl et al. 2010). Other frameworks that have been applied in the past have concerned the adaptive capacity of institutions (Gupta et al. 2010) and organizations (Ballard 2008), or have been scale-independent (e.g. Moser and Ekstrom 2010; Ford and King 2013).

We identified key conditions for good urban water governance and classified them into three dimensions: knowing, wanting, and enabling. The "knowing" dimension refers to the need to be fully aware, understand, and learn the actual or possible risks and impacts of actions, policy, and strategic choices. We created the "wanting" dimension because actors need to commit to cooperate, express, and act upon ambitions, and apply their skills and capabilities to find solutions. Finally, the "enabling" dimension was created because actors need to have the network, resources, and instruments to enable them to implement their ambitions. The resulting framework has nine governance conditions; an in-depth literature study for each condition yielded three indicators. The results are shown in Table 5.1, below the findings from the literature research are described.

Condition 1: Awareness

Awareness is a prerequisite to enable effective change. It refers to a more profound understanding of the causes, impact, and risks of governance challenges (Raaijmakers et al. 2008). Awareness is both cognitively and emotionally felt by individuals, organizations, and society (Ballard 2008) and forms the base for learning and action (Adger et al. 2009). *Awareness* is assessed by the indicators 1.1 *community knowledge,* 1.2 *local sense of urgency* and 1.3 *behavioral internalization*. *Community knowledge* refers to the extent to which different stakeholders possess relevant knowledge about the challenges. This is the first step in achieving conscious

TABLE 5.1 — The water Governance Capacity Framework (GCF). The GCF consists of nine conditions, each defined by three indicators. For each indicator, a Likert-type scoring scale has been developed, which ranges from very encouraging (++) to very limiting (--) to the governance capacity.

DIMENSIONS	CONDITIONS	INDICATORS
Knowing	1 Awareness	1.1 Community knowledge
		1.2 Local sense of urgency
		1.3 Behavioral internalization
	2 Useful knowledge	2.1 Information availability
		2.2 Information transparency
		2.3 Knowledge cohesion
	3 Continuous learning	3.1 Smart monitoring
		3.2 Evaluation
		3.3 Cross-stakeholder learning
Wanting	4 Stakeholder engagement process	4.1 Stakeholder inclusiveness
		4.2 Protection of core values
		4.3 Progress and variety of options
	5 Management ambition	5.1 Ambitious and realistic management
		5.2 Discourse embedding
		5.3 Management cohesion
	6 Agents of change	6.1 Entrepreneurial agents
		6.2 Collaborative agents
		6.3 Visionary agents
Enabling	7 Multi-level network potential	7.1 Room to manoeuvre
		7.2 Clear division of responsibilities
		7.3 Authority
	8 Financial viability	8.1 Affordability
		8.2 Consumer willingness to pay
		8.3 Financial continuation
	9 Implementing capacity	9.1 Policy instruments
		9.2 Statutory compliance
		9.3 Preparedness

behavior (Gifford 2011). *Local sense of urgency* reflects the perception of importance of the governance challenge, which may or may not result in actions and policies (O'Connor et al. 1999). Finally, *behavioral internalization* indicates that a higher level of knowledge affects actors' problem- framing, goals, values, and perceptions, changing their behavior and increasing their commitment to sustainable approaches (Gifford 2011).

Condition 2: Useful knowledge
The field of information science distinguishes between data, information and knowledge (Zins 2007). Data in itself is not necessarily informative, as useful knowledge can only be obtained by data interpretation and analysis (Zins 2007; Rowley 2007; Van Leeuwen 2007). *Useful knowledge* consists of 2.1 *information availability*, 2.2 *information transparency*, and 2.3 *knowledge cohesion*. *Information availability* refers to the extent that reliable knowledge is available. A lack of knowledge inhibits informed decision-making (Rowley 2007; Van Rijswick et al. 2014). Many cities authorities recognize the lack of knowledge of how future trends, such as urbanization and climate change, will affect them (Amundsen et al. 2010). *Information transparency* refers to the effective communication and sharing or co-creation of knowledge with all interested stakeholders. The information needs to be good quality, credible, understandable, and accessible for non-experts, in order to prevent miscommunication, knowledge gaps, and fragmented policy (Lemos et al. 2012; Füssel 2007b). Finally, *knowledge cohesion* refers to the conformity of knowledge across actors, sectors, and administrative layers.

Condition 3: Continuous learning
Continuous learning is required, in order to adapt to changing situations with many uncertainties, complexities, and unknowns (Folke et al. 2005). Continuous learning is assessed by 3.1 smart monitoring, 3.2 evaluation and 3.3 cross-stakeholder learning. Smart monitoring is a precondition for learning and may serve as tool for identifying alarming situations, clarifying underlying processes, and predicting future developments (Van Leeuwen 2007). Regular monitoring and evaluation are imperative for continuous learning and enhance preparedness for uncertain futures. In order to conceptualize evaluation, the theory of triple-loop learning is used, which has three levels: 1) single-loop learning which is incremental learning to refine current management and policy; 2) double-loop learning refers to the critical investigation of assumptions and key relationships, which reframes problems; 3) triple-loop learning questions underlying norms and values and can transform the wider social and institutional structure (Pahl-Wostl 2009). Finally, the third indicator,

cross-stakeholder learning is crucial for learning in a public policy context, as the interaction among actors and their understanding of different perspectives lead to a more comprehensive, if not consensual, evaluation (Emerson et al. 2012). Furthermore, this can prevent overly limited scopes or path-dependencies (Termeer et al. 2015; Brown and Farrelly 2009).

Condition 4: Stakeholder engagement process
The importance of stakeholder engagement is widely recognized from a normative, substantive, and instrumental rationale (Glucker et al. 2013; OECD 2015b; UNDP 2008). Stakeholder engagement may lead to more complete problem-framing and widely accepted optimized solutions for all parties involved (Pahl-Wostl 2009; Carlsson and Berkes 2005). Active stakeholder engagement is generally more time-consuming than unilateral decision-making. However, this can be more than compensated for by time gains in the implementation phase (Ridder et al. 2005). The *stakeholder engagement process* consists of 4.1 *stakeholder inclusiveness*, 4.2 *protection of core values* and 4.3 *progress and variety of options*. *Stakeholder inclusiveness* refers to the extent to which the representatives are able to speak and decide on behalf of all relevant stakeholders in clear and transparent engagement processes (Ford and King 2015; Ridder et al. 2005). *Protection of core values* refers to the importance of ensuring that all stakeholders feel confident that their core values are not harmed, in order to create a safe environment for trust relationships (Ridder et al. 2005; Pahl-Wostl et al. 2011). Therefore, it is essential that stakeholders become actively involved and commit to the process, rather than the outcome is predetermined or intermediate decisions are made early on (Folke et al. 2005). Moreover, stakeholders' contribution should influence the end-result. *Progress and variety of options* encompasses the prospect of gain for each stakeholder, which is ensured by clear and realistic procedures. Stakeholders should co-produce and, at the end of the process, select from a variety of options, to ensure learning and authoritative decisions (Ridder et al. 2005).

Condition 5: Management ambition
Management ambition is a measure of the extent to which sustainable management and policy is interwoven with historical, cultural, normative, and political context. This is measured by assessing the sustainability ambitions within policies. Management ambition is assessed by 5.1 ambitious and realistic management, 5.2 discourse embedding, and 5.3 management cohesion. Ambitious and realistic goals need to be long-term, with intermittent measurable targets, all provided with sufficient resources and flexible mechanisms to deal

with changing situations (Brown and Farrelly 2009). Discourse embedding is important, as management ambitions need to match the dominant values, discourses, and principles, in order to be successful (Van Rijswick et al. 2014). Hence, the degree to which the challenges of water, waste, and climate change are embedded in the dominant discourse, strongly determines the effectiveness of ambitious management and policy. Management cohesion assesses the level of integration between different sectorial policies and strategies, across governance levels, and between organizations. Often, the over-fragmentation of roles and responsibilities means that no single agency is in charge of water policy, and opportunities to create co-benefits are not seized (OECD 2011a,1015a; Head and Alford 2013)..

Condition 6: Agents of change

The concept of agents of change is often described in the fields of organizational change, AM, and innovation studies, although different terminology is used (e.g. leaders, policy entrepreneurs, institutional entrepreneurs; Pahl-Wostl et al. 2011; Ballard 2008; Brouwer and Biermann 2011). "Agents of change" refers to the intrinsic motivation of people, their willingness to take risks, and the support given to these efforts to change current approaches. The concept is therefore not limited to people in leading positions (Brouwer and Biermann 2011; Head and Alford 2013; Schultz and Fazey 2009). For this condition, three types of agents of change are distinguished: 6.1 entrepreneurial agents, who have the means and skills to gain access to resources, seek opportunities, and manage risks; 6.2 collaborative agents, who have the skills to build bridges and coalitions between actors; and 6.3 visionary agents, who envision long-term adaptive approaches and are able to steer current policy and actions (Brouwer and Huitema 2017; Termeer et al. 2012; Gupta et al. 2010; Ford and King 2015).

Condition 7: Multi-level network potential

Flexible and dynamic networks are important, in order to deal with governance challenges with different interests and perspectives, and with stakeholders acting at different levels (Pahl-Wostl 2009; Gupta et al. 2010; Moser and Ekstrom 2010). *Multi-level network potential* consists of 7.1 *room to manoeuvre*, 7.2 *clear division of responsibilities*, and 7.3 *authority*. *Room to manoeuvre* assesses the opportunity that actors have to explore different alternative pathways, develop knowledge, and put ideas into practice. This also involves the possibility and autonomy of actors to form new fit-for-purpose partnerships that can address unconventional and emerging challenges (Gupta et al. 2010; Folke et al. 2005). *Clear division of responsibilities* refers to the accurate and clear division of tasks and roles for which stakeholders can be held accountable (Mees et al. 2014a). *Authority* refers to the presence of legitimate forms of authority (e.g. embedded in policy or law), regulations, and policy networks that promote the necessity to address water-related challenges (Van Rijswick et al. 2014).

Condition 8: Financial viability

Addressing urban water-related challenges requires the assurance of long-term financial support (OECD 2015a; UNECE 2009), as short budgetary cycles prevent long-term thinking (Ford and King 2015) and will most likely substantially increase overall cost (UNEP 2013; Koop and Van Leeuwen 2017). Two important aspects of financial viability are the costs and benefits of measures: e.g., who is affected, who benefits, and, therefore, who should pay (UNECE 2009). *Financial viability* is characterized by 8.1 *affordability*, 8.2 *consumer willingness to pay*, and 8.3 *financial continuation*. *Affordability* of water and climate adaptation services is assessed with a focus on the poor and marginalized groups (OECD 2011a; UNDP 2008). *Consumer willingness to pay* assesses how expenditure and risks are perceived. Often, trust in local authorities and their accountability, as well as the sense of urgency or worry, are key (Raaijmakers et al. 2008). Finally, *financial continuation* is needed for solving long-term challenges and avoiding resources being squandered as a result of uncoordinated investments (Adger et al. 2005).

Condition 9: Implementing capacity

Most studies mention policy implementation as crucial (Adger et al. 2005; Ekstrom et al. 2011; Van Rijswick et al. 2014). *Implementing capacity* is substantiated through 9.1 *policy instruments*, 9.2 *statutory compliance* and 9.3 *preparedness*. *Policy instruments* can be used to stimulate desired behavior and discourage undesired activities (Mees et al. 2014a). Examples are the inclusion of the user-pays and polluter-pays principles in pricing. Continuous monitoring, evaluation, and adjustments are needed, to check and improve the effectiveness of instruments. *Statutory compliance* ensures that stakeholders respect and understand agreements, objectives, and legislation, which contributes to the accountability of authorities. *Preparedness* increases the implementation capacity, as the existence of action plans, procedures, and scripts supports policy and prepares the city for both gradual and sudden changes, events, and calamities (Gupta et al. 2010; Raaijmakers et al. 2008; Runhaar et al. 2016).

5.4 DETERMINING LEVELS OF GOVERNANCE CAPACITY

Despite the rich literature on governance capacity which provides many clues, it remains a puzzle to identify gradual levels of increasing governance capacity and only a few studies explicitly described them (e.g. Gupta et al. 2010; Ballard 2008). Hence, a better understanding of these gradual levels of governance capacity is needed to provide valuable insights into key governance processes. It should also be noted that a scaling system provides cities with a better and more nuanced indication of where they are, and what steps to take to improve their capacity. For each of the twenty-seven indicators we therefore developed a Likert-type scoring system, with scores ranging from very encouraging to the overall governance capacity (++) to very limiting to the overall governance capacity (--). The indicator levels were determined from a wide-ranging perusal of the literature, including AM theory (e.g. Folke et al. 2005; Engle and Lemos 2010; Gupta et al. 2010) in combination with specific theory for each condition. In addition, we included practical indicators from governance assessments and policy documents (BAGroep 2016; KING 2016). Table 5.2 illustrates the scoring methodology. Each of the twenty-seven indicators is scored by answering a predefined question, which are illustrated for the indicators belonging to condition 4 *stakeholder engagement process*. Next, the Likert-type scoring scale for indicator 4.2 *protection of core values* is provided. The Likert-type scoring levels, together with predefined questions, and the five main literature sources are available for each indicator at the EIP Water website (EIP Water 2017). The Likert-type scoring scale for indicator 4.2 *protection of core values* is based on three main aspects which together ensure that stakeholders feel confident that their core values are not harmed (Ridder et al. 2005):

1. Stakeholders need to be asked to commit to the process rather than to a predetermined outcome or intermediate decisions early in the process.
2. The existence of clear rules and procedures that have been agreed upon before the start of the engagement process, in order to ensure a sound environment in which trust relationships can be developed.
3. The actual influence stakeholders have on the end-result is important. It is largely determined by the type of stakeholder interaction, which can be conceptualized into three layers. The first layer *(information supply)* indicates one-way communication. The second layer *(consultation)* indicates that stakeholders can give feedback on developed plans. The third layer *(active involvement)* actively involves stakeholders throughout the policy-making and implementation process (CIS Working Group 2.9 2003).

TABLE 5.2 — Illustrative overview of the GCF scoring methodology. First, an overview of the predefined questions for the indicators belonging to condition 4 stakeholder engagement process is given. Second, the indicator 4.2 protection of core values Likert-type scoring is provided as an illustration. The predefined questions, the Likert-type scoring scale and a literature overview for each of the twenty-seven indicators are summarized at the EIP Water website (EIP Water 2017).

PREDEFINED QUESTIONS FOR CONDITION 4 *STAKEHOLDER ENGAGEMENT PROCESS*

INDICATOR	PREDEFINED QUESTION
4.1 Stakeholder inclusiveness	To what extent do stakeholders interact in the decision-making process interaction (i.e., are merely informed, are consulted, or are actively involved)? Are their engagement processes clear and transparent? Are stakeholders able to speak and decide on behalf of a group?
4.2 Protection of core values	To what extent 1) is commitment focused on the process instead of on early end-results? 2) do stakeholders have the opportunity to be actively involved? 3) are the exit procedures clear and transparent? (All 3 ensure that stakeholders feel confident that their core values will not be harmed.)
4.3 Progress and variety of options	To what extent are procedures clear and realistic, are a variety of alternatives co-created and thereafter selected from, and are decisions made at the end of the process in order to secure continued prospect of gain and thereby cooperative behavior and progress in the engagement process?

LIKERT-TYPE INDICATOR LEVELS FOR INDICATOR 4.2 *PROTECTION OF CORE VALUES*

LEVEL		DESCRIPTION
Very encouraging (++)	**Maximal protection of core values**	Stakeholders are actively involved and co-create the end-result. There are clear exit possibilities and clear process procedures. All relevant stakeholders are engaged and a variety of options are assessed. The final options are chosen at the end of the engagement process
Encouraging (+)	**Demand for commitment to early output**	Stakeholders are actively involved and expected to commit to early process outcomes. Hence some relevant stakeholders are discouraged from committing, as not all options are being assessed and at this stage the stakeholder's contribution might be small. The stakeholders have influence on the end-result
Indifferent (0)	**Suboptimal protection of core values**	Stakeholders are consulted or actively engaged for short periods. The number of options considered and influence on the end-result are limited. Exit rules are vague. Decisions mainly comply with the interests of the initiating party
Limiting (-)	**Low influence on end-result**	Stakeholders are kept informed or consultation meetings are taking place for already partly or fully elaborated plans. The influence on the end-result is small and resistance may be evoked
Very limiting (--)	**Ignorance of core values**	Stakeholders are hardly engaged, not informed or only informed after decisions have already been made. Resistance to implementation often occurs, as do distrust and lack of stakeholder participation, and no clear communication

5.5 ILLUSTRATING THE FRAMEWORK: GOVERNANCE CAPACITY IN AMSTERDAM

Assessing the governance capacity

We applied the GCF to the five water governance challenges faced by the city of Amsterdam. Amsterdam has a complex hydrological setting: large areas are below sea level, many canals and sluices regulate the different water levels, and there is a sophisticated system for supplying drinking water, which involves infiltrating surface water into the nearby dunes. A triangular method was applied to score indicators according to the Likert-type method. First, analyses of policy documents and reports provided preliminary scores. Second, fifteen interviewees, three for each of the five governance challenges, were selected. To this end, the most relevant stakeholders were identified and their interdependencies were plotted, and key persons from different levels of decision-making were selected (Reed 2009). As explained above, there were twenty-seven predefined questions that the research needed to answer: one for each indicator and each asked separately with respect to the five governance challenges. In this way, a consistent assessment approach was applied that enables basic comparisons to be made between, on the one hand, governance challenges, and, on the other hand, between cities. The interview questions were aimed to gather all the information needed to answer the predefined questions. They were open and non-technical, with follow-up questions to target specific elements, or to achieve further clarification. Finally, after the interviews, the participants received the predefined questions with the preliminary indicator scoring and were asked to provide constructive feedback and additional information to be included in the final scoring. The assessment was fully transparent, as the Likert-type scales, twenty-seven predefined questions, and the full list of references are publicly available.

Results

Each of governance challenges was separately assessed and scored: from very encouraging (++) to very limiting (--) to the governance capacity (Table 5.3).

This first assessment suggests that Amsterdam excels in flood risk governance, and most indicators regarding water scarcity and wastewater treatment are encouraging. However, more governance capacity needs to be developed to address Urban Heat Islands (UHI), since the number of tropical days (>30 °C) in the Netherlands is predicted to rise substantially, from 4 days at present to 7-13 days by 2050 and 8-21 by 2100 (KNMI 2014). Interestingly, cities in Northern Europe appear to be most affected by the predicted rise in high temperatures, because here, temperatures will strongly exceeded the usual seasonal conditions (EEA 2012). Despite this, in the Netherlands, no

TABLE 5.3 — Overview of the twenty-seven governance indicator scores for each of the five water-related governance challenges for the city of Amsterdam. Scores range from very encouraging (++) to very limiting (--) to the city's governance capacity to find dynamic solutions.

	WATER SCARCITY	FLOOD RISK	WASTE WATER TREATMENT	SOLID WASTE TREATMENT	URBAN HEAT ISLANDS
1.1 Community knowledge	-	0	-	0	-
1.2 Local sense of urgency	-	++	-	0	-
1.3 Behavioral internalization	+	++	++	+	-
2.1 Information availability	++	++	0	0	0
2.2 Information transparency	0	0	0	-	-
2.3 Knowledge cohesion	+	0	0	0	+
3.1 Smart monitoring	++	++	++	++	-
3.2 Evaluation	++	++	++	++	-
3.3 Cross-stakeholder learning	+	++	++	0	-
4.1 Stakeholder inclusiveness	++	++	++	0	++
4.2 Protection of core values	++	++	0	+	-
4.3 Progress and variety of options	++	++	0	0	0
5.1 Ambitious and realistic management	+	+	+	0	--
5.2 Discourse embedding	++	+	0	++	-
5.3 Management cohesion	++	+	++	+	-
6.1 Entrepreneurial agents	++	+	++	+	-
6.2 Collaborative agents	+	+	+	0	-
6.3 Visionary agents	+	++	+	0	+
7.1 Room to manoeuvre	+	+	0	+	0
7.2 Clear division of responsibilities	+	++	+	0	--
7.3 Authority	+	++	+	++	--
8.1 Affordability	+	+	+	+	+
8.2 Consumer willingness to pay	-	+	0	0	0
8.3 Financial continuation	+	+	+	+	0
9.1 Policy instruments	+	+	+	+	0
9.2 Statutory compliance	++	++	++	+	0
9.3 Preparedness	+	++	+	+	--

separate policy on UHI has been developed so far. Consequently, Amsterdam lacks specific targets and policies regarding UHI. The lack of policy may explain the low multi-level network potential (condition 7) to address UHIs. Averaging the scores of the five challenges for each indicator yields a more general overview of Amsterdam's water governance capacity (Fig. 5.1). It suggests that the knowledge level of communities (indicator 1.1) and the access to understandable information for non-experts (indicator 2.2) may slightly limit local sense of urgency regarding water challenges (indicator 1.2) and consumer willingness to pay (indicator 8.2). These results are in line with the OECD (2014) analyses of the Dutch water governance, which conclude that Dutch citizens take water services for granted and that this "awareness gap'' tends to decrease public involvement and the willingness to pay for water services. Therefore, the most feasible way for Amsterdam to further enable effective policy change is to focus on improving the indicator scores found to be limiting (-) or very limiting (--) to the city's governance capacity.

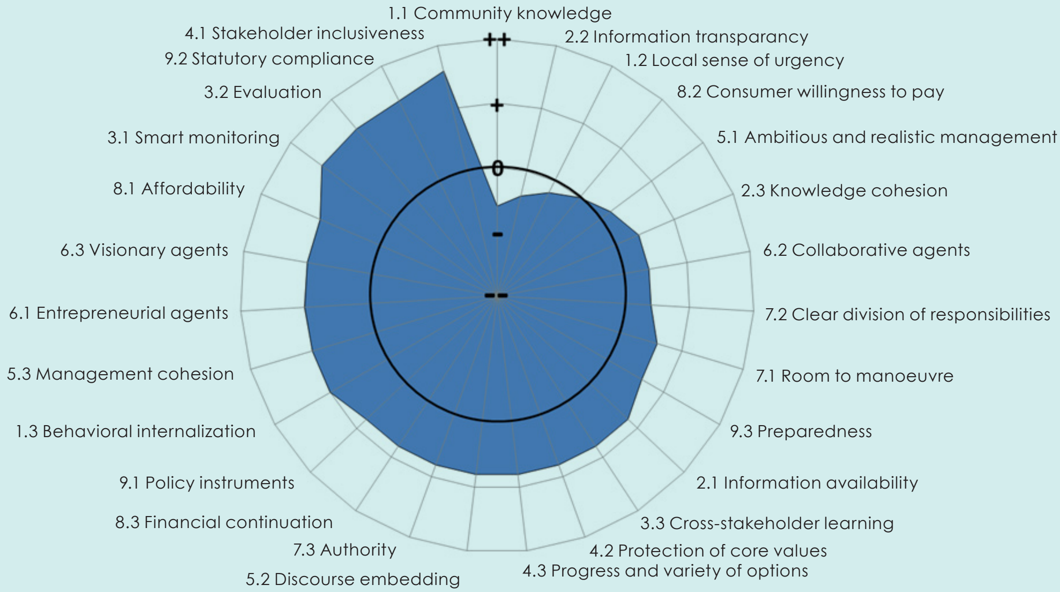

FIGURE 5.1 — Overview of the governance capacity of the city of Amsterdam. The twenty-seven indicators scores are ranked clockwise from low to high. Scores range from very encouraging (++) to very limiting (--) to the governance capacity that is a prerequisite for finding dynamic solutions to address the identified governance challenges.identified governance challenges.

5.6 DISCUSSION AND CONCLUSION

First, we will briefly discuss some limitations of the GCF. Next, we will outline the main contributions of the GCF to theory and practice and, more specifically, its role in connecting science, policy, and implementation.

5.6.1 FRAMEWORK DISCREPANCIES AND REPRODUCIBILITY

As governance processes are often interconnected, some of the conditions and indicators identified in our framework are inherently interrelated. Although each indicator is designed to provide an independent score, inevitably, a hypothetical "ideal" situation will not always result solely in very encouraging (++) indicator scores. For example, entrepreneurial, collaborative, and visionary agents of change (condition 6) are all relevant but their importance is context-dependent (Patterson et al. 2013): visionary agents, for example, may be more necessary in times of crisis, whereas collaborative agents are more valuable in initiating new joint activities in established collaborative networks, and entrepreneurial agents operate best in open governance networks that are ambitious and flexible (Brouwer and Huitema 2017). Hence, situations may exist in which entrepreneurial and collaborative agents of change are very encouraging (++) while, as a consequence, visionary agents are less prominently active. Another important interrelation is between indicators 5.1 *ambitious and realistic goals* and 9.2 *statutory compliance*, as it is easier to comply with non-ambitious goals. Furthermore, indicators 6.1 *entrepreneurial agents of change* and 7.3 *room to manoeuvre* are reinforcing, and their scoring is interrelated. Their main difference is that entrepreneurial agents of change focuses on actors' ability and skills to create and seize opportunities, whereas the score for room to manoeuvre represents the degree of freedom and existing opportunities that actors can utilize.

5.6.2 BRIDGING THEORY AND PRACTICE

Different time frames, reward structures, process cycles, epistemologies, and goals impede the effective use of scientific knowledge in practice (Hegger et al. 2012). Scientific knowledge is often fragmented, as it is intertwined with values, discourses, disciplinary scopes, and traditions that are often context-specific. Therefore, existing knowledge often fails to provide applicable insights that can help decision-makers achieve their intended goals and objectives. The gap between science, policy, and implementation has been widely acknowledged in water governance (OECD 2011a; Medema et al. 2008; Patterson et al. 2013). Our work provides three important contributions to improve the connection between scientific knowledge, policy, and implementation in the field of water governance, climate adaptation, and beyond:

1. **Integration:** The GCF is one of the first attempts to integrate the plethora of contradicting, overlapping, and fragmented governance gaps, barriers, and capacities with respect to prevailing urban water challenges. It may reveal more effective and efficient pathways for cities to increase their governance capacity. At present, our understanding of underlying interconnections and relations is often insufficient to provide overarching pragmatic insights that facilitate decision-makers.
2. **Communication:** The GCF is designed to be easy to understand and transparent, and has been developed with the end-users (who include decision-makers, stakeholders, and citizens) in mind. Information needs to be understandable for them. This is essential, to facilitate constructive discussions, knowledge co-production, and cooperation.
3. **City comparison:** The GCF provides a framework for comparison cities and the accumulation of empirical data that can improve our understanding of underlying governance processes that limit or encourage governance capacity. At the same time, it provides a practical framework for cities to exchange learning experience, knowledge, and good practices.

Because the framework is embedded in the literature of governance and transformation processes, it is possible to assess a broader range of issues that involve processes of change in multi-organizational networks. An empirical database is currently being developed, as the GCF is being used to assess the cities of Melbourne (Australia), Quito (Ecuador; Schreurs et al. 2017), New York (USA) and Ahmedabad (India; EIP 2017). Moreover, the results of the city of Quito (Ecuador) are about to be published (Schreurs et al. 2017). The GCF has the potential to act as a portal of communication for constructive cross-city, cross-sector, and cross-stakeholder discussions, learning and theory building. Finally, the framework provides the basis for common understanding and action, by revealing the most effective and efficient pathways for increasing the governance capacity needed to address the challenges of water, waste, and climate change.

ACKNOWLEDGMENTS

Our gratitude goes to the Amsterdam water network for their participation: Roelof Kruize, Jos Ketelaars, Ingrid Heemskerk, Alice Fermont, Peter Simoës, Mark Nijman, Lex Lelijveld, Kees van der Drift, Rolf Steenwinkel, Jeroen Ponten, Martine Lodewijk, Ed Cousin, Gerard Korrel, Geertje Wijten, Maarten Claassen, Rob Koeze and Wiegert Dulfer. We thank Joy Borrough for her editorial contribution. The Governance Capacity Framework is part of City Blueprint Approach developed at KWR Watercycle Research Institute in the context of Watershare® (http://www.watershare.eu). The City Blueprint Action Group is part of the European Innovation Partnership on Water of the European Commission (http://www.eip-water.eu/City_Blueprints). The European Commission is acknowledged for Funding POWER in H2020-Water under Grant Agreement No. 6878809.

CHAPTER 6

ASSESSING THE CAPACITY TO GOVERN FLOOD RISK IN CITIES AND THE ROLE OF CONTEXTUAL FACTORS

This chapter is published as: Koop S.H.A., Monteiro Gomes F., Schoot, L.G.L., Dieperink C., and Driessen P.P.J., Van Leeuwen C.J. (2018) Assessing the capacity to govern flood risk in cities and the role of contextual factors. Sustainability 10(8), 2869

ABSTRACT

This chapter addresses research 4: What contextual factors influence capacity building?

Sea level rise and increased storm events urge cities to develop governance capacity. However, a cohesive conceptual and empirical-based understanding of what governance capacity implies, how to measure it, and what cities can learn, is largely lacking. Understanding the influence of context is critical to address this issue. Accordingly, we aim to identify crosscutting contextual factors and how they prioritise different elements of governance capacity to address urban flood risk. In doing so, a framework of nine conditions and 27 indicators is applied in two Dutch cities and two cities in the United Kingdom. Three crosscutting contextual factors are identified that may explain differences in capacity-development priorities: (1) flood probability and impact; (2) national imposed institutional setting; and, (3) level of authority to secure long-term financial support. Capacity-priorities include the recent political devolution in the UK, which emphasizes the role of citizen awareness, stakeholder engagement, entrepreneurial agents, and the overall necessity for local capacity-development. The Dutch focus on flood safety through centralised public coordination reduces flood probability but inhibits incentives to reduce flood impacts and lowers public awareness. In conclusion, the three identified contextual factors enable a better understanding of capacity-building priorities and may facilitate learning between cities.

6.1 INTRODUCTION

Flood challenges are becoming ever more pending in a world of rapid population growth and increasing climate change impacts (Koop and Van Leeuwen 2017). About 15% of the global population—including almost all megacities—are under threat as a consequence of combined impacts of sea-level rise, river flooding, and human pressure, while storm events are expected to increase both in frequency and magnitude. Flood risk is, like other sustainability challenges, multi-scalar, multi-faceted, and interrelated in complex ways that require integration across multiple levels of governance and sectors (Jerneck et al. 2009; Kates et al. 2001; Hegger et al. 2014; Driessen et al. 2016). Typically, multiple governance layers and a variety of stakeholders, sectors, and policies are involved, each with different responsibilities, interests, and time horizons (OECD 2011). Because of the nature of these challenges, the governance capacity of public and private actors to collaborate is often much more decisive than the role of single organizations or institutions (Adger and Jordan 2009). In different contexts, organisational structures can vary substantially and municipalities therefore can provide a useful spatial unit and institutional scope to compare, learn and evaluate processes of multi-level flood risk governance.

Over the last decades, various societal initiatives—affiliated with sustainable development goals, resilience or climate change adaptation—established city platforms to improve the dialogue between cities, practitioners, technology facilitators, and scientists. These city platforms often aim to achieve a transition or transformation towards sustainable urban practices. Examples include C40, 100 Resilient Cities, Europe's Covenant of Mayor Adapt and IWA's Principles for Water-Wise Cities (C40 Cities 2017; Rockefeller Foundation 2017; Covenant of Mayors Adapt 2017; IWA 2017). Despite these valuable and highly necessary attempts, it remains difficult to utilise the large potential gain of mutual learning between cities because each city has to operate in a different contextual setting and may have different priorities. Accordingly, it is a scientific challenge to develop new approaches that can facilitate meaningful exchange of knowledge, experiences, and learning practice in order to enable these cities to develop the governance capacity necessary to transform themselves towards sustainable practices (Weaver and Jansen 2004; Jäger 2009).

The scientific literature on climate change adaptation, water governance, and adaptive capacity has identified a plethora of barriers, enablers, and conditions that influence the problem-solving capability of the public and private sectors (e.g., Adger et al. 2009; Eisenack et al. 2014; Biesbroek et al. 2013). However, despite the valuable insights provided by these studies, the body of literature has arguably not yet established sufficient conceptual coherence to empirically validate the large number of theoretical premises. First, many identified conditions are predominantly based on theoretical considerations that are not sufficiently supported by empirical findings (Biesbroek et al. 2013; Plummer et al. 2012; Van Rijswick et al. 2014). Second, the definitions of these identified barriers, enablers, and conditions are often neither made explicit, nor is it clear how they are operationalized, measured, and how they relate to one another (Eisenack et al. 2014; Plummer et al. 2012). Third, many barriers or enablers are applied within the context of individual case studies, often without considerable efforts to identify general patterns or transferable lessons (Biesbroek et al. 2013; Measham et al. 2011). These limitations call for a more coherent diagnostic analysis regarding the capacity of cities to govern flood risk.

Conceptual definitions generally establish themselves through repeated testing, evaluations, and refinements. Accordingly, the notion of governance capacity can be considered as the product of a conceptual integration of empirical knowledge from many different case studies and theoretical debates. Therefore, the concept of governance capacity is, in an implicit manner, a rationale that has to be derived from comparative analyses. In order to do so, a coherent, empirical-based diagnostic framework is required that can be used to assess existing governance capacities in different urban contexts. In this way, a database can be developed that can be used to identify overarching patterns and transferable lessons across a range of case studies, while, at the same time, it can improve our understanding of cause-effect relations in detail through individual cases. Such a mutual purpose requires a thorough understanding of how contextual factors influence the governance capacity. However, it is not well-understood in what way governance capacity is influenced by context and which contextual factors account for differences between urban flood risk governance (Eisenack et al. 2014; Biesbroek et al. 2013, 2014). Such an understanding can however be considered as a precondition for learning, in particular city-to-city learning.

In this paper, we aim to contribute to a better understanding of the context-specific capacity development priorities of urban flood risk governance in the United Kingdom (UK) and the Netherlands. Our second aim is to explore crosscutting contextual factors that may explain the observed differences. In order to fulfil this research aim, a comparative case-study approach will be applied in four cities in both countries (see

Section 3). Section 2 provides the conceptual framework behind the analysis of governance capacity that will be applied in this paper and introduces the definition of crosscutting contextual factors. Section 3 first provides a rationale for the selection of the four case-study cities. Second, the data collection methods are provided. In Section 4, the case study results are presented and crosscutting contextual factors that may impede, enhance, or prioritise different elements of governance capacity are explored. Section 5 discusses other potential context factors and the implications of the identified contextual factors for interpreting governance capacity analyses in other cities. We end with the conclusions in Section 6.

TABLE 6.1 — Overview of nine governance conditions and 27 indicators that comprise the governance capacity analysis (Koop et al. 2017). The Likert scoring system for each indicator is included in the supplementary information.

INDICATOR	PREDEFINED QUESTION
Condition 1: Awareness Awareness refers to the understanding of causes, impact, scale and urgency of flood risk.	
1.1 community knowledge	*To what extent is knowledge regarding the current and future risks, impacts, and uncertainties of flood risk dispersed throughout the community and local stakeholders which may results in their involvement in decision-making and implementation?*
1.2 Local sense of urgency	*To what extent do actors have a sense of urgency, resulting in widely supported awareness, actions, and policies that address flood risk?*
1.3 Behavioural internalization	*To what extent do local communities and stakeholders try to understand, react, anticipate and change their behaviour in order to contribute to solutions regarding flood risk?*
Condition 2: Useful knowledge The availability, transparency and cohesiveness of information that actors can use.	
2.1 Information availability	*To what extent is information on the water challenge available, reliable, and based on multiple sources and methods, in order to meet current and future demands so as to reveal information gaps and enhance well-informed decision-making?*
2.2 Information transparency	*To what extent is information on the water challenge accessible and understandable for experts and non-experts, including decision-makers?*
2.3 Knowledge cohesion	*To what extent is information cohesive in terms of using, producing and sharing different kinds of information, usage of different methods and integration of short-term targets and long-term goals amongst different policy fields and stakeholders in order to deal with the water challenge?*
Condition 3: Continuous learning Continuous learning refers to the level of social learning ranging from refining current practices, critical investigation of fundamental beliefs or questioning underlying norms and values.	
3.1 Smart monitoring	*To what extent is the monitoring of process, progress, and policies able to improve the level of learning (i.e., to enable rapid recognition of alarming situations, identification or clarification of underlying trends)? Or can it even have predictive value?*
3.2 Evaluation	*To what extent is the monitoring of process, progress, and policies able to improve the level of learning (i.e., to enable rapid recognition of alarming situations, identification or clarification of underlying trends)? Or can it even have predictive value?*
3.3 Cross-stakeholder learning	*To what extent are stakeholders open to and have the opportunity to interact with other stakeholders and deliberately choose to learn from each other?*

continuation of table 6.1

INDICATOR	PREDEFINED QUESTION
Condition 4: Stakeholder engagement process Stakeholder engagement is required for common problem framing, gaining access to a wide variety of resources and creating general support that is essential for effective policy implementation.	
4.1 Stakeholder inclusiveness	*To what extent are stakeholders interact in the decision-making process interaction (i.e., are merely informed, are consulted or are actively involved)? Are their engagement processes clear and transparent? Are stakeholders able to speak on behalf of a group and decide on that group's behalf?*
4.2 Protection of core values	*To what extent 1) is commitment focused on the process instead of on early end-results? 2) do stakeholders have the opportunity to be actively involved? 3) are the exit procedures clear and transparent? (All three ensure that stakeholders feel confident that their core values will not be harmed.)*
4.2 Protection of core values	*To what extent are procedures clear and realistic, are a variety of alternatives co-created and thereafter selected from, and are decisions made at the end of the process in order to secure continued prospect of gain and thereby cooperative behaviour and progress in the engagement process?*
Condition: 5 Management ambition Policy ambitions assesses if current policy is ambitious, feasible, well-embedded in local context and if it forms a cohesive set of long-term and short-term goals within and across sectors.	
5.1 Ambitious and realistic management	*To what extent are goals ambitious (i.e., identification of challenges, period of action considered, and comprehensiveness of strategy) and yet realistic (i.e., cohesion of long-term goals and supporting flexible intermittent targets, and the inclusion of uncertainty in policy)?*
5.2 Discourse embedding	*To what extent is flood risk management policy interwoven in historical, cultural, normative and political context?*
5.3 Management cohesion	*To what extent is policy relevant for flood risk management and coherent regarding 1) geographic and administrative boundaries, and 2) alignment across sectors, government levels, and technical and financial possibilities?*
Condition 6: Agents of change In order to drive change, agents of change are required to show direction, motivate others to follow and mobilize the resources required.	
6.1 Entrepreneurial agents	*To what extent are the entrepreneurial agents of change enabled to gain access to resources, seek and seize opportunities, and have influence on decision-making?*
6.2 Collaborative agents	*To what extent are actors enabled to engage, build trust & collaborate and connect business, government & sectors in order to address flood risk in an unconventional & comprehensive way?*
6.3 Visionary agents	*To what extent are actors in the network able to manage and effectively push forward long-term and integrated strategies which are adequately supported by interim targets?*

continuation of table 6.1

INDICATOR	PREDEFINED QUESTION
Condition 7: Multi-level network potential Urban flood risk governance involves a plethora of actors and interests from all levels of government, organizations and (private) stakeholders. For sustainable solutions, working in networks is an essential determinant for effective solutions.	
7.1 Room to manoeuvre	*To what extent do actors have the freedom and opportunity to develop a variety of alternatives and approaches (this includes the possibility of forming ad hoc, fit-for-purpose partnerships that can adequately address existing or emerging flood risk challenges)?*
7.2 Clear division of responsibilities	*To what extent are responsibilities clearly formulated and allocated, in order to effectively address the flood risk challenges?*
7.3 Authority	*To what extent are legitimate forms of power and authority present that enable long-term, integrated and sustainable solutions for flood risk challenges?*
Condition 8: Financial viability The continuation of flood risk funding is crucial which needs to be supported by affordable flood risk related services and an overall willingness to pay for floor risk management.	
8.1 Affordability	*To what extent are flood risk related services and climate adaptation measures available and affordable for all citizens, including the poorest?*
8.2 Consumer willingness to pay	*How is expenditure related to flood risk perceived by all relevant stakeholders (i.e., is there trust that the money is well-spent)?*
8.3 Financial continuation	*To what extent do financial arrangements secure long-term, robust policy implementation, continuation, and risk reduction?*
Condition 9: Implementing capacity Implementing capacity is about the effectiveness of policy instruments. The effectiveness is also related to the compliance to policy and regulation and the familiarity with flood emergency plans.	
9.1 Policy instruments	*To what extent are policy instruments effectively used (and evaluated), in order to stimulate desired behaviour and discourage undesired activities and choices?*
9.2 Statutory compliance	*To what extent is legislation and compliance, well-coordinated, clear and transparent and do stakeholders respect agreements, objectives, and legislation?*
9.3 Preparedness	*To what extent is the city prepared (i.e. there is clear allocation of responsibilities, and clear policies and action plans) for both gradual and sudden uncertain changes and events?*

6.2 A FRAMEWORK TO ANALYSE CONTEXT-SPECIFIC GOVERNANCE CAPACITIES

Like other consensus concepts—such as adaptive capacity, resilience, or sustainability—concrete definitions for governance capacity are strongly debated and differ considerably. Nevertheless, a few communalities can be identified (Koop et al. 2017). First, governance capacity is related to the ability of actors to address collective problems across organisations, and often includes multiple levels of governance (Dang et al. 2016). Second, governance capacity is formed through actor's interactions, which are shaped by social-institutional settings and allocation of resources (Pahl-Wostl 2009). Third, actors' frame of reference, which includes their interests, values, and culture, shape interactions, and thereby the capacity to address joint problems. Since actors' interactions are by definition complex, unpredictable, and susceptible to external social, economic, and environmental developments, governance capacity in itself does not guarantee effective change, but can rather be considered as a precondition or enabler. The institutional setting, rules, and regulations that enable actors to collaborate and address shared problems are generally referred to as institutional capacity (e.g. Amundsen et al. 2010). Governance capacity is broader as it also includes the role of resources and discourses.

Due to this broad scope, there is little agreement on which indicators or proxies are most valid to assess governance capacity. Consequently, the researchers' normative assumptions of what governance capacity entail leads to implicit accenting of certain issues over others. However, both impasses and opportunities result from many interconnected processes with often unforeseen effects that cannot be explained by a single barrier or event (Biesbroek et al. 2014). Hence, in order to understand dynamic governance mechanisms, it is necessary to consider a broader range of conditions that together form the capacity to address flood risk. Based on an extensive literature review, Koop et al. (2017) developed a diagnostic framework that coherently assesses the most important conditions that together determine the capacity of cities to govern water challenges. This empirical-based Governance Capacity Framework (GCF) consists of nine conditions (Table 6.1) and three dimensions: knowing, wanting, and enabling. The "knowing" dimension refers to the need to involve actors to be aware, understand, and learn about the risks and impacts of strategic choices and policy. In this dimension, the level of awareness (condition 1), existence of useful knowledge (condition 2) and the network's ability to continuously learn (condition 3) are being assessed. The "wanting" dimension relates to the necessity that actors commit, cooperate, act upon ambitions, and use their skills to find solutions. More specifically, the stakeholder engagement process (condition 4), management ambition (condition 5), and the role of agents of change (condition 6) are being assessed. Finally, the “enabling” dimension analyses the network potential to address water challenges (condition 7), the financial viability (condition 8), and existing policy instruments and action plans that actors can use to implement policies that address flood risk (condition 9). Table 6.1 provides an overview of the nine conditions and 27 indicators that form the capacity to govern flood risk.

The framework is designed with the aim to consistently analyse the governance capacity of cities across various world regions in order to identify opportunities for mutual learning between them. However, the governance capacity of cities is a result of multi-level governance processes and it is shaped by the local contextual setting. In order to enable meaningful exchange of knowledge, experiences and learning practices, contextual factors have to be taken into account. According to the principle of parsimony, we aim to identify the most influential reoccurring contextual factors that need to be considered. These contextual factors are referred to as ‘crosscutting contextual factors’.

6.3 METHODS

6.3.1 CASE STUDY SELECTION

In order to better understand the context-specific governance capacity development priorities of urban flood risk governance, two countries with (1) considerable flood vulnerability and (2) with a long track record in flood risk management, were selected: the UK and the Netherlands. In both countries, two cities were selected that resemble the flood risk challenges and exemplify the policy efforts of their country. In the UK, Milton Keynes (261,800 inhabitants) and Leicester (394,000 inhabitants) were selected. Like most other flood prone cities in the UK, both selected cities are vulnerable for river flooding and inundation of urban areas due to rainfall runoff.
In the Netherlands, Rotterdam (638,000 inhabitants) and Amsterdam (833,624 inhabitants) were selected. As for at least 25% of the Netherlands, both cities are situated below sea level and potentially exposed to sea flooding, river flooding, and inundation due to rainfall runoff. For both countries, an 'old' city and a 'new' city were selected to better represent the diversity within both countries. The 'old' cities of Leicester and Amsterdam both have an historic city centre and high population densities (respectively, 4494 people km^{-2} and 5042 people km^{-2}) that complicate the implementation of physical flood risk measures. On the other hand, the 'new' cities of Milton Keynes and Rotterdam have lower population densities (respectively 2584 people km^{-2} and 2920 people km^{-2}), which results in greater flexibility to adapt urban infrastructure in order to cope with flood risks. As experiences with recent flood events is an important determinant for adaptation efforts (e.g., Thaler and Priest 2016; Wiering et al. 2017), all four selected cities did not experience any significant flood events in the last decades. The European Union (EU) Water Framework Directive (WFD) applies to all four cities and the cities are more or less equally affected by the 2008 financial crisis. Furthermore, climate change mitigation and adaptation have become a central theme in the national policy in both countries (Wiering et al. 2015).

6.3.2 DATA COLLECTION

Each of the 27 indicators that are listed in Table 6.1 have a pre-defined question and a Likert scoring system that ranges from very encouraging (++) to very limiting (--) the overall governance capacity (the Likert scale indicator scoring is provided in the supplementary information). A three-tiered approach was applied to score each indicator in all four case studies in order to validate findings by different sources:

Preparatory Desk Study

A desk study of primary sources, such as governmental reports, legal documents, and secondary sources, such as scientific literature, websites, newspapers, and etcetera, resulted in a substantiated preliminary score for each indicator.

Stakeholder Selection & Interviews

Stakeholders were identified, categorized, and their responsibilities, relations, and main interactions were mapped in order to select a range of stakeholders that include the largest variety of interests. At least one stakeholder that, respectively, represents the government, the market, and civil society was included, as suggested by Lange et al. (2013). We also included at least one knowledge institute or university per city. The following organisations were selected for interviews. Leicester: University of Leicester, Trent Rivers Trust, Leicester City Council, local consultancies, Flood Warden, and the Environment Agency. Milton Keynes: Milton Keynes City Council, Cranfield University, local consultancies, the Highways Agency, the Environment Agency, and Bedford Group of Internal Drainage Boards. Amsterdam: Waternet, Municipality of Amsterdam, local consultancies, University of Amsterdam, and the Municipal Health Service (GGD); Rotterdam: Evides (drinking water company), Delta Programme Climate adaptation, local consultancies, Rotterdam University of Applied Science, Municipality of Rotterdam, and the water board Hoogheemraadschap Schieland en de Krimpenerwaard. In many cases, multiple persons from the identified key stakeholders were selected with different roles, areas of expertise, and responsibilities in order to minimize the risk of bias and unravel socially desirable responses. In total, 30 in-depth interviews were conducted. The face-to-face interviews lasted for about an hour and were made anonymous in order to reduce socially biased answers. The pre-defined questions that are listed in Table 6.1 formed the common thread for the researcher. In the interviews, questions were reformulated in alignment with the person's background and expertise. In fact, some interviews focused only on a few indicators. For each indicator, at least five different persons were interviewed as a minimum requirement. The scores were determined based on the preparatory desk study, interviews, and additional collection of reliable and accessible information that may ratify or provided nuances to the interview findings.

Exploring Crosscutting Contextual Factors

Based on the GCF analyses, the indicator scores that mostly differed between the four cities were examined more closely through in-depth interviews and document analyses in order to explore crosscutting contextual factors that could explain these differences. In each of the previously mentioned interviews, national contextual differences between the UK and the Netherlands were explored as well. In addition, flood management related documentation in both countries was studied (documents such as the Pitt review (2008) in the UK and the Delta Programme (2017) in the Netherlands) and a detailed analysis of local, regional, national, and international policies that are related to flood risk management was performed.

6.4 RESULTS

Table 6.2 shows the overall results of the GCF analyses. Section 4.1 will present the national flood risk management context in the UK, followed by the results of the city of Milton Keynes and Leicester. In Section 4.2, the national flood risk management context of the Netherlands is provided, followed by the results of the cities of Rotterdam and Amsterdam. In Section 4.3, crosscutting contextual factors are explored that may impede, enhance, or prioritise different elements of governance capacity.

6.4.1 FLOOD RISK GOVERNANCE IN THE UK

The UK has a long history in flood events, mainly with respect to rivers bursting their banks, as well as local water nuisance

TABLE 6.2 — Flood risk governance capacity analysis of Milton Keynes, Leicester, Rotterdam, and Amsterdam. The scores range from very encouraging (++) (green) to very limiting (--).

		ENGLAND		NETHERLANDS	
CONDITIONS	INDICATORS	MILTON KEYNES	LEIC-ESTER	ROTTER-DAM	AMSTER-DAM
1 AWARENESS	1.1 Community knowledge	-	0	0	0
	1.2 Local sense of urgency	-	+	+	++
	1.3 Behavioural internalization	0	+	0	++
2 USEFUL KNOWLEDGE	2.1 Information availability	+	+	++	++
	2.2 Information transparency	++	+	+	0
	2.3 Knowledge cohesion	0	+	++	0
3 CONTINUOUS LEARNING	3.1 Smart monitoring	0	+	0	++
	3.2 Evaluation	+	+	0	++
	3.3 Cross-stakeholder learning	0	+	0	++
4 STAKEHOLDER ENGAGEMENT PROCESS	4.1 Stakeholder inclusiveness	+	0	++	++
	4.2 Protection of core values	0	0	+	++
	4.3 Progress and variety of options	0	0	+	++
5 MANAGEMENT AMBITION	5.1 Ambitious and realistic management	++	+	++	+
	5.2 Discourse embedding	0	0	++	+
	5.3 Management cohesion	0	0	+	+
6 AGENTS OF CHANGE	6.1 Entrepreneurial agents	-	0	+	+
	6.2 Collaborative agents	0	0	0	+
	6.3 Visionary agents	0	+	+	++
7 MULTI-LEVEL NETWORK POTENTIAL	7.1 Room to manoeuvre	0	0	0	+
	7.2 Clear division of responsibilities	0	0	+	++
	7.3 Authority	-	0	++	++
8 FINANCIAL VIABILITY	8.1 Affordability	++	+	+	+
	8.2 Consumer willingness to pay	0	0	0	+
	8.3 Financial continuation	0	0	++	+
9 IMPLEMENTING CAPACITY	9.1 Policy instruments	0	0	++	+
	9.2 Statutory compliance	0	+	++	++
	9.3 Preparedness	0	+	+	+

due to unsustainable drainage systems. The UK has a risk-based approach with a recognition that floods cannot be fully prevented (DEFRA 2004). In this context, citizens and property owners are considered to have a fundamental role. For example, the UK's private flood risk insurance system appeals to individuals being aware of their flood risk and taking action to protect their property (Surminski 2018; Lo and Chan 2017). The summer floods of 2007 proved to be a determining event. Between May and July, the highest rainfall intensity was recorded since records started in 1766 (Met Office 2013). About 55,000 properties were inundated along the major rivers Severn, Don, and Thames. The total damage amounted to £4 billion (EA 2007).

A review led by Sir Michael Pitt (Pitt 2008) identified that a lack of clarity over which organisations were responsible for surface water flooding and emergency action led to contrasting and uncoordinated messages. Moreover, flood impact data was found to be fragmented and replicated. Consequently, the Pitt review called for a permanent centralised coordinating body. As a result, the Government's Department for Environment, Food, and Rural Affairs (DEFRA) took coordinated action (DEFRA 2008). First, the Environment Agency (EA), responsible for the main rivers, coasts and reservoirs, got more authority to maintain a strategic overview (Benson et al. 2018). Second, Regional Flood and Coastal Committees (RFCCs) were established. At the regional level, the EA is required to consult RFCC and get approval for implementing and expending revenues raised (UK Government 2010). Third, more power was directed to local authorities through the Lead Local Flood Authority (LLFA). The LLFAs are obliged to develop, maintain, apply, and monitor a strategy for local flood risk management of surface runoff, groundwater, and ordinary watercourses within its area (Benson et al. 2018; UK Government 2010). The LLFA is required to register flood risk assets, investigate flood incidents, and promote Sustainable Drainage systems (SuDS) through close cooperation with the highway authority, local risk management authorities, the regional Internal Drainage Boards (IDBs), and through public consultation. The sewer system is management by private companies who fund their operations through water bills under the supervision of Ofwat, the economic regulator for water, and sewerage services in England and Wales.

Milton Keynes

Milton Keynes is a designed city and national frontrunner in sustainability and innovation. Of the 261,800 inhabitants, 1753 properties in the older, lower areas have a high flood risk (Milton Keynes Council 2016). The citizens, who have recently experienced water nuisance, apply mitigation measures, such as walls and airbricks, to protect their property (indicator 1.3 behavioural internalisation). However, most citizens have little knowledge or commitment with flood risk challenges (indicators 1.1 community knowledge and 1.2 local sense of urgency; Milton Keynes Council 2016) and are not willing to pay more than they already do (indicator 8.2 consumer willingness to pay). Flood risk information is provided transparently through real-time warning systems that monitors river and sea levels: https://www.gov.uk/check-flood-risk. The EA flood risk maps are complemented with detailed assessments from the local authorities providing accurate information about current and future flood risks (indicator 2.1 information availability). Moreover, local flood risk prediction maps are available for periods of five days and further ahead, and a free flood warning service for house owners and businesses is available: https://www.gov.uk/sign-up-for-flood-warnings (indicator 2.2 information transparency).

Milton Keynes' City Council has a coordinative task as LLFA. In their local flood risk management strategy (Milton Keynes Council 2016), the suggested agreements and goals are realistic and moderately ambitious, taking into account funding limitations. Each objective is translated into three measures, each with intermittent targets that have clear deadlines (indicator 5.1 ambitious and realistic management; UK Government 2010). All stakeholders are free to engage in projects and have the opportunity to express their concerns and provide feedback on draft plans through workshops and on paper (indicator 4.1 stakeholder inclusiveness). Different departments within the City Council are responsible for narrowly defined flood-related tasks, each with different drivers and budget allocations. For example, interests for spatial development can contest flood risk management goals. The division of responsibilities (indicator 7.2) with respect to SuDS is somewhat complex. Highways departments are tasked with ensuring good traffic flow through, amongst others, SuDS. Other actors outside City Council also have an important role. Anglian water is tasked with the sewer system. Parks Trust is a charity who takes care of Milton Keynes parks and green spaces and the Bedford Group of IDBs manages the regional drainage system. The jurisdiction of the IDB is inconsistent with the river catchment area, leading to difficulties in both upstream and downstream coordination. Despite many efforts, the fragmented organisational structure leads to limited knowledge cohesion (indicator 2.3) and suboptimal management cohesion (indicator 5.3).

Due to recent devolution of political power and cuts in national funding (Environment Agency 2011), local authorities have to find new funding sources, such as local investors. The City Council reviews the funding opportunities every six months. However, this system may reduce financial security for long-term more proactive measures (indicator 8.3 financial continuation). Likewise, the window of opportunity for entrepreneurial agents (indicator 6.1) to innovate is also financially limited. Hence, the national imposed institutional setting and financial constraints are considered to be important contextual factors that impact the local governance capacity.

Leicester

Leicester is situated in the wide flat River Soar valley and it is particularly vulnerable to heavy downpours and prolonged periods of rain. From the East and West hills, a number of large watercourses flow quickly towards the River Soar through urban areas. Major developments projects are expected upstream, which could increase the surface water runoff and flood vulnerability. It is estimated that about 1915 residential and commercial properties are at risk of a 1 in 75 years flood (Environment Agency 2016). Leicester, therefore, recognises the importance that residents understand the causes, risk and impact of their properties being flooded, how to respond to emergencies, and how they can be involved in local decision-making. This is also reflected in the high availability, transparency, and cohesion of flood risk information (condition 2 useful knowledge; Leicester City Council 2015).

In general, differences in culture and language form barriers for people's awareness, preparedness, and their ability to recover from flood events (Fielding 2018). As one of the most culturally diverse cities in the UK, Leicester allocates many resources to effectively communicate with multicultural communities. For example, flood risk information is translated in multiple languages. It also poses extra challenges to include citizens in the stakeholder engagement process (condition 4). Consultation procedures are clear, adhere to national requirements, and all relevant stakeholders and responsible risk authorities are involved. For example, everyone could provide feedback on the draft local flood risk management strategy through consultation meetings and online platforms. However, citizen involvement heavily depends on a select group of well-informed, non-transient, and often highly educated citizens. Stakeholders can also raise issues themselves in council or ward meetings. However, the level of influence that stakeholders have on the end-result is somewhat limited. Engagement is mainly via consultation and not that frequently through focus groups that co-produce knowledge to explore optimal solutions. Leicester is open for this type of stakeholder engagement, but is also restricted by financial resources.

As a result of diminished national funding, Leicester needs to fund flood-defence projects through their own resources, partnership funding, or local developers. However, these funding mechanisms may limit the long-term financial security necessary to pro-actively adapt to challenges of climate change and land-use change. Consequently, the role of local individuals that provide a long-term vision, promote initiatives, bring actors together, and mobilize the required local resources, has become critical (indicator 6.1 entrepreneurial agents). The room to manoeuvre (indicator 7.1) that these agents of change need to effectively seize opportunities for new projects and innovations is somewhat limited. The division of responsibilities, interests, and tasks are divided over many actors (indicator 7.2 clear division of responsibilities) and they pose constraints for the coordination of different policies (indicator 5.3 management cohesion). The EA is responsible for the main river Soar while Leicester City Council (LCC) is the LLFA and is responsible for flood risk and spatial planning. The Leicestershire county and district councils carry out flood risk management works on minor watercourses surrounding the municipality. The water and sewerage company Severn Trent has the duty to maintain the sewer system and drain their area. Successful attempts have been made to integrate the development of green space with flood risk management (Leicester City Council 2012). However, the flood risk goals are much less synergetic with respect to national targets for housing development that the LCC has to comply with. In terms of contextual factors, the city's vulnerability to heavy downpours and prolonged periods of rain requires a high level of citizen awareness to adapt, anticipate, and cope with 'unavoidable' flood events. Moreover, limited national and local flood management authority leads to uncertainties with respect to local financial resources.

6.4.2 FLOOD RISK GOVERNANCE IN THE NETHERLANDS

About 55% of the Netherlands is flood prone and about 25% lies below sea level, including the country's main economic district and largest cities. In 1953, the levees in the south-eastern delta region were unable to withstand a major storm surge. In total, 1836 people died, over 2000 square kilometres of land was flooded, and the damage was estimated at €5.2 billion (Gerritsen 2005). In response to this disaster, the national Delta Plan was initiated which included the embankment of the estuaries in the south-eastern areas. The Delta works were designed to prevent such a large-scale disaster to ever happening again.

The Delta Plan has a strong emphasis on engineering flood defence structures and it is controlled by the national authority 'Rijkswaterstaat'. The Dutch government fully compensates flood damages. However, a number of river flood incidences in the 1990s changed this dominant discourse. In 1993, the river Meuse burst through its banks and flooded one-fifth of the southern province of Limburg. Moreover, the risk of river flooding led to the largest post-war evacuation of about 80,000 people in 1995. As a consequence, the 'Room for the Rivers' policy was developed, which emphasized the role of spatial planning in dealing with climate change induced extreme weather events. Accordingly, the focus shifted from reducing flood probabilities to reducing flood impacts (Bergsma 2017).

The national government's Delta Commission formulates the strategic goals and provides a financial structure for flood defence and freshwater provision within the Delta Programme. The provinces are responsible for the regional operationalization of these national strategies and to manage groundwater bodies. The Ministry of Infrastructure and Water Management is responsible for protection against the sea, main rivers, and canals. The water boards manage the regional water systems. The water boards raise their own public taxes to recover their costs and have their own elected representatives. Finally, the municipalities have a duty of care regarding the sewer system, rainwater, and groundwater, which is financed through a specific tax. Due to significant damages of recent storm events and new more extreme climate predictions, the Delta Programme (2017) announced extra investments for urban areas. Municipalities are required to perform a 'water stress test' in order to map their long-term resilience and to identify the required action with respect to flooding, drought, and heat stress (Delta Programme 2017).

Rotterdam

Rotterdam is home to 638,000 people and has Europe's biggest port. The city has large flood risk challenges as it is situated below sea level in the delta of the river Rhine and Meuse, and its main canal 'de Nieuwe Waterweg' is openly connected to the North Sea. Rotterdam has a long tradition of flood risk management and the city's water safety is highly dependent on the national dikes and sea barriers (indicator 5.2 discourse embedding). Rotterdam is one of the safest delta cities in the world. The main responsibilities lie with the municipality, the water boards, and the Dutch government through the Delta Programme. Local policies strictly adhere to national flood risk policies and safety standards (Waterplan 2 2013). At the local level, the division of responsibility (indicator 7.2) between public and private actors is more determined on a case-by-case fashion. Regular inter-sectorial meetings, in particular, between the city's three water boards, the municipality, and main businesses in the harbour enable cohesive water management. Nevertheless, inter-sectorial exploration of synergies can be further enhanced (indicator 3.3 cross-stakeholder learning and 5.3 management cohesion). For example, through smarter, more integrated monitoring and evaluation of the city's drainage system (indicator 3.1 smart monitoring and 3.2 evaluation).

Overall, long-term goals are ambitious and implemented by intermittent targets that are embedded in various policies (indicator 5.1 ambitious and realistic management; Waterplan 2 2013; Rotterdam Climate Change Adaptation Strategy 2013). Within Rotterdam's Climate Proof programme, climate change adaptation is considered to be a means for creating employment, social cohesion, and citizen engagement, which enhances economic growth. Delta technology and knowhow are referred to as the blue-green economy and are considered as export products. Investments in a safe and vital infrastructure are expected to attract international investments, ensure long-term growth, and prosperity. There is much room for experimentation. Many small-scale pilots and experiments such as floating houses, farms, hotels and forests are supported by local authorities. Initiatives, such as collective city gardens, nature-based playgrounds, and child friendly neighbourhoods, are combined with climate change adaptation goals and improve the attractiveness and liveability of Rotterdam. Important climate change adaptation projects are realised, such as a water square, which combines water storage with the improvement of the quality of urban public space. Another example is the large underground parking lot that can also store excess stormwater. In some cases, more unconventional collaboration with the private sector has been established leading to for example the development of tidal parks along the main canals: the 'Nieuwe Maas' and the 'Nieuwe Waterweg' (indicator 6.2 collaborative agents). Visionary agents (indicator 6.3), who push for long-term, integrated, and climate adaptive flood risk management at the political or strategic level are most active at the national scale. In Rotterdam, entrepreneurial agents (indicator 6.1), who initiate new concepts, innovations, and ideas, are most active.

Whilst Rotterdam is not a rich city according to Dutch standards, the municipal and regional taxes are generally being considered affordable (indicator 8.1 affordability). The High Water Protection Programme, which is a part of the Delta fund, ensures funding for water safety measures. An additional benefit of this financial structure is that the municipality saves time and resources otherwise spend on acquisition (indicator 8.3 financial continuation). In the context of high potential flood impact and substantial future challenges, the city is forced to be proactive. In these efforts, Rotterdam is strongly supported by the authority of national and regional policy and institutions, which is an important contextual factor that provides the necessary financial resources for Rotterdam to be innovative and proactive.

Amsterdam

Amsterdam is an old and densely populated city with a complex hydrological setting. The city is protected from the North Sea, the Lek River, lake Marker, and regional water bodies through a complex system of dikes, dams, and sluices. The city is connected to the North Sea via a canal running through the city centre. North and south of the canal, the city is protected by dikes under national authority which ensure high safety standards (flood risk of once in 10,000 years). In some areas, a lower safety standard of once every 1250 years is operational. Amsterdam has applied a flood safety approach. However, recently the national Delta Programme has initiated a 'Multi-layer Safety' (MLS) approach, which is being piloted in six voluntary cases, one of them is Amsterdam. MLS consists of three layers (Delta Programme 2017):

1. Reducing flood probability through flood defence infrastructure
2. Reducing flood impact through adaptive spatial planning
3. Reducing flood impact by preparing flood response strategies

A thorough scanning according to the MLS revealed that suboptimal spatial planning, in particular, with respect to vital infrastructure, largely increases the potential flood impact. In particular, the harbour area Westpoort is vulnerable. The Westpoort area is vital for the supply of electricity for a third of the city. Furthermore, flooding of its wastewater treatment plants, data centres and the chemical industry would lead to large scale damage. Despite a long-term preparedness to anticipate flood risks, the flood response strategy was found to be insufficiently equipped (indicator 9.3 preparedness; Koeze and Drimmelen 2012). Cost-efficiency of spatial adaptation is low due to the low flood probability. However, the city is pioneering with a strategy that combines flood adaptation with projected infrastructure refurbishments and with measures to reduce heat stress, air pollution, or water nuisance. For example, soil remediation can be combined with measures to increase the ground-level. This integral cost-efficient approach can slowly reduce the flood impact over the next decades. However, the implementation of this strategy is hampered by limited awareness and knowledge of flood risks beyond the water authorities (indicator 1.1 community knowledge; Koeze and Drimmelen 2012). Amsterdam is served by one municipally owned utility for water, called 'Waternet'. Waternet manages the entire urban water cycle, including drinking water, water safety, surface water and wastewater transport, and treatment (indicator 7.2 clear division of responsibilities). This integrated approach and close ties with the municipality and regional water board is unique and it provides sufficient authority (indicator 7.3 authority) and room to manoeuvre (indicator 7.1 room to manoeuvre) for individual agents to coordinate the long-term implementation of cost-efficient synergies (condition 7).

By 2040, the city expects an additional 70,000 houses within its borders, resulting in further densification of sealed areas, such as roofs, streets, and parking spaces. A climate-induced increase in the frequency and intensity of storm events will further increase the city's vulnerability for water nuisance. The Amsterdam Rainproof programme was created to make Amsterdam resistant to the increasingly common downpours. Adaptive measures, such as constructing green roofs, urban gardening, and the use of rainwater for toilet flushing are being mainstreamed into urban planning. However, it is challenging to do this in a city with limited awareness. Hence, there is not yet a fully shared ambition, rather low commitment, and a lack of an inter-sectorial policy and coordination. More understandable and cohesive knowledge provision (indicator 2.2 information transparency and 2.3 knowledge cohesion) may facilitate a better integration between urban planning, climate adaptation, and flood impact reduction objectives. The new national imposed obligation to perform a water stress test may provide an opportunity for improvement (Gemeente Amsterdam 2013). The national imposed institutional setting leads to a clear division of responsibility but it also limits the involvement of citizens and stakeholders beyond the water management authorities. Moreover, a strong focus on reducing flood probability complicates local efforts to reduce the impact of potential flooding.

6.4.3 CROSSCUTTING CONTEXTUAL FACTORS FOR CITIES

Reflecting on the indicator scores within the four case studies (Table 6.2), we can identify a few key differences (Table 6.3). The root cause of these differences may be explained by crosscutting contextual factors. Moreover, the relative importance of some indicators differed between cities in the two case-studies in the UK and the Netherlands. In particular, indicators 1.2 local sense of

TABLE 6.3 — Overview of indicators that differed the most between on the one hand the Milton Keynes and Leicester, and on the other hand Rotterdam and Amsterdam.

INDICATOR	CITY	SCORE	PRE-DEFINED QUESTION
4.2 Protection of core values	Milton Keynes	0	To what extent 1) is commitment focused on the process instead of on early end-results? 2) do stakeholders have the opportunity to be actively involved? 3) are exit procedures clear and transparent? (All three ensure that stakeholders feel confident that their core values are not harmed)
	Leicester	0	
	Rotterdam	+	
	Amsterdam	++	
4.3 Progress and variety of options	Milton Keynes	0	To what extent are procedures clear and realistic, are a variety of alternatives co-created and thereafter selected from, and are decisions made at the end of the process in order to secure continued prospect of gain and thereby cooperative behaviour in the engagement process?
	Leicester	0	
	Rotterdam	+	
	Amsterdam	++	
5.2 Discourse embedding	Milton Keynes	0	To what extent is sustainable policy interwoven in historical, cultural, normative and political context?
	Leicester	0	
	Rotterdam	++	
	Amsterdam	+	
6.1 Entrepreneurial agents	Milton Keynes	-	To what extent are the entrepreneurial agents of change enabled to gain access to resources, seek and seize opportunities, and have influence on decision-making?
	Leicester	0	
	Rotterdam	+	
	Amsterdam	+	
7.2 Clear division of responsibilities	Milton Keynes	0	To what extent are responsibilities clearly formulated and allocated, in order to effectively address the water challenge?
	Leicester	0	
	Rotterdam	+	
	Amsterdam	++	
7.3 Authority	Milton Keynes	-	To what extent are legitimate forms of power and authority present that enable long-term, integrated and sustainable solutions for the water challenge?
	Leicester	0	
	Rotterdam	++	
	Amsterdam	++	
8.3 Financial continuation	Milton Keynes	0	To what extent do financial arrangements secure long-term, robust policy implementation, continuation, and risk reduction?
	Leicester	0	
	Rotterdam	++	
	Amsterdam	+	
9.1 Policy instruments	Milton Keynes	0	To what extent are policy instruments effectively used (and evaluated), in order to stimulate desired behaviour and discourage undesired activities and choices?
	Leicester	0	
	Rotterdam	++	
	Amsterdam	+	

urgency, conditions 2 useful knowledge, condition 4 stakeholder engagement process, and indicator 6.1 entrepreneurial agents, were found to be relatively important within the context of the UK. Whereas, condition 1 awareness, indicator 8.2 consumer willingness to pay, and indictor 9.3 preparedness, may require most attention in the Dutch context. The observed differences in relative importance, and key differences in indicator scoring, were examined in more detail through in-depth interviews, document analyses, and a multi-level policy analyses. The aim of this explorative exercise was to find crosscutting contextual factors that can explain these differences. As a result of this explorative exercise, we have identified three crosscutting contextual factors: (1) flood probability and impact; (2) national imposed institutional setting; and, (3) level of authority to secure long-term financial support.

1. Flood probability and impact
The hydro-physical setting largely determines the probability and impact of flood events and pre-selects the viable solutions. The Netherlands faces flood challenges that are characterised by a low probability but high impacts and a short warning time (Bubeck et al. 2015). As a consequence, high safety standards are required that are accomplished through structural flood prevention measures. Improving flood defences in vulnerable reclaimed areas—the 'Polders'—increases feelings of safety that stimulate investments and further economic development in these areas. It becomes a logical choice to invest in flood defence of increasingly valuable social and economic assets. Due to the large investments that have already been made, each additional investment receives an increasing return creating a path-dependency. This self-reinforcing phenomenon has also been described as the 'levee effect' (Ludy and Kondolf 2012). On the contrary, in the UK most flood risks tend to have a relatively lower impact but higher probability and it is possible to predict and prepare for floods well in advance. In this hydro-physical setting, not all floods can be prevented.

These diverging processes that are related to flood probability and impact have important repercussions for the role and responsibility of individuals, their expectations and trust that they have in water management authorities (Jabareen 2015). In the Netherlands, the government monopoly on flood safety has greatly reduced the involvement of citizens and the private sector. Moreover, the government has compensated damages that are caused by major floods, while flood insurances do not exist. Consequently, most people are rather disconnected from flood challenges and take their safety for granted. Measures to reduce the flood impact (indicator 9.3 preparedness) are typically not cost-efficient and are difficult to implement due to limited awareness beyond the water sector. On the contrary, the UK does not apply a minimum safety standard. A cost-benefit analysis fully determines the optimal protection at the local scale. Individuals can therefore be exposed to a great variety of flood probability and impact.

The UK's private flood risk insurance system requires individuals to be aware of their own flood probability and impact, and act accordingly by protecting and insuring their property (Surminski 2018; Lo and Chan 2017). In this context, the availability and transparency of local flood risk information for citizens becomes critical (indicator 2.1 information availability and 2.2 information transparency). Accordingly, these indicators score high for both Milton Keynes and Leicester. Citizen awareness also becomes critical, and in fact, an interesting difference was found between the analysed cities in the UK and in the Netherlands. Awareness of local authorities was found to be highest in the Netherlands, whereas citizen awareness was low (indicator 1.1 community knowledge and 1.2 local sense of urgency). In the English cities, this was rather different. Leicester has a higher citizen behavioural internalisation, which can be explained as a necessity given the high flood probabilities. In fact, knowledge, awareness, and behavioural internalisation of citizens can be considered as key indicators in the UK context of considerable food probability and appeal on individual to take their responsibility. The flood probability and impact characteristics largely explain the different management pathways that both countries have taken. Overall, this contextual factor lead to differences in condition 1 awareness, condition 2 useful knowledge, and in particular, to indicator 9.3 preparedness. These elements are particularly relevant for cities in the UK to help citizens to cope with higher flood risks and particularly relevant for Dutch cities to reduce their flood impact in the long run.

2. National imposed institutional setting

The existing institutional context defines, to a large degree, which actors will be involved, how they act, and which new initiatives emerge. In fact, new initiatives are likely to be discussed in already existing coordination bodies in order to avoid large transaction costs that are involved in setting up new bodies (Dieperink et al. 2018). The institutional setting in both countries is rather different as a result of the 1953 Dutch catastrophe and the social-political reactions afterwards. The 1953 event has led to a strong discourse of flood safety coordinated by the central government through the Delta Programme. Flood risk is considered as a matter of public safety and national priority. Regional water management is controlled by the water boards. Water boards have separate elections and raise their own tax. In turn, municipalities are responsible for urban drainage, spatial planning, and the sewer system. Urban flood risk management is strongly driven by national legislation and policy leading to cohesive knowledge production (indicator 2.3 knowledge cohesion) and largely integrated management practices (indicator 5.3 management cohesion). The 'water stress test', that was mandated by the Delta Programme for all Dutch cities, is a clear illustration of this national coordination. Hence, the institutional setting is characterised by a national monopoly on flood safety and public institutions responsible for regional and urban flood safety. The dominance of a single public governance arrangement in the Netherlands seems to limit the scope, interaction and learning of other actors, in particular with respect to the reduction of flood impacts (indicator 1.2 local sense of urgency, 1.3 behavioural internalisation, and 3.3 cross-stakeholder learning, (Dieperink et al. 2018).

Traditionally flood risk management in the UK was focused on drainage of mainly agricultural land, organised through IDBs in the lowlands. From the 1970s onwards, priorities shifted from agriculture towards urban flood protection and ecological non-structural measures within a river basin approach (Wiering et al. 2015). The central government incrementally changed from almost completely decentralised towards more centralised decision-making and funding. However, a process of political devolution can be observed throughout the last decade. In particular, the Cameron administration's 'National Flood and Coastal Erosion Risk Management Strategy' (Environment Agency 2011) ushers for a shift in responsibility towards the LLFA while the central government continues to coordinate policy.

The government has no statutory duty of care to protect land or property from flooding, but has only permissive powers. Private insurance companies provide cover against floods for residential properties and the majority of commercial buildings since the 1950s. Due to technological progress that increases knowledge about flood risk exposure, the pricing system has become much more accurate in revealing previously unknown cross-subsidy (Penning-Rowsell et al. 2014). The risk-based approach led to a great variety in premiums including some 'uninsurable' properties where governmental rehousing programmes or higher safety standards are necessary. This national imposed institutional setting may jeopardise stakeholders' core values, such as their house prices, insurance, and liveability (indicator 4.2 protection of core values). Finally, the responsibilities for emergency planning, spatial planning, and emergency response may be allocated to different local risk management authorities. The flood response strategy therefore tends to be fragmentally organised, whereas proactive flood mitigation is impeded due to a lack of a resourceful authorities that can address SuDS measures at the river basin scale (indicator 9.3 preparedness). In fact, flood risk management largely depends on SuDS measures, particularly in upstream areas which are managed by a variety of local organisation. At the city scale, SuDS also involve the LLFA and water companies that are responsible for sewer drainage system. Therefore, the division of responsibilities, roles, and tasks is rather dispersed and each actor is only accountable for their own often narrowly defined tasks (indicator 7.2 clear division of responsibilities), leading to suboptimal use of policy instruments (indicator 9.1 policy instruments).

The differences in national imposed institutional setting between the UK and the Netherlands also emphasizes different governance conditions. In the Netherlands, city's need to pay extra attention with respect to condition 1 awareness and condition 3 continuous learning, particularly with respect to learning together with stakeholders outside the water sector. In the UK, condition 4 stakeholder engagement process is of particular important because many decisions that impact them are made locally. In addition, the city's multi-level network potential requires priority (condition 7), given the rather fragmented division of tasks and roles.

3. Level of authority to secure long-term financial support
The liberal governance style in the UK regards the task of the government as ensuring the most cost-effective outcome for taxpayers' money (Alexander et al. 2016). Accordingly, the allocation of funding to LLFAs is done on a case-by-case cost-benefit evaluation based on nine Outcome Measures (Johnson and Penning-Rowsell 2010). Since the general election in 2010, a process of political devolution also introduced significant cuts in national funding in response to the state budget deficits. In order to fill this funding gap, local projects that do not or only partially qualify for central funding require a significant financial contribution from local communities, industries, or governmental agencies; a process that is referred to as 'partnership funding' (Environment Agency 2011). Different studies have indicated that these local investments are often initiated after recent flood events through active engagement of Flood Action Groups (FAGs) (e.g., Thaler and Priest 2016; Fielding 2018). In these cases, awareness, knowledge, and learning (conditions 1, 2 and 3) have

to be well-established in order to successfully apply for funding. In particular, cross-stakeholder learning (indicator 3.3) is essential in these cases. However, in most cases, such a financial structure tends to be erratic and may inhibit investments in more holistic and proactive measures (Carter et al. 2015).

In our four case-study cities, we recognised a well-known pattern that shows that often the non-transient well-educated citizens tend to organise themselves and gain a significant influence on local decision-making through various forms of co-management and knowledge co-production (e.g., Michels and De Graaf 2017; Beierle 2002). Therefore, the partnership funding system tends to work appropriately in well-educated middle class communities but not so well in more deprived areas (Thaler and Priest 2016; Fielding 2018). Hence, flood protection levels are diverging in the UK and the local agents of change (condition 6); the stakeholder engagement process (condition 4) and overall capacity-building have become critical for ensuring adequate flood safety standards throughout the country. This is particularly challenging in cities with more deprived communities that lack significant recent floods-experiences (e.g. Thaler and Priest 2016; Fielding 2018; Begg et al. 2015), such as the city of Leicester.

In the Netherlands, differences in flood safety between cities are rather limited. The Delta Programme ensures long-term funding of flood defence through the Delta Fund. In period 2017–2031, about €17 billion is reserved, for which 66% is to ensure water safety measures. Every year, the funding programme is extended with one year (Delta Programme 2017). Regional flood risk is managed by the water boards. Water boards have elected representatives and have the authority to raise tax for regional flood risk management. Likewise, the municipality raises public taxes to finance the sewer system. In this way, long-term financial security is largely ensured, irrespective of political turns, and to some extent, financial crises. Hence, the level of authority to ensure financial support is largely related to condition 6 agents of change. In the Netherlands, visionary agents have secured long-term financial support. In the UK, local entrepreneurial and collaborative agents are essential to gain access to resources, seek and seize opportunities, and to have a significant impact on local decision-making.

6.5 DISCUSSION

In this paper, we found three crosscutting contextual factors that may explain the root cause of the observed differences (Table 6.3) between the analysed cities: (1) flood probability and impact; (2) national imposed institutional setting; and, (3) level of authority to secure long-term financial support. The three crosscutting contextual factors provide a useful narrative to interpret the impeding and enhancing element of governance capacity and help cities in the UK and the Netherlands to identify priorities for flood risk management. Moreover, these contextual factors may enable a better interpretation and prioritisation of activities to increase the capacity to govern flood risk in European cities, because they also adhere to the EU WFD, have comparable levels of wealth and demographics, and they all apply democratic principles. Further research may help us to understand whether these contextual factors also apply to other world regions, or that other contextual factors need to be considered as well to understand the most important impeding and enhancing elements that determine the urban capacity to govern flood risk. Such crosscutting contextual factors may include social-cultural factors. For example, the way that different cultures experience time, frame problems and conceive solutions (Segrave et al. 2014), public-private arrangements (Mees et al. 2014b), or the perception and communication of environmental risk (Wachinger et al. 2013; Buchecker et al. 2013; Morgan et al. 2001), may influence the capacity-building process (Pahl-Wostl et al. 2008). Moreover, urban feedback loops may be different in other world regions. For example, Rahmasary et al. (2018) found that insufficient solid waste collection and treatment led to sewer clogging and urban flooding in Bandung, Indonesia. Such urban flooding also poses the risk of malaria outbreaks and substantial traffic congestion (Abbas and Routray 2014). Moreover, ground subsidence as a consequence of groundwater over-abstraction aggravates urban flooding. Hence, in order to address flood risks in such an urban context requires an improved provision of basic services, such as drinking water, sanitation, and solid waste collection.

The type of assessment being applied in this research provides a snapshot and is merely an indication of what might be expected in the long-term urban transformation process. In order to identify the overarching lessons and to provide applicable and effective knowledge to individual cities, the consistent empirical-based analysis of governance capacity in combination with the identification of influential contextual factors is required. The three crosscutting contextual factors emphasize different elements of governance capacity in both countries. The higher flood probability, decentralised institutional setting, and recent political devolution in the UK emphasizes the responsibility of individuals to pursue their own interests. National budget cuts require local public and private stakeholders to financially contribute to flood management measures. Within this context, condition 1 awareness, 2 useful knowledge, and 4 stakeholder engagement process appear to be essential to empower citizens and local actors and to create the right conditions for them to fulfil the responsibility that is given to them. In particular, the role of individuals that gain access to resources, seek and seize opportunities, and influence decision-making becomes critical (indicator 6.1 entrepreneurial agents). In the Netherlands, the low flood probabilities, national monopoly on flood safety, and long-term financial continuation of flood safety programmes, results in low awareness beyond the water authorities (condition 1). However, sea level rise, increased river discharges, storm events, and ground subsidence necessitate alternative approaches focussed on flood preparedness and the reduction of flood impact (indicator 9.3 preparedness). This will be challenging because these measures are often not cost-efficient due to low flood probabilities and prioritises condition 1 awareness. In both countries, the role of local digital social platforms may provide interesting opportunities to engage citizens and local stakeholders in decision-making and improve awareness and behavioural change (POWER 2018).

At large, individual case studies can provide a deep contextual understanding of the policy process at the cost of generalizability (Gerring 2006). On the other hand, comparative studies parallel several case studies across contexts in order to explain variation, but at the cost of contextual understanding (Dupuis and Biesbroek 2013). The identified contextual factors may serve both purposes. It helps to understand the variation between cities and countries and provides guidelines for individual cities to understand their capacity-development priorities. The literature related to variables limiting or enabling the governance capacity to address water challenges in the context of climate change lack coherence (Eisenack et al. 2014; Plummer et al. 2012). Conceptual rationales and individual case studies provide a plethora of plausible suppositions that are, however, not sufficiently tested on generalizability (Biesbroek et al. 2013; Plummer et al. 2012; Van Rijswick et al. 2014Measham et al. 2011). This study illustrates a diagnostic framework to measure governance capacity consistently across various urban contexts in order to identify overarching patterns, test conceptual presumptions, and validate results that are obtained from individual case studies in order to allow for theory-building. A precondition for such an exercise is to properly account for key crosscutting contextual factors. Based on the principle of parsimony, we limited the number of contextual factors to the minimum required to interpret differences in governance capacity between cities with varying national backgrounds. The crosscutting contextual factors can identify capacity-development opportunities and priorities, and provides a heuristic to pool cities with similar contexts or challenges to enhance mutual learning between them. In this way, the learning potential between cities can be utilised by providing a concrete, applicable, and empirical-based assessment frame that bundles scientific insights regarding the main contextual factors, barriers, and enablers that determine the capacity of cities to govern water-related challenges. Such a coherent assessment in dozens of cities would provide a unique opportunity to test hypotheses' and identify transferable lessons for cities to better address water-related challenges that are based on structured empirical research. Such an approach may facilitate and accelerate the necessary transformation of cities in the face of the unprecedented challenges of water, waste, and climate change in a rapidly urbanizing world (Koop and Van Leeuwen 2017).

6.6 CONCLUSIONS

Urbanization, sea level rise, and extreme rainfall urge cities to further develop their capacity to govern their flood risks. A cohesive conceptual understanding of what governance capacity implies, how it can be measured, and what cities can learn from existing practices, is largely lacking. Empirical studies may be essential to better understand capacity-development opportunities with respect to the various contextual factors at play. Accordingly, we aimed to contribute to a better understanding of the context-specific capacity development priorities of urban flood risk governance in the UK and the Netherlands, and explore crosscutting contextual factors that may explain the observed differences in both countries. We found that the institutional setting in the UK and recent political devolution and national austerity measures enlarged differences in flood safety standards. In this context, the role of citizen awareness, useful knowledge, stakeholder engagement process, and entrepreneurial agents of change become critical components of governance capacity. On the contrary, the Dutch focus on flood safety through centralised public coordination with long-term financial continuity results in high flood safety standards. However, this approach also inhibits incentives to reduce flood impacts and lowers awareness, as most citizens take flood protection for granted. The three crosscutting contextual factors that we have identified provide a useful narrative for cities in the UK and the Netherlands to improve their capacity to govern flood risk. These contextual factors may also apply in other European cities. More research is necessary to gain a deeper understanding of governance capacity development in other world regions and for other urban environmental challenges. We found that urban governance capacity is, to a large extent, a product of multi-level governance processes and therefore cities have to respond to broader national or international contextual factors in order to identify and seize available opportunities to improve their capacity to govern flood risk. A thorough understanding of the different elements of governance capacity and how broader national and international contextual factors influence them is therefore indispensable.

Author Contributions

Conceptualization, S.K., P.D., C.D. and K.v.L. ; Methodology, S.K., P.D., C.D. and K.v.L.; Formal Analysis and investigation, F.G.M., L.S. and S.K.; Writing-Original Draft Preparation, S.K.; Writing-Review & Editing, F.M.G., L.S., C.D., P.D. and K.v.L.

Funding

The European Commission is acknowledged for funding POWER in H2020-Water under Grant Agreement No. 687809.

Acknowledgments

Our gratitude goes to those interviewed, whose participation in interviews was crucial to this investigation. The Governance Capacity Framework is part of City Blueprint Approach developed at KWR Watercycle Research Institute in the context of Watershare (http://www.watershare.eu). The City Blueprint Action Group is part of the European Innovation Partnership on Water of the European Commission (http://www.eip-water.eu/City_Blueprints).

Conflicts of Interest

The authors declare no conflict of interest.

CHAPTER 7

RELATING WATER MANAGEMENT PERFORMANCE TO GOVERNANCE CAPACITY: WHAT ARE THE CAPACITY-DEVELOPMENT NEEDS?

ABSTRACT

This chapter addresses research 5: How does water management performance relate to observed differences in governance capacity between cities?

Urban challenges related to floods, water scarcity and water pollution are amplified by both climate change and unprecedented urban expansion. Although the necessity of capacity-development is widely recognised and emphasized as an important precondition for sustainable water management, it is often unclear how governance capacity is defined, operationalized and measured. In fact, the relation between governance capacity and water management performances remains therefore largely ambiguous. As a consequence, most cities struggle to understand their own water management performances and capacity-development priorities. For these reasons, this chapter is aimed at understanding the key capacity conditions and their inter-relations to explore how water management performance relates to the observed differences in governance capacity between cities. In doing so, we analysed seven cities with respect to their capacity to govern flood risk, water scarcity and wastewater treatment challenges. An in-depth insight into the capacity profiles of each city provided valuable insights regarding the barriers and enablers for improved water management. In particular, cities with high management performance are found to be well-prepared for both gradual and sudden changes and events through the existence of policy and plans with clear allocation of resources and responsibilities, which enables a high statutory compliance. In addition, smart monitoring ensures that gaps in compliances are identified and can be addressed through a process of continuous evaluation and optimization of the use of policy instruments. Such an interaction between implementing capacity and the ability of local authorities to continuously monitor, evaluate and learn seems to be essential to achieve and maintain high water management performance. The number of cities (n=7) is too small to statistically extrapolate this trend. Furthermore, this correlation is not necessarily a cause-effect relation. Nevertheless, it does seem to be a good indication that management performance results from a high governance capacity. Further research is necessary to confirm a causal relation between management performance and governance capacity.

7.1 INTRODUCTION

The frequency and magnitude of challenges such as floods, water scarcity or water pollution put climate change related issues high on the international political agenda. As a result, climate adaptive and water-wise cities are envisioned and promoted and present on various platforms such as C40, 100 resilient cities, Europe's Covenant of Mayors Adapt and IWA's principles of water-wise cities (C40 cities 2017; Rockefeller Foundation 2017; Covenant of Mayors Adapt 2017; IWA 2017). For example, Europe's Covenant of Mayors Adapt aims to assist cities in coordinating the integration of climate change and adaptation measures in urban planning through improved cooperation and coordination between cities. In particular, the synergies of integrating climate policy into an inter-sectoral approach are considered key (CovenantofMayors.eu 2017). IWA's principles of water-wise cities is another example inspiring people to instigate a transition towards water-wise cities according to their principles of 1) generating water services for all, 2) water sensitive urban design, 3) basin connected cities, and 4) water-wise communities. The Sustainable Development Goals (SDGs) of the United Nations are an important global initiative where urban water management is propagated by all 17 SDGs and in particular by SDGs 6 *Ensure access to water and sanitation for all* and 11 *Making cities inclusive, safe, resilient and sustainable* (UN SDGs 2017; UN-Water 2017; UN Habitat III). Specific *targets* have been formulated, such as reducing water pollution, halving the proportion of untreated wastewater, increasing water efficiency, water recycling and safe water reuse. The reduction of water scarcity, improving mitigation and adaptation to climate change, and risk reduction of water-related disasters such as floods also are important goals. Importantly, the SDGs also specify *how* these goals have to be achieved, i.e., through an inter-sectorial, participatory and inclusive approach with an important role for multi-stakeholder cooperation to share knowledge, expertise, technology and financial resources (UN-Water 2017). Accordingly, the role of capacity development is considered as pivotal in enabling these transformations in water governance. Moreover, the various international programmes and initiatives, although somewhat different in their aim and scope, address similar water-related issues and also suggest corresponding strategies. That is to say, they provide a broad long-term vision and emphasize the necessity to transform cities and their water management through capacity-development. Such an overarching rationale – propagated by leading international organisations and programmes – requires better insight into what governance capacity is how it can be measured and how it relates to water management performances.

A better diagnosis of the capacity-development priorities becomes essential to facilitate mutual learning processes between cities. Such a diagnosis enables cities to identify and specify concrete practical steps to understand, evaluate and improve water management. Although the role of governance capacity is often framed as indispensable for such a process, it is often unclear how governance capacity is exactly defined, operationalized and measured (Biesbroek et al. 2013; Eisenack et al. 2014; Plummer et al. 2012). This lack of clarity hinders the identification of the most promising opportunities for city-to-city learning. Therefore, *this chapter is aimed at understanding the key capacity conditions and their inter-relations in order to explore how water management performance relates to the observed differences in governance capacity between cities.* In this way, mutual priorities for city-to-city learning may be identified. In order to do so, seven cities have been selected across the globe. Section 7.2 first provides the key characteristics of these case study cities. Section 7.3, briefly introduces their water management performances. The governance capacity of these cities is consistently analysed in order to understand the key conditions and their interactions in a variety of contexts (section 7.4). Next, section 7.5 delves deeper into the relation between water management performance and the city's governance capacity to address water challenges. Finally, we provide the discussion (section 7.6) and end with the conclusions (section 7.7).

7.2 SCOPE OF THE RESEARCH AND CASE SELECTION

Water challenges transcend administrative boundaries and include many different organizations, each with different responsibilities and interests. Therefore, it may be insightful to analyse how well these organisations work together to address shared water challenges rather than to focus on a single institution. For this reason, the governance capacity has been analysed with respect to three prevailing urban water challenges:

1. **Flood risk:** Approximately 15% of all people worldwide live in flood prone areas including almost all of the world's mega-cities. Sea level rise, vast urban expansion and more extreme rainfall will increase flood vulnerability in cities (Ligtvoet et al. 2014).
2. **Water scarcity:** By 2030, the world is expected to face a 40% freshwater shortage (WRG 2009) which will have a profound impact on human development and social stability.
3. **Wastewater treatment:** Cities are large water polluters due to insufficient treatment of domestic and industrial wastewater. Urban growth will strongly increase water pollution. For example, the nutrient emissions in Africa and Asia are estimated to double or triple within 40 years which will result in large scale eutrophication, biodiversity loss, drinking water insecurity as well as negative effects on fisheries, aquaculture and tourism (Ligtvoet et al. 2014).

Seven cities have been selected to assess these three prevailing water-related challenges. All the cities are national and international centres and the analysis focusses on the municipal jurisdictions in each city. The cities have been selected to give the greatest geographical variety and include most world regions in order to obtain a worldwide scope. Since demographic developments vary substantially, the selected cities also vary in population size and urbanization rate. According to this rationale, the level of urgency also differs with respect to the three prevailing water-related challenges. In order to get a good representation of urban water-related developments worldwide, cities with a variety of water management performances are selected. Water management performance is measured by the City Blueprint performance framework consisting of 25 indicators that assess the urban water cycle and the geometric mean of these indicators, the Blue City Index (BCI; chapters 3 and 4). The seven selected cities are Bandung (Indonesia; Rahmasary et al. 2018a), Ahmedabad (India; Aartsen et al. 2018), New York City (USA; Feingold et al. 2017), Cape Town (Madonsela et al. 2018a,b), Melbourne (Australia), Seoul (Republic of Korea; Kim et al. 2018), and Amsterdam (The Netherlands; Koop et al. 2017; Koop et al. 2018a). The key characteristics of these cities are provided in table 7.1, followed by a concise description of the seven cities. The overall scores are summaries in table 7.2. A more elaborate description can be found in appendix 4.

Ahmedabad (BCI: 3.0)
Ahmedabad is expected to grow by at least 2 million people by 2025 (UN Habitat 2016) while access to safe drinking water and sanitation are limited (Aartsen et al. 2018). Uncontrolled urbanisation and infrastructure development leads to vast urban drainage floods in the rainy season. For example, in 2017 Ahmedabad was affected by 200mm of rainfall in 24 hours that led to 54,000 evacuated people and 123 casualties. Poorly treated wastewater from heavy industry, agriculture and urban sewerage leads to alarming water pollution of the Sabarmati River that runs through the city (Prajapati 2014). Furthermore, unregulated abstractions decrease the groundwater table by several metres annually (Gupte 2011). Finally, the city has regular droughts, aggravated by climate change.

TABLE 7.1 — Key characteristics of seven cities assessed by the Governance Capacity Framework with respect to flood risk, water scarcity and wastewater treatment.

	POP. SIZE[1]	AVERAGE URBANIZATION RATE 2000-2016 (% YEAR^{-1})[2]	LEVEL OF URGENCY		
			FLOOD RISK[3]	WATER SCARCITY[4]	WASTE WATER TREATMENT[5]
Ahmedabad	5,633,927	+ 3.4	High	High	High
Bandung	2,394,873	+ 1.2	High	Low	High
New York City	8,537,673	+ 0.3	High	Medium	Medium
Cape Town	4,014,765[6]	+ 1.9	Medium	High	Low**
Melbourne	4,485,211	+ 1.3	Medium	Low*	Low
Seoul	9,776,305	- 0.1	High	High	Low
Amsterdam	821,752	+ 0.6	High	Medium	Low

1 UNdata City population http://data.un.org/Data.aspx?d=POP&f=tableCode%3A240#f_1
2 UN Data outlook 2016 The World's Cities in 2016 https://www.un-ilibrary.org/population-and-demography/statistical-papers-united-nations-ser-a-population-and-vital-statistics-report_e59eddca-en
3 Percentage of the city that would flood with 1 metre rise in river or sea level: 0-5%: low urgency, 5-40%: medium urgency; 40-100%: high urgency
4 Water exploitation index (freshwater withdrawal as % of renewable resource): 0-10%: low urgency, 10-40%: medium urgency, 40-100%; high urgency
5 Percentage of wastewater treated with secondary treatment standards: 95-100%: low urgency, 70-95% medium urgency, 0-70 high urgency
6 Western Cape Government 2016. Socio-economic profile. https://www.westerncape.gov.za/assets/departments/treasury/Documents/Socio-economic-profiles/2016/City-of-Cape-Town/city_of_cape_town_2016_socio-economic_profile_sep-lg.pdf
* Water exploitation index is currently low. However, Melbourne has experienced a 12 year Millennium Drought that showed that water scarcity was very serious for the city.
** Percentage of wastewater that is treated is high. However, urbanization and under-investments have resulted in overloaded and insufficient wastewater treatment in these plants

Bandung (BCI: 3.9)
Bandung together with Jakarta is part of a growing mega-urban region (Firman 2009). Bandung has more than 120.000 slum dwellers, limited and poorly-maintained wastewater treatment (35% coverage) and groundwater depletion caused by uncontrolled private withdrawals (Rahmasary et al. 2018). Despite an annual precipitation of 1700 mm, Bandung struggles with access to clean water due to strong pollution. Moreover, groundwater recharge is limited by a largely impermeable urban surface (Afiatun et al. 2018). This lack of permeability together with an undersized drainage system, and obstructed by non-collected solid waste, land subsidence and monsoons, leads to many floods and associated health risks (Diskamtam 2015; Rahmasary et al. 2018).

New York City (BCI: 4.8)
In 2012 Hurricane Sandy led to 43 deaths and a $19 billion loss (SIRR 2013). Sandy also led to gas shortages, power outages, evacuation of hospitals, fires due to gas line breaks, and 55% of the 162,700 flooded residences were not insured. Sandy boosted the city's adaptation efforts (NPCC 2013). Off-shore breakwaters, sand-nourishment, green infrastructure and affordable flood insurances were identified as adaptation priorities (Feingold et al. 2017). Based on rainfall data over the past 500 years, the current water surplus is an anomaly and the city can expect drier future conditions (Hayhoe et al. 2007). Continued investments in wastewater treatment to prevent combined sewer overflows, and grey and green infrastructure have improved water quality and are required to further reduce water pollution in the future (NYCEP 2018).

Cape Town (BCI: 4.9)
Cape Town has a low annual precipitation of 348mm. The rapidly urbanizing city and surrounding agriculture rely on water basins fed by winter rainfall, making the city susceptible to rainfall anomalies (New 2002). Climate change-related increase in temperatures, evapotranspiration as well as reduced and more erratic rainfall, form an imminent threat for Cape Town's water supply (Midgley et al. 2007). In 2018, the situation was desperate as despite stringent water use restrictions, supplies were almost emptied. The city also has considerable numbers of slums with limited access to potable water and sanitation, and an annual flood exposure (Madonsela et al. 2018). Finally, urbanization and under-investments have resulted in overloaded and insufficient wastewater treatment (CoCT 2007).

Melbourne (BCI: 6.1)
Melbourne's water provision relies on catchment water which is sensitive to fluctuations in water levels. The city has experienced a decade-long drought (1997-2009), known as 'the Millennium

TABLE 7.2 — The City Blueprint water management performance for the cities of Ahmedabad (Ahm), Bandung (Ban), New York City (NYC), Cape Town (Cap), Melbourne (Mel), Seoul (Seo) and Amsterdam (Ams). Scores are standardized from 0 (low performance to 10 (high performance). Scores are determined through a questionnaire (see chapter 3).

CITYBLUE CITY INDEX (BCI)	**AHM 3.0**	**BAN 3.9**	**NYC 4.8**	**CAP 4.9**	**MEL 6.1**	**SEO 7.3**	**AMS 8.3**
1. Secondary WWT	5	2	7	10	10	10	10
2. Tertiary WWT	0	0	4	10	10	10	10
3. Groundwater quality	4	5	3	5	6	10	6
4. Solid waste collected	9	7	0	0	1	6	2
5. Solid waste recycled	3	1	4	1	4	9	10
6. Solid waste energy recovered	0	0	2	0	0	7	10
7. Access to drinking water	8	6	10	10	10	10	10
8. Access to sanitation	9	7	10	10	10	10	10
9. Drinking water quality	6	6	10	10	10	10	10
10. Nutrient recovery	0	0	7	0	10	1	10
11. Energy recovery	0	0	7	3	9	10	10
12. Sewage sludge recycling	1	2	1	8	1	10	10
13. WWT Energy efficiency	6	2	10	9	7	10	10
14. Average age sewer	6	0	0	4	4	1	6
15. Operation cost recovery	3	6	3	4	5	6	8
16. Water system leakages	5	3	8	8	8	10	9
17. Stormwater separation	3	8	4	10	10	4	8
18. Green space	1	0	1	10	6	4	6
19. Climate adaptation	5	7	10	7	8	10	10
20. Drinking water consumption	9	10	5	9	8	7	10
21. Climate robust buildings	5	6	10	7	4	10	7
22. Management and action plans	4	8	10	7	10	10	7
23. Public participation	2	0	7	4	8	5	8
24. Water efficiency measures	6	6	10	6	9	10	10
25. Attractiveness	6	7	10	4	8	10	9

Drought' (CSIRO 2012; Van Leeuwen 2017). To mitigate this drought, water demand reduced by almost 50% through water restrictions and by replacing drinking water with recycled water and harvested rainwater and stormwater (Grant et al. 2013). Nevertheless, water stress remained high throughout the millennium drought. Recycling of treated wastewater also was applied to improve wastewater treatment effluent (Harris et al. 1996). Finally, in the Port Philip Bay, high density developments with limited drainage capacity put more than 100,000 properties at risk of flooding (Victorian Auditor-General's Office 2005).

Seoul (BCI: 7.3)
Seoul struggles with a strong annual rainfall variety and torrential rain due to climate change. Together with a lack of vegetation and water bodies that infiltrate rainwater, groundwater tables are decreasing leading to land subsidence (Kim et al. 2016). This also leads to runoff, flood-related casualties and infrastructure damage (Park et al. 2013). Torrential rain also causes pollution of the Han River which is by law the only water resource, leading to increased vulnerability to rainfall anomalies (Vrba 2016). Because of contamination episodes, only 5% of the people drink tap water (Ko et al. 2007). Improved wastewater treatment is necessary to reduce river water quality fluctuations. Other water sources are explored and measures, such as permeable surface materials and green roofs, are being adopted.

Amsterdam (BCI: 8.3)
The city is protected from the sea, rivers and lakes through a complex system of dikes, dams and sluices. Flood safety is high but flood response strategy is limited. Due to climate change, the city will experience more droughts and increased heavy downpours while the population density rises (Doomen et al. 2006). About 75% of Amsterdam's sewers separate stormwater, which reduces water pollution from combined sewer overflows (Van der Hoek et al. 2014). The expected temperature rise reduces Dissolved Oxygen (DO) levels in the city's canals. Advanced DO monitoring enables timely flushing with cleaner water from regional water bodies (Korving et al. 2012). Amsterdam's drinking water supply is complex. Most water is transported over 60km from an intake point in the river Rhine to the dunes where it is artificially recharged. After filtration, only moderate post-treatment is required.

7.3 GOVERNANCE CAPACITY PROFILES

This section provides a comparative analysis of the governance capacity profiles with respect to flood risk, water scarcity and wastewater treatment. In total, 105 interviews were conducted, some interviews covering multiple indicators. Each indicator score shown in tables 7.3, 7.4 and 7.5 is based on at least five interviews and extensive literature study. The results are discussed systematically according to the three dimensions knowing, wanting and enabling, and their associated governance indicators as shown in table 7.3 (Koop et al. 2017).

7.3.1 FLOOD RISK

Dimension 1: Knowing

The level of community knowledge (indicator 1.1) of flood risks, impacts, and uncertainties is encouraging (**+** or **++**) in Cape Town, Seoul and Ahmedabad. People are aware of the flood probability and impact because they experience floods regularly, in particular in slums. On the contrary, community knowledge is limited in Melbourne (**-**) and Amsterdam (**0**). Flood risks are considerable with high potential impacts, but most people do not feel responsible and take flood safety for granted. The sense of urgency that responsible authorities feel for flood protection (indicator 1.2) is however high in Amsterdam (**++**) because of a strong institutional embedding primarily at the national level. In Melbourne, local authorities do not feel a sense of urgency to emphasize flood risk management (**-**). For most of the other cities, the sense of urgency is high enough to support small changes but too low for more structural long-term measures (**0**). In most cities, communities and stakeholders try to understand, react, anticipate and change their behaviour in order to address flood risks (**+**). However, flood risk is not fully integrated into a clear inter-sectorial approach that supports adaptive behaviour.
In Ahmedabad and Bandung, there is a growing flood risk awareness resulting in local exploratory research and activities. However, the behaviour of most stakeholders is mostly determined by a rigid policy frame that limits their efforts to address the root causes of floods. Information is available, reliable, and based on multiple sources and methods in Amsterdam, Bandung, Cape Town and Seoul (indicator 2.1). Accordingly, current and future information gaps can be revealed to facilitate well-informed decisions (**+** or **++**). For Ahmedabad, New York City and Melbourne, information availability fits the local demand but exploratory research about local flood risk implications is limited (**0**). Moreover, information may not always be accessible or understandable for non-experts (indicator 2.2; 0). Despite high information availability, transparency also remains limited in Amsterdam. Inter-sectorial knowledge cohesion (indicator 2.3) is generally encouraging (**+**). However, Ahmedabad, Bandung

TABLE 7.3 — Profile of the capacity to govern flood risk in seven cities. Indicators are scored from very encouraging (++) to very limiting (--) the overall governance capacity. Results include the city of Ahmedabad (AHM), Bandung (BAN), New York City (NYC), Cape Town (CAP), Melbourne (MEL), Seoul (SEO) and Amsterdam (AMS). Values in parentheses represent the Blue City Index (BCI).

DIMENSION	INDICATOR	AHM (3.0)	BAN (3.9)	NYC (4.8)	CAP (4.9)	MEL (6.1)	SEO (7.3)	AMS (8.3)
KNOWING	1.1 Community knowledge	+	0	0	++	-	+	0
	1.2 Local sense of urgency	0	0	0	++	-	+	++
	1.3 Behavioural internalization	0	0	+		+	+	++
	2.1 Information availability	0		0		0	+	++
	2.2 Information transparency	0		0		0	+	0
	2.3 Knowledge cohesion	0	0	+		+	+	0
	3.1 Smart monitoring	-		0		++	+	++
	3.2 Evaluation	-		0		++	0	++
	3.3 Cross-stakeholder learning	0		0		0	0	++
WANTING	4.1 Stakeholder inclusiveness	0		+		0	+	++
	4.2 Protection of core values	0		0		+	+	++
	4.3 Progress & variety of options	0	0	+	0	0	0	++
	5.1 Ambitious and realistic goals	0	0	+		+	0	+
	5.2 Discourse embedding	-	0	+		0	+	+
	5.3 Policy cohesion	0	0	+		-	+	+
	6.1 Entrepreneurial agents	-		+		+	+	+
	6.2 Collaborative agents	0	0	0		0	+	+
	6.3 Visionary agents	-	0	++		+	++	++
ENABLING	7.1 Room to manoeuvre	0		+		0	+	+
	7.2 Clear division of responsibilities	0		+	0	0	0	++
	7.3 Authority	0	0	+		0	+	++
	8.1 Affordability	0	0	+	0	0	0	+
	8.2 Consumer willingness to pay	+	0	+		++	-	+
	8.3 Financial continuation	+		+		0	-	+
	9.1 Policy instruments	-	0	+	0	0	+	+
	9.2 Statutory compliance	-		+		-	+	++
	9.3 Preparedness	0	0	+		0	+	++

and Amsterdam have considerable knowledge fragmentation (**0**). In Ahmedabad and Bandung, a basic monitoring (indicator 3.1) of key flood risk features – such as maps of flood depth and flood probability, or early warning systems – are insufficient (**-**) to evaluate the policy effectiveness and improvement options. New York City's monitoring system is able to recognise alarming situations (**0**). For example, weather forecasts enabled impact estimation of Hurricane Sandy well in advance and preparations could have been made (Hewson 2012). However, Sandy also showed that the monitoring system was insufficient to recognize underlying dynamics such as the evacuation of hospitals. Authorities also underestimated the impact on the transportation network, and social deprivation because many people were not insured. Monitoring systems appeared to be more advanced in Melbourne, Cape Town, Seoul and Amsterdam (**+** or **++**). In particular, Melbourne and Amsterdam have a monitoring system that enables them to continuously evaluate, learn and improve policy and anticipate potential future changes. Such an understanding enables continuous evaluation of routines, underlying assumptions, or may even question existing paradigms that are locked in by path-dependency (indicator 3.2). This continuous multi-tier evaluation and cross-stakeholder learning (indicator 3.3) is considered a necessity to achieve long-term integrated management (Armitage 2007; Pahl-Wostl 2009; Pahl-Wostl et al. 2007).

Dimension 2: Wanting

There is a great variety in structures and procedures to ensure that stakeholders feel confident that their core values - such as their livelihoods, jobs or strong convictions - are not harmed (indicator 4.2). Cape Town's and Bandung's stakeholder engagement process can be characterised as non-inclusive (indicator 4.1; **-**). Not all stakeholders are promptly informed, stakeholder consultation is limited, and active engagement is rare. In fact, the stakeholder engagement process is suboptimal for most cities and can be typified as 'rushed' because stakeholders are often not given the time to develop a set of alternatives before a final strategy is selected (indicator 4.3). Policy goals (indicator 5.1) have a confined scope (**-**) in Ahmedabad, Bandung and Seoul. For the other cities, more long-term ambitions are determined based on various future scenarios; however, these goals are often not fully supported by a clear framework of intermediate targets. For most cities, flood policies are interwoven in the historical, cultural and political context (indicator 5.2; 0 or **+**). In Ahmedabad however, a discrepancy between political priorities and flood safety is observed (**-**). In addition, flood risk policy is generally coordinated with coherent multi-sectoral actions that show some overlap (indicator 5.3; **+**). For Ahmedabad and Bandung, policy is more fragmented (**0**). Likewise, Melbourne invests predominantly in other sectors at the expense of flood risk (**-**). The role of individuals who gain access to resources, seek and seize opportunities, and influence decision-making is generally considered to be key (e.g. Patterson et al. 2013; Meijerink and Huitema 2010; Brouwer and Huitema 2017). Interestingly, entrepreneurial agents (indicator 6.1) appeared to be a limiting (**-**) factor in Ahmedabad and Bandung, while it is an encouraging factor in the other cities (**+**). The latter might be related to a limited number of individuals who are able to manage and effectively push forward long-term and integrated flood risk strategies in both cities (indicator 6.3; -). It can also be partly explained by a more top-down managerial culture with stringent tasks and a fragmented division of responsibilities (indicator 5.3).

Dimension 3: Enabling
The limitations in entrepreneurial agents in Ahmedabad and Bandung may be related to the limited freedom of individuals to develop a variety of alternatives and approaches to address flood risk (indicator 7.1; **-**). In turn, this may be explained by the limited availability of skilled staff and restricted financial resources to support staff training. Moreover, the level of legitimate forms of authority that promote long-term and coordinated flood risk management (indicator 7.3) was also restricted (**-**), whereas this was encouraging (**+**) in the other cities. The division of responsibilities was clear but also inflexible and confined to conventional actors (**0**) in most cities. However, Bandung, New York City and Amsterdam are actively changing their division of responsibilities to better govern unprecedented flood risk challenges (**+**). Most cities do not provide affordable climate adaptation services such as dikes, drainage systems and green infrastructure that sufficiently protect citizens (**0**). The willingness to pay for flood protection is generally high, in particular in Cape Town and Melbourne. However, this is limited (**-**) in Seoul due to the high cost of refurbishing the aging infrastructure. This lack of willingness to pay complicates financial continuation (indicator 8.3; **-**). Financial continuation is also problematic in Bandung (**-**), in particular the allocation of limitedly available resources could be optimized better. The use of policy instruments (indicator 9.1) – such as financial incentives, regulations or permits – was suboptimal in all cities. In Ahmedabad, the impact of policy instruments was not monitored and largely unknown (**-**), leading to unintended results (Aartsen et al. 2018). In Bandung, Cape Town and Melbourne the use of policy instruments is fragmented (**0**), with contradicting steering mechanisms. However, knowledge of the impact of policy instruments is increasing in an effort to

optimise its application. In New York City, Seoul and Amsterdam, profound explorative efforts are being made to better use policy instruments (**+**) to achieve coherence with connected policy areas such as spatial planning and water quality. In Ahmedabad and Bandung, statutory compliance (indicator 9.2) is weak (**-**). This can be explained by a limited capacity to enforce policies, but also by inefficient and ineffective policies, and challenges related to urbanisation. In this context, community-based education programmes seem promising (Rahmasary et al. 2018). Investments in flood protection and increased infiltration and storage capacity are required. Experiences with adaptive green and blue infrastructure in Melbourne and Amsterdam are valuable to address the root causes of floods in both cities.

7.3.2 WATER SCARCITY

Dimension 1: Knowing

Knowledge of risks, impacts and uncertainties related to water scarcity (indicator 1.1) is encouraging (**+**) in Ahmedabad and Bandung, whereas this is limiting (**-**) in Amsterdam and indifferent (**0**) in New York City, Cape Town and Seoul. In fact, Ahmedabad and Bandung are the only cities with insufficient access to potable water and an extensive use of private wells. In Seoul, insufficient knowledge of drinking water quality may explain why only 5% of the inhabitant drinks tap water. For Amsterdam, community knowledge is low and people consider it as a task of the government to address water scarcity (OECD 2014). In Cape Town, limited knowledge about the city's vulnerable water supply has led to an alarming water shortage (year 2017/2018) and a steep increase in the local sense of urgency. However, it is unknown how long this sense of urgency will last (Madonsela et al. 2018). Stakeholders in most cities are knowledgeable about the basic dynamics related to water scarcity, have memories of water stress episodes and some notion of possible threats. Still, generally there is a limited (-) sense of urgency (indicator 1.2) leading to only marginal support for water conservation initiatives. Similarly, water conservative behaviour (indicator 1.3) is limited (**-**) in Ahmedabad, Bandung and Seoul. Melbourne is the great exception because the city has, due to its extensive experiences with the twelve years Millennium Drought, much experience with water scarcity. Information availability and in particular access to intelligible information forms a barrier (**-**) in Ahmedabad and Bandung (indicators 2.1 and 2.2). In Melbourne, citizens were engaged in water conservation efforts through many projects that harvested rainwater and stormwater in parks, golf courses or gardens. Water use restriction guidelines were operational, and many water conservation campaigns were launched. For example, '*Target 155*' aimed to reduce per capita

TABLE 7.4 — A comparison of governance capacities to address water scarcity in the cities of Ahmedabad (AHM), Bandung (BAN), New York (NYC), Cape Town (CAP), Melbourne (MEL), Seoul (SEO) and Amsterdam (AMS). Indicators are scored from very encouraging (++) to very limiting (--) the overall governance capacity. Values in parentheses represent the Blue City Index (BCI).

DIMENSION	INDICATOR	AHM (3.0)	BAN (3.9)	NYC (4.8)	CAP (4.9)	MEL (6.1)	SEO (7.3)	AMS (8.3)
	1.1 Community knowledge	+	++	0	0	++	0	-
	1.2 Local sense of urgency	-	0	-	+	++	-	-
	1.3 Behavioural internalization	-	-	+	0	++	-	+
	2.1 Information availability	0	0	0	+	++	+	++
KNOWING	2.2 Information transparency	-	-	0	0	++	+	0
	2.3 Knowledge cohesion	-	0	+	0	+	+	+
	3.1 Smart monitoring	-	-	++	+	++	+	++
	3.2 Evaluation	-	-	0	-	++	+	++
	3.3 Cross-stakeholder learning	0	+	0	+	+	0	+
	4.1 Stakeholder inclusiveness	-	0	0	-	++	+	++
	4.2 Protection of core values	-	0	0	+	+	0	++
	4.3 Progress and variety of options	0	0	0	+	++	+	++
	5.1 Ambitious and realistic goals	0	0	++	0	++	0	+
WANTING	5.2 Discourse embedding	-	0	0	0	++	0	++
	5.3 Policy cohesion	0	+	+	+	+	0	++
	6.1 Entrepreneurial agents	-	0	0	0	++	0	++
	6.2 Collaborative agents	0	0	-	++	+	0	+
	6.3 Visionary agents	0	+	0	0	+	-	+
	7.1 Room to manoeuvre	0	0	0	+	+	-	+
	7.2 Clear division of responsibilities	0	+	0	0	++	0	+
	7.3 Authority	0	0	++	+	+	-	+
	8.1 Affordability	0	0	0	0	++	++	+
ENABLING	8.2 Consumer willingness to pay	+	0	0	+	0	0	-
	8.3 Financial continuation	+	0	+	0	++	0	+
	9.1 Policy instruments	-	0	0	0	+	0	+
	9.2 Statutory compliance	-	-	0	0	++	0	+
	9.3 Preparedness	-	0	+	0	++	+	+

water use to 155 litres a day. A number of programmes aimed to stimulate water saving showers, toilets and washing machines. Finally, the '*School Water Efficiency Programme*' committed 1737 schools to conserve water (Low et al. 2015). Consequently, everyone understood how water could be saved (indicator 2.2; **++**) because of the provision of cohesive knowledge (indicator 2.3; **++**). Water availability, water withdrawals and domestic, industrial and agricultural consumption are largely unmonitored in Ahmedabad and Bandung (indicator 3.1; **-**). Many citizens in both cities lack access to potable water leading to many private wells, groundwater depletion and land subsidence. The piped system is also poorly monitored with erratic supply and insufficient water quality mainly related to unknown chemical and microbial pollution in the distribution system. Consequently, it is unknown which measures are most cost-efficient and evaluation is rather ad-hoc using unclear criteria (indicator 3.2; **-**). Cape Town's evaluation capacity is limited (**-**). The city's water stress vulnerability was well understood but action to conserve water, harvest rainwater and stormwater, and apply water reuse, were limited until the situation became alarming. Seoul's monitoring and evaluation processes are encouraging (**+**). However, cross-stakeholder learning (indicator 3.3) requires improvement (**0**), in particular with respect to quality perception of the piped water system (Kim et al. 2018).

Dimension 2: Wanting

Ahmedabad and Cape Town do not have standard procedures to inform or consult stakeholders. Moreover, participation procedures are unclear, and stakeholders have little influence on the outcome. Social tensions such as the remnants of the Apartheid regime have led to difficulties in including all stakeholders (indicator 4.1; **-**). Melbourne and Amsterdam have a long tradition in stakeholder engagement while New York City and Seoul can still improve. New York City often limits engagement to consulting stakeholders about plans that are already advanced, with limited time and opportunity for stakeholders to amend them (**0**). Ahmedabad, Bandung, Cape Town and Seoul have realistic goals but do not take longer-term processes into account, such as population growth, climate change and water stress (indicator 5.1; **0**). In Melbourne and Amsterdam realistic and ambitious water conservation goals are embedded into the existing discourse (indicator 5.2; **++**). This is also reflected in coherent policy across geographical and administrative boundaries, sectors and, technical and financial possibilities (indicator 5.3; **+** and **++**). Seoul's fragmented management across sectors and utility services may explain the observed limitations to formulate effective overarching goals and implementation strategies (indicators 5.1, 5.2 and 5.3; **0**). Individuals who show direction, motivate others to follow and mobilize the resources, are active in Melbourne and Amsterdam (indicators 6.1, 6.2 and 6.3; **+** or **++**). However, Ahmedabad, New York City and Seoul show limitations here (**-** or **0**).

Dimension 3: Enabling

The marginal role of agents of change in Ahmedabad, New York City and Seoul might be related to the freedom and opportunity that actors have to develop a variety of alternatives, approaches and innovations (indicator 7.1; **-** or **0**). Seoul has few legitimate forms of power and authority (indicator 7.3; **-**) that push for integrated planning to ensure long-term water provision. In Ahmedabad, New York City, Cape Town and Seoul, the inflexible division of responsibilities (indicator 7.2; **-**) hampers early recognition of risks and may induce more reactive governance. Bandung, Melbourne and Amsterdam, on the other hand, recognize that knowledge and expertise has been scattered and initiate new strategic alliances (**+** or **++**). Limited access to potable water in Ahmedabad, Bandung and Cape Town leads to affordability issues for marginalised groups (indicator 8.1; **0**). Affordability issues also arise for insurances for damages related to water stress in New York City (**0**). The importance of addressing water scarcity is perceived differently by different stakeholders in Amsterdam. In particular, citizens often do not know that the city faces water scarcity. This lack of understanding may explain the reluctance to pay for water services (indicator 8.2; **-**). Ahmedabad, New York City and Amsterdam allocate many resources to address water scarcity. However, resource allocation is based on projects that explore new solutions but lack long-term institutionalised financial continuity (indicator 8.3; **+**). Ahmedabad's implementing capacity (indicators 9.1, 9.2 and 9.3) can be considered a priority (**-**). Responsible agencies are short on expertise and manpower to implement and ensure statutory compliance (indicator 9.2; **-**; Aartsen et al 2018). Consequently, the city is ill-prepared (**-**) for water stress episodes (indicator 9.3). On the contrary, in Melbourne, water retailers are obliged by the state to adopt a joint drought response plan with various levels of water use restrictions depending on the water storage levels. Consequently, retailers have to enforce the restrictions through advance monitoring and fines for non-compliance (indicator 9.2; **+**). In addition, many subsidy programmes stimulated water reuse, grey water systems, and the harvesting of rainwater and stormwater (indicator 9.1; **++**). Melbourne had to apply a reactive approach to cope with the unprecedented droughts. For example, the city installed a $6 billion desalination plant. The drought ended before the plant was completed and no desalinised water has been supplied ever since (Van Leeuwen 2017). Nevertheless it can be concluded that the city, based on its reaction to the Millennium Drought, is relatively well-prepared for a new drought period (indicator 9.3; **++**).

7.3.3 WASTEWATER TREATMENT

Dimension 1: Knowing

In all seven cities, the understanding of causes, impact and urgency to treat wastewater is, although for different reasons, strikingly limited. In fact, community knowledge (indicator 1.1) and the local sense of urgency (indicator 1.2) are slightly more limited for Melbourne, Seoul and Amsterdam, which have more advanced wastewater treatment. These cities require more advanced wastewater treatment to mitigate deteriorating water quality during droughts. In addition, cities will face resource scarcity and have to accomplish a renewable energy transition. Local authorities in Amsterdam and Melbourne are developing approaches to anticipate these challenges through resource and energy recovery from wastewater (indicator 1.3 behavioural internalisation; **++**). In Cape Town, the local sense of urgency to treat wastewater is very encouraging (**++**) since it mitigates the deteriorating water quality caused by water scarcity. In addition, the reuse of wastewater is an important drought mitigation measure. In Ahmedabad and Bandung poor wastewater treatment substantially affects economic output, drinking water supplies and leads to the spread of infectious diseases. However, the understanding of the importance of wastewater treatment is limited. Information availability generally fits the local demand but exploratory research into local water quality dynamics and the role of wastewater treatment is limited in most cities (**0**). Moreover, information may not always be accessible and understandable for non-experts (indicator 2.2; **0**). Cape Town, Melbourne and Seoul are able to use, produce and share different kinds of information and integrate short-term targets and long-term goals amongst different sectors (indicator 2.3; **+**). Knowledge is largely fragmented (**0**) in the other cities leading to ad-hoc goals. In Ahmedabad and Bandung, basic monitoring (indicator 3.1) of domestic and industrial emissions is largely lacking and the wastewater treatment process is poorly monitored (**-** and **0**). The lack of sufficient monitoring is not only a problem in itself; it also hampers policy evaluation (indicator 3.2; **-**). In addition, wastewater treatment authorities work more or less in silo without considering cross-sectorial actions and learning (indicator 3.3; **-**). Interestingly, despite its adequate monitoring systems Cape Town has limited and non-directional evaluation (**-**). Evaluation is irregular, using inconsistent and even ad-hoc criteria.

TABLE 7.5 — Profile of the capacity to govern wastewater treatment challenges in seven cities. A comparison of governance capacities to address wastewater treatment challenges in the cities of Ahmedabad (AHM), Bandung (BAN), New York (NYC), Cape Town (CAP), Melbourne (MEL), Seoul (SEO) and Amsterdam (AMS). Indicators are scored from very encouraging (++) to very limiting (--) the overall governance capacity. Values in parentheses represent the Blue City Index (BCI).

DIMENSION	INDICATOR	AHM (3.0)	BAN (3.9)	NYC (4.8)	CAP (4.9)	MEL (6.1)	SEO (7.3)	AMS (8.3)
	1.1 Community knowledge	0	0	0	0	-	0	-
	1.2 Local sense of urgency	-	0	0	++	0	-	-
	1.3 Behavioural internalization	0	-	0	-	++	-	++
	2.1 Information availability	0	0	+	++	0	0	0
KNOWING	2.2 Information transparency	0	0	0	+	+	0	0
	2.3 Knowledge cohesion	0	0	0	+	+	+	0
	3.1 Smart monitoring	0	-	+	++	+	+	++
	3.2 Evaluation	-	-	0	-	+	0	++
	3.3 Cross-stakeholder learning	-	0	+	+	++	+	++
	4.1 Stakeholder inclusiveness	-	+	+	0	++	+	++
	4.2 Protection of core values	-	+	0	+	++	+	0
	4.3 Progress and variety of options	-	+	0	+	++	0	0
	5.1 Ambitious and realistic goals	+	0	0	++	0	0	+
WANTING	5.2 Discourse embedding	0	0	+	+	+	0	0
	5.3 Policy cohesion	0	0	0	+	-	0	++
	6.1 Entrepreneurial agents	-	+	+	+	++	+	++
	6.2 Collaborative agents	0	+	0	++	+	+	+
	6.3 Visionary agents	+	+	0	+	0	+	+
	7.1 Room to manoeuvre	-	0	0	+	+	+	0
	7.2 Clear division of responsibilities	-	+	+	0	+	+	+
	7.3 Authority	+	0	++	+	+	+	+
	8.1 Affordability	+	0	+	-	+	++	+
ENABLING	8.2 Consumer willingness to pay	0	0	0	++	0	0	0
	8.3 Financial continuation	+	0	+	++	++	0	+
	9.1 Policy instruments	-	0	0	+	+	+	+
	9.2 Statutory compliance	-	-	0	+	+	+	++
	9.3 Preparedness	-	-	0	+	+	+	+

(indicator 7.3; **+**) to address water quality and implement wastewater treatment ambitions. Consequently, agents of change are encouraged to be active and seize opportunities. Ahmedabad is an exception. Wastewater treatment is a big issue that is not embedded in a clear institutionalised division of tasks and responsibilities. In fact, fragmentation leads to situations where no one feels responsibility to tackle water quality issues. Moreover, the room to manoeuvre (indicator. 7.1) is limiting (**-**) entrepreneurial agents in finding innovative approaches to tackle water pollution. In response to many river pollution episodes that affected Seoul's tap water quality, the city strongly invested in more advanced wastewater treatment and quality control at an affordable cost for its citizens (indicator 8.1; **++**). Despite these efforts, most people still perceive tap water as unreliable and do not trust that their money is well spent to ensure good water quality (indicator 8.2; **0**). The latter jeopardizes the financial continuation (indicator 8.3) of an expensive treatment and distribution system that is increasingly subjected to extreme rainfall anomalies. Cape Town's affordability is limited (**-**) due to large social disparities. Particularly, people who do not have access to piped drinking water experience affordability issues. In general, consumer willingness to pay (indicator 8.2) is limited (**0**), which is largely linked with the low levels of awareness about water quality. The financial continuation of current wastewater treatment activities is sufficient (**+** or **++**). However, this does not include the financial continuation of necessary additional investments to improve water quality in Ahmedabad, Bandung, New York City and Cape Town. A very clear distinction can be observed between limited implementing capacities (**-**) in Ahmedabad and Bandung on the one hand, and encouraging (**+**) implementing capacity in Cape Town, Melbourne, Seoul and Amsterdam on the other hand. New York City is somewhat in between with restricted capacity (**-**) to implement water quality policy. In Ahmedabad ad Bandung iparticular, statutory compliance is problematic since it requires better monitoring (indicator 3.1), evaluation (indicator 3.2) and manpower to enforce existing regulations (indicator 9.2) through the adequate use of policy instruments (indicator 9.1).

Dimension 2: Wanting

The stakeholder engagement process is very encouraging (**++**) in Melbourne. In Ahmedabad, it is generally presumed that stakeholders with a supportive attitude are more likely to be engaged than those with a critical stance (indicator 4.1; **-**). Governmental agencies perceive stakeholder consultation as an obstacle that slows down the city's rapid development. In addition, civil society's voice is limited as people are poorly organized through, for example NGOs (Aartsen et al. 2018), which can lead to poor protection of stakeholders' core values (indicator 4.2; **-**). In Melbourne, many projects to replace drinking water with rainwater, stormwater or recycled water, involves close cooperation with citizens and companies. Accordingly, extra effort is being made to improve the inclusiveness of stakeholder engagement (indicator 4.1; **++**). Continued active stakeholder engagement is encouraged to ensure adequate progress, allowing stakeholders to develop a variety of alternatives to choose (indicator 4.3; **++**). Bandung, New York City, Melbourne and Seoul have a more restricted vision about water quality and the role of wastewater treatment as it is restricted to improving the existing situation while assuming that conditions will not change (indicator 5.1; **0**). However, Ahmedabad, Amsterdam and Melbourne, have a much more long-term vision which is supported by a comprehensive set of intermediate targets (**+** or **++**). Amsterdam's policy cohesion (indicator 5.3) is high (**++**). The city has an inter-sectoral approach to improve water quality and finance these measures. For example, stormwater is collected separately from the sewers, flood protection standards of the city's wastewater treatment plant are increased, and the city has an advanced network to monitor dissolved oxygen levels in order to determine when its canals need to be flushed. In addition, Amsterdam is active in resource recovery from wastewater. In particular, the recovery of phosphates is taking place at an industrial level and the city has also found a market to ensure a payback time of 10 years (Van der Hoek et al. 2014). On the contrary, policy cohesion is limited (**-**) in Melbourne, since most of the budget is allocated to addressing other policy fields. For water quality, agents of change are very active in mobilizing the resources, showing direction and motivate others to follow. Notably, Bandung's entrepreneurial, collaborative and visionary agents are encouraging (**+**). However, in Ahmedabad the role of entrepreneurial agents is limited (**-**).

Dimension 3: Enabling

In general, agents of change have moderate room to manoeuvre (indicator 7.1). The division of responsibilities is generally clear (**+**) and there is a substantial level of legitimate forms of authority

7.4 RELATION BETWEEN WATER MANAGEMENT & GOVERNANCE CAPACITY

Considering the governance capacity profiles of the seven cities represented in table 7.3, 7.4 and 7.5, an overall trend can be observed that cities with a lower water management performance expressed in the Blue City Index (BCI) also score lower with respect to the governance capacity indicators. In order to verify this possible correlation, it is first necessary to calculate an index for the governance capacity of a city, i.e., the Governance Capacity Index (GCI). In order to do so, the ordinal scale has been converted into numbers, where ++ (very encouraging) is 4 points; + (encouraging) is 3 points, 0 (indifferent) is 2 points, - (limiting) is 1 point and – (very limiting) is 0 points. This conversion is made for all three challenges (i.e. flood risk, water scarcity and wastewater treatment) and the scores of the three challenges are averaged for each indicator. Next, the geometric average of the 27 averaged indicator is calculated and is plotted against the BCI (Fig. 7.1). This process is repeated for all seven cities. A positive correlation (r=0.83) is found. It is important to note that the number of cities (n=7) is too small to extrapolate this trend and more research is necessary to explore this correlation. Moreover, it should be emphasized that correlations are not necessarily cause-effect relations. However, it does seem to be a good indication that management performance results from a higher governance capacity, as described in the previous assessments. Figure 7.2 also shows the correlation of each governance condition in order to explore which conditions may account for high management performances.

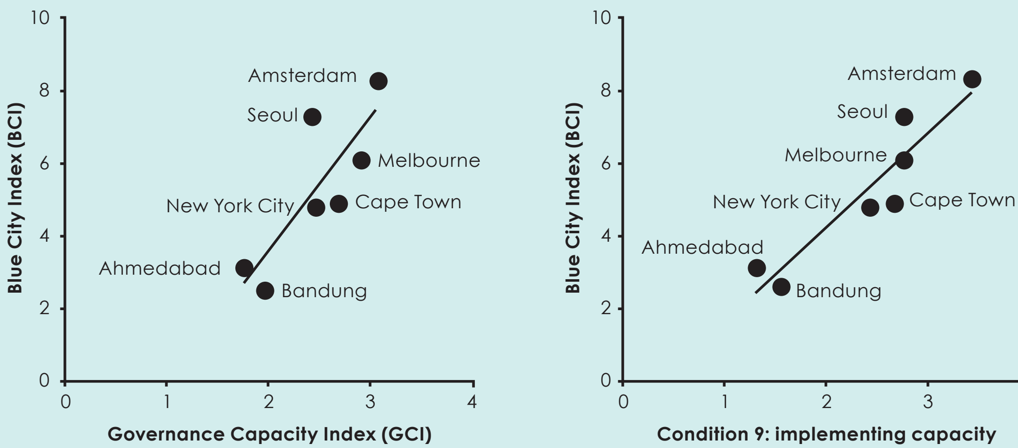

FIGURE 7.1 — Left: Correlation (r=0.83) between water management performance and governance capacity. Management performance is expressed by the geometric mean of 25 City Blueprint indicators, the Blue City Index (BCI). The capacity scores for flood risk, water scarcity and wastewater treatment are first averaged. Next, the Governance Capacity Index (GCI), the geometric mean of the 27 indicators, is calculated. Indicator scores range from very limiting (a score of 0) to very encouraging (a score of 4). Right: Correlation (r=0.93) between BCI and condition 9 *implementing capacity*.

Condition 9 *implementing capacity* has the highest correlation with the BCI (r=0.93). Also condition 3 *continuous learning* (r=0.89), condition 4 *stakeholder engagement process* (r=0.84) and condition 6 *agents of change* (r=0.75) correlate well with the water management performance. Accordingly, the nine indicators belonging to these conditions correlate well too. Cities with high management performance seem to be well-prepared (indicator 9.3 *preparedness*; r=0.89) for both gradual and sudden changes and events through the existence of policy and plans, with clear allocation of resources and responsibilities which enables a high statutory compliance (indicator 9.2 *statutory compliance*; r=0.94). In addition, smart monitoring (indicator 3.1 *smart monitoring*; r=0.87) ensures that gaps in compliances are identified and can be addressed through a process of continuous evaluation (indicator 3.2 *evaluation*; r=0.82) and optimization of the use of policy instruments (indicator 9.1 *policy instruments*; r=0.87). Such an interaction between implementing capacity (condition 9) and the ability of local authorities to continuously monitor, evaluate and learn (condition 3) seems to be essential to achieve and maintain high water management performance.

The role of individuals who provide a long-term vision, promote initiatives, bring actors together, and mobilize the required local resources, seems to be important to achieve higher management performances (indicator 6.1 *entrepreneurial agents*; r=0.81).

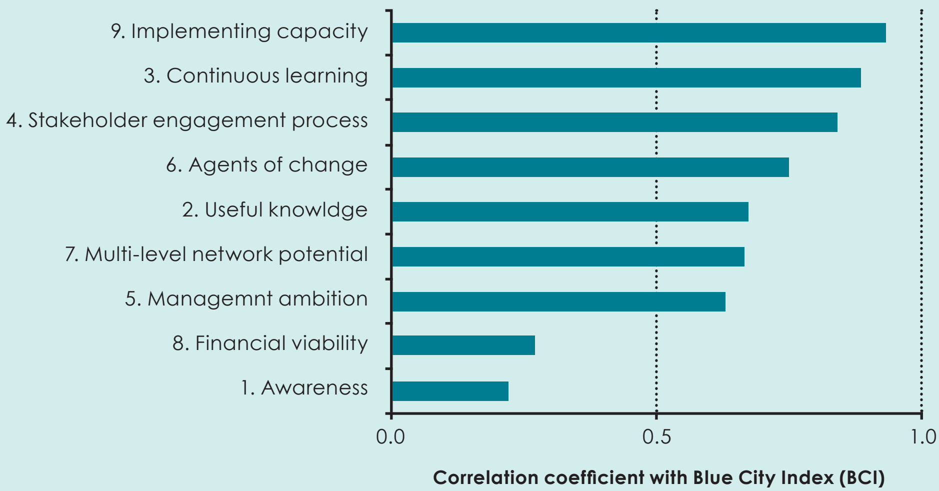

FIGURE 7.2 — Correlation of each governance condition with the Blue City Index (BCI) based on seven cities each assessed with respect to three water challenges: flood risk, water scarcity and wastewater treatment.

Accordingly, individuals who are able to manage and effectively push forward long-term and integrated strategies are more active in cities with higher management performances (indicator 6.3 *visionary agents*; r=0.72). It is also observed that stakeholder engagement is more embedded in the cities with higher management performances. In particular, the inclusion of all relevant stakeholders (indicator 4.1 *stakeholder* inclusiveness; r=0.82) and ensuring that their core values - such as people's livelihood, jobs or core convictions - are not harmed (indicator 4.2 *protection of core* values; r=0.78), are associated with improved water management practices.

However, the general positive relation between water management performance and governance capacity does not apply to all governance indicators. These indicators include 1.1 *community knowledge* (r=-0.76), indicator 8.2 *consumer willingness to pay* (r=-0.27) and indicator 1.2 *local sense of urgency* (r=-0.02). These negative correlations might indicate that cities with lower water management performances that result in substantial flood risk, water scarcity issues and water pollution, in fact lead to higher community knowledge, since people experience the direct consequences and have knowledge of how to deal with it. On the contrary, cities with high management performances like Amsterdam, Melbourne or Seoul have sufficient capacity to govern these challenges and, as a consequence, the direct risks and exposure for most people is marginal. As a result, most people take these services for granted and have limited knowledge and sense of urgency regarding current and future risks, impacts and uncertainties of water challenges. These limiting indicators may lead to less willingness to pay for water services in cities with higher water management performances. For example, if people know little about the flood risk they are likely to underestimate the costs and importance of such protective measures and accordingly may be less willing to pay for flood defences. Similarly, if people have limited knowledge about water pollution and what happens if existing wastewater treatment schemes are not maintained, they might be less willing to pay for wastewater treatment services. However, the contrary also applies. Communities in flood-prone, polluted or water scarce areas tend to know more about the implications of these challenges and are a bit more willing to pay extra for management improvements. However, trust in the proficiency and reliability of local authorities might be a limiting factor.

7.5 DISCUSSION

7.5.1 GOVERNANCE CAPACITY AS A PREMISE FOR IMPROVED WATER MANAGEMENT PERFORMANCES

Based on a total of 21 independent analyses with respect to flood risk, water scarcity and wastewater treatment in seven cities, a positive correlation (r=0.83) between BCI and GCI has been found. This correlation supports the implicit assumption that governance capacity is required to improve management performances. Beyond these seven cities, the analyses have also been performed with respect to one of these water challenges in seven other cities. In Quito (Ecuador) the capacity to govern drinking water conservation has been assessed (Schreurs et al. 2017). The governance capacity to reuse treated wastewater for non-potable application to reduce water stress has been assessed for the Spanish city of Sabadell (Šteflová et al. 2018) and in Jerusalem, Israel (Koop et al. 2018b). Flood risk governance capacity has been assessed in the city of Taipei, Taiwan (Rahmasary et al. 2018b) and the city of Utrecht, the Netherlands (Brockhoff 2018). Moreover, the previous chapter also provides results of governance capacity analyses of flood risk in the cities of Leicester (UK), Milton Keynes (UK) and Rotterdam (The Netherlands). Although applying the exact same assessment methodology, these case studies have not been included in this chapter because they did not include an analysis of all three challenges in each city. In Melbourne, for example, a variance in the governance capacity was observed with respect to the three

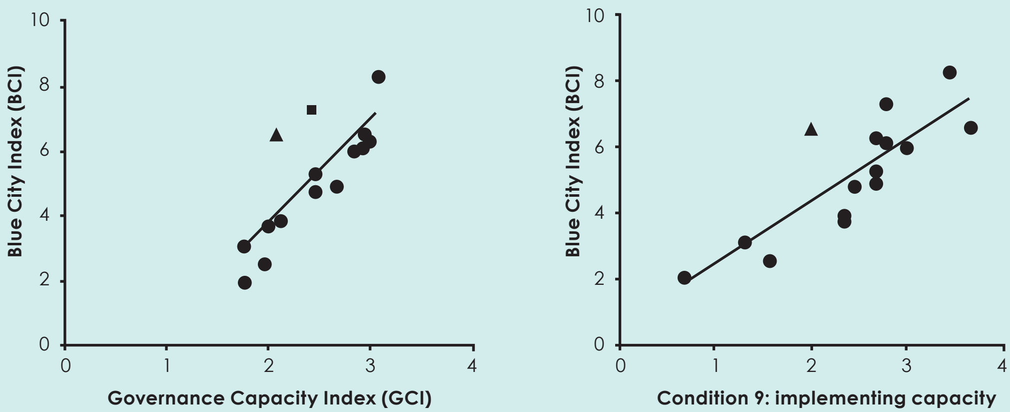

FIGURE 7.3 — Left: the positive correlation (r=0.81) between the Blue City Index (BCI) and the arithmetical average of the 27 governance capacity indicators with respect to flood risk, water scarcity and wastewater treatment in 15 cities. Seoul is marked as square and Milton Keynes as a triangle. Right: positive correlation (r=0.83) between water management performance and the implementing capacity of flood risk, water scarcity and wastewater treatment in 15 cities. Milton Keynes is marked as a triangle.

challenges that would be neglected if only one of the three most profound urban water challenges were analysed. Despite these considerations, the results of these seven other case-studies are in figure 7.3. In this case, the correlation between management performances and governance capacity increases (r=0.81). Similar to the correlations observed in this chapter, condition 9 *implementing capacity* has the highest correlation with management performances (r=0.83).

It is important to note that the BCI, the geometric mean of 25 performance indicators, includes four indicators related to governance which may form an overlap with the governance capacity indicators. In particular, indicator 22 *management and action plans* and indicator 23 *public participation* may measure similar features to indicator 9.3 *preparedness* and indicator 1.2 *local sense of urgency*. An important methodological improvement would be to exclude the four indicators belonging to the category of governance in the City Blueprint performance framework. Another important nuance is that the BCI also includes three indicators related to solid waste treatment which are not related to the three governance capacity analyses topics. If we exclude the indicators belonging to solid waste and governance category from the City Blueprint framework, the correlation between BCI and GCI is higher (r=0.83) because Seoul is more in line with the overall trend. Milton Keynes however remains a bit of an outlier. An explanation would be that only the governance capacity with respect to flood risk has been assessed in Milton Keynes. The city might be more in line with the overall trend if the governance capacity with respect to water scarcity and wastewater treatment were analysed and averaged as was done for the seven cities included in the result sections. The GCI for 15 cities also correlates well with all six World Bank Governance indicators: political instability (r=0.80), control of corruption (r=0.76), rule of law (r=0.74), regulatory quality (r=0.74), government effectiveness (r=0.74) and voice and accountability (r=0.67). These correlations seem to support that the way governance capacity is operationalized and measured across cases is relatively accurate.

7.5.2 METHODOLOGICAL EVALUATION: DATA QUALITY AND CONSISTENCY

In this chapter we show a comparative analysis of the governance capacity framework and embed it into a strategy to facilitate city-to-city learning. In doing so, the way we measure governance capacity has to be as consistent as possible in order to ensure reproducibility of results. Three essential aspects have been taken into account in the governance capacity analyses' procedure in order to ensure the reproducibility of the results:

SQ1 Consistency of what is being measured
SQ2 Minimization of researcher's bias
SQ3 Ensuring inclusiveness

Consistency in what is being measured
To ensure that cities are scored based on the same criteria, the method provides a detailed description of indicators and their associated Likert scoring. In this way, definitions have been made explicit. Furthermore, based on constructive feedback and critical reflections of participants and other researchers, the descriptions have been iteratively refined to further reduce internal overlap and improve clarity and accuracy of operationalization. The methods are transparent, publicly available and published in peer-reviewed journals. The procedure of scoring the indicators has been standardized in order to ensure the scope, level of depth and way of acquiring information has a high level of similarity across different case studies. This procedure is also included in standardized online software: http://beta.tools.watershare.eu/gca/$/. The method explicitly relies on both desk study and interviews. Interview statements have to be supported with written reports, policy documents or scientific knowledge in order to be of value in the indicator scoring. Hence interviewees are continuously asked to provide such information and to provide illustrative examples or others that can confirm certain statements.

Minimization of researcher's bias
The standardized governance capacity analysis procedure also includes two steps explicitly targeted to minimise the researcher's potential bias. First, the interviews are recorded, the length of the interviews is standardized to about an hour and the indicators are structured. Based on the interview the indicator scores are determined and substantiated. The results from the desk study are also included here. This summary is returned to the interviewee with the request to provide constructive feedback in the form of additional argumentation, information to confirm statements and to check whether the summary is in line with their perceptions. This explicit inclusion of feedback is repeated for all the interviews (at least 15 on average). Second, indicator scores and in particular the argumentation of the indicator scores is peer-reviewed by an independent researcher who has access to the recorded files and the consulted literature. In addition, checks are made on the stakeholder selection, and also on whether important literature is missing.

Ensuring inclusiveness
By including all relevant stakeholders in the governance capacity analysis, the results will reflect all the different perspectives within

the local network and ensure legitimate results that are accepted by all. In addition, full inclusiveness ensures that all available knowledge is included for the analysis. The first and most important procedure that ensures inclusiveness is the selection of interviewees. This is made through a specific stakeholder analysis (e.g. Šteflová et al. 2018). All identified stakeholders are divided into an importance/influence matrix in order to categorize them, and ri specify their roles and responsibilities (DFID 2003). In this matrix, importance refers to the priority given to satisfy the needs and interests of a stakeholder. Influence refers to the power of stakeholders to enhance or impede a policy, plan or objective. The importance/influence matrix consists of four classes: (1) crowd (low importance and low influence); (2) context (low importance and high influence); (3) subjects (high importance and low influence); and (4) key players (high importance and high influence). For each class, at least one stakeholder representing the government, the market and civil society were selected as suggested by Lange et al. (2013). Moreover, all key stakeholders also need to be included. The stakeholder analysis is also shared with the local authorities, using their input to include all relevant stakeholders. Multiple persons from the identified key stakeholders are selected, with different roles, areas of expertise, and responsibilities, to minimize the risk of bias and discover socially desirable responses. In addition, the interviewees remain anonymous to ensure that they can speak freely regardless of their position.

Overall it should be emphasized that the results of the governance capacity analysis like other capacity assessments (e.g. Meijer 2018) is temporal in nature and may call for a longitudinal research design. The analysis provides a snapshot, though it is not (yet) explored to what extent the governance capacity is subject to changes over time. One can speculate that changes in staff, austerity measures or capacity development processes can change substantially in relatively short periods of time, in particular at the local level. A longitudinal research design can provide valuable insights into capacity development over time or the impacts of policies and organizational or network reforms. The level of reproducibility may allow for the identification of general patterns of urban capacity development. The comparison of individual indicator scores between cities is also possible provided that the score justifications and contextual background of these cities are taken into account. Accordingly, the correlation between the average of 27 governance capacity indicators and the BCI seems to hold with respect to the identification of general patterns. However, the observed correlation is not a proven causal relation. Because both variables are snapshots of one moment in time, a more elaborate analysis approach to both methods that track changes over time is necessary to understand the covariance between the two variables. In addition, such a research approach could test the hypothesis that a change in governance capacity precedes a change in the water cycle management performance. Finally, the elimination of alternative hypotheses needs to be addressed. In order to do so, the role of contextual factors could be investigated.

7.5.3 CONTEXTUAL FACTORS

In chapter 6, three contextual factors have been identified that can hind at the root causes of observed differences in governance capacity and may enable an adequate interpretation of the relative importance of difference governance conditions. The three contextual factors are: 1) flood probability and impact, 2) nationally imposed institutional setting, and 3) level of authority to secure long-term financial support. These three contextual factors have been identified with respect to flood risk in the Netherlands and the United Kingdom. However, they may be applicable in a broader perspective provided that their formulation is slightly adjusted to: 1) probability and impact of environmental risk, 2) national imposed institutional setting, and 3) level of authority to secure long-term financial support.

The probability and impact of floods, water scarcity episodes and water pollution may emphasize the importance of some conditions and indicators over others. In general, higher probabilities of lower impact events tend to create a stronger appeal to the responsibility of individuals be aware of the risks and act accordingly. For example, many people in Ahmedabad and Bandung use private water purification systems to deal with erratic water supplies. In this context, a high level of citizen awareness to adapt, anticipate, and cope with regular events becomes essential (condition 1 *awareness*). As a result, access to intelligible, applicable and cohesive knowledge also becomes essential (condition 2 *useful knowledge*). In addition, the city's preparedness (indicator 9.3) to deal with regular hazards is important, through mitigation, adaptation and emergency plans that can manage the existing risks. For cities with a low probability of high impact events, preparedness is also key, in particular the anticipation of potential calamities in the case of a high-impact event. Moreover, one could argue that low probability but high-impact events all for local authorities to continuously monitor, evaluate and improve policy and implementation (conditions 3 *continuous learning*, 4 *policy ambition*, and 9 *implementing capacity*). In particular, a long-term and integrated scope seems to be indispensable to be prepared for such events. The probability and impact of water challenges may influence the governance capacity profiles as they have been measured in the seven case studies. The probability of floods, water scarcity and water pollution episodes are relatively high in Ahmedabad and Bandung, which implies that people have experienced events, hazards or nuisance in the recent past and probably expect similar challenges in the near future. Accordingly, awareness and knowledge is to some extent developed to cope with these regular episodes. For New York City, hurricane Sandy was an event with a relative low probability but severe impact, which initiated substantial capacity development. Amsterdam's capacity to govern flood risk is largely related to an even more severe flood in 1953 where 1836 people died. Similarly, Melbourne's experiences with the Millennium Droughts had a far-reaching impact on the city's water supply and led to development of capacity to govern water scarcity. These high-impact events led to a strong discourse embedding (indicator 5.3; + or ++) and thorough capacities development. However, New York City's capacity to govern water scarcity or wastewater treatment is less developed. Likewise, Melbourne's capacity to govern flood risk is relatively poor due to the lack of major flood events. Amsterdam and Seoul have higher capacity to govern all three challenges, although awareness becomes an issue in many cases due to a low probability, meaning that people experience few direct impacts from water challenges. The city of Cape Town is experiencing such an unprecedented high-impact event in the form of water scarcity. The capacity to govern water scarcity was found to be relatively low. Knowledge about the potential threats was well known but specifically a lack of evaluation (indicator 3.2) may have led to the current water scarcity crisis. If the drought is prolonged, capacity development will become a necessity for the city to secure its water supply.

The level of authority and resources given to local actors to govern water challenges has important implications for governance conditions. A decentralized institutional setting provides more freedom to optimise different policy fields to meet the goals, interests and co-benefits of all local actors involved. In such a context, the roles of stakeholder engagement processes (condition 4) and cross-stakeholder learning (indicator 3.3) are emphasized. In addition, entrepreneurial individuals (indicator 6.1) sho promote new initiatives, bring actors together, and mobilize the required local resources, become key players. As a result, the room to manoeuvre (indicator 7.1) that is given to these actors becomes an important precondition for improved urban water governance. Overly strict national directives, policies and laws may limit integrated solutions and inter-sectoral courses of action. For example, the city of Seoul dictates that only surface water can be used for the production of piped drinking water. However, this surface water is vulnerable to pollution because of debris from extreme rainfall or algae blooms due to droughts, whereas groundwater seepage from the underground infrastructure is not reused. Despite the close connections, most cities control water quality, quantity, drinking water and wastewater treatment through different administrative authorities (Lee et al. 2018). Important exceptions are Melbourne's water scarcity policy, and Amsterdam's integrated institutionalized approach to managing drinking water supply, sewerage, wastewater treatment, surface water management, groundwater management, control of the city's canals and providing flood protection (Van der Hoek et al. 2014). Such an integrated approach may be the product of governance capacity or reinforce the local governance capacity.

The financial continuation of existing policies and management practices (indicator 8.3) did not correlate with management performance (r=0.10). However, the continuation of current spending is not the whole story. Success in the joint development, implementation and continuous evaluation of innovative policies and projects requires a substantial staff with sufficient skills, expertise and experience (Collier 1997; Mathy 2007). The financial resources to support sufficient staff are substantial. Moreover, the level of expertise requires high levels of education and specialization which also depends on access to good education, universities and specialized training. For these reasons, it may be no surprise that the Governance Capacity Index correlates high with the country's GDP (r=0.71).

7.6 CONCLUSION

Although the necessity of capacity-development is widely recognised and emphasized as an important precondition for resilient, sustainable or adaptive management, it is often unclear how governance capacity is defined, operationalized, and measured and how it relates to management performance. In particular, with respect to water management and water governance in cities, the role of governance capacity in achieving and maintaining high water management performance is rarely scrutinised in empirical studies. As a consequence, most cities struggle to understand their own water management performances and capacity-development priorities. For these reasons, this chapter is aimed at *understanding the key capacity conditions and their inter-relations in order to explore how water management performance relates to the observed differences in governance capacity between cities*. Using a coherent assessment framework (https://link.springer.com/article/10.1007/s11269-017-1677-7), the governance capacity in seven cities across five continents was assessed and compared with the water management performances, which were measured by the City Blueprint indicator framework. An in-depth insight into the capacity profiles of each city and how they compare with one another provided valuable insights regarding the barriers and enablers for improved water management. In particular, cities with high water management performance seem to be well-prepared for both gradual and sudden changes and events through their advanced policies and plans, with clear allocation of resources and responsibilities. These policies and plans enable a high statutory compliance. In addition, smart monitoring ensures that gaps in compliances may be better identified and can be addressed through a process of continuous evaluation and optimization of the use of policy instruments. Such an interaction between implementing capacity and the ability of local authorities to continuously monitor, evaluate and learn seems to be essential to achieve and maintain high water management performance. The number of cities (n=7) is too small to extrapolate this trend. Furthermore, correlations are not necessarily cause-effect relations. However, the observed positive correlation (r=0.83) between water management performance and governance capacity does seem to be a good indication that management performance results from a higher governance capacity. In order to find a cause-effect relation, it is necessary for more city analyses that are repeated over time, to test for covariance, investigate whether capacity-development precedes improvements in management performances, and in order to exclude alternative explanations. Thus, further research may enable the identification of causal relations and facilitate a better understanding of capacity-development priorities.

CONCLUSIONS & REFLECTIONS

Chapter 8
Conclusion and reflections

CHAPTER 8

CONCLUSION AND REFLECTIONS

8.1 INTRODUCTION

Water challenges are becoming ever more urgent in a world of unprecedented population growth, depleting resources and increasing climate change impacts (UNFCCC 2015). Vulnerability continues to increase, due to the combined impacts of sea-level rise, river flooding, increased frequency and magnitude of extreme rainfall, heatwaves, forest fires, water scarcity and water pollution in a rapidly urbanising world. These challenges call for improved water management and governance capacity in cities to learn and make progress on the path to becoming *water-wise*. Accordingly, the research objective of this dissertation is to increase our understanding of what water-wisdom is and which governance conditions cities require to achieve it, by consistently analysing the water management performance and governance capacity of cities across the globe. Specifically, it deals with the empirically-based understanding of the key conditions for cities to improve their capacity to manage, govern and ultimately become water-wise. In chapter 1, it is argued that the lack of empirically-based comparative research limits our understanding of concrete steps to achieve this goal. More specifically, three reasons are provided that emphasize the relevance of this research.

First, a lack of empirically-based understanding is observed about what a sustainable integrated urban water cycle specifically implies, how it can be operationalized and measured, which concrete steps may exist on the path towards a sustainable integrated water cycle. Moreover, it is hardly empirically explored how a desired situation – such as resilience, sustainability or adaptive capacity – may actually take shape in the field of urban IWRM (Biesbroek et al. 2014; Eisenack et al. 2014; Feola 2014; Patterson et al. 2017). The development of a diagnostic indicator framework may be a meaningful contribution to address this gap in literature.

Second, the governance capacity may have a key role in improving water cycle management of cities. The literature provides a plethora of social factors and conditions that can impede or enhance the ability to adapt and respond proactively to water-related challenges (e.g. Plummer et al. 2012; OECD 2013; Moser and Ekstrom 2010). Despite the valuable insights that these studies provide, the body of literature has arguably not yet established sufficient conceptual coherence necessary to empirically validate the large number of theoretical premises (Biesbroek et al. 2013; Plummer et al. 2012; Van Rijswick et al. 2014). The definitions of many identified barriers and enablers are often not made explicit, nor is it clear how they are operationalized, measured, and how they relate to one another (Eisenack et al. 2014; Plummer et al. 2012). In addition, most of these barriers or enablers are theoretical concepts or are applied within the context of individual case studies without considerable efforts to identify general patterns (Biesbroek et al. 2013; Measham et al. 2011). These limitations call for a more coherent diagnostic analysis that can empirically measure the capacity of cities to govern water challenges. Through consistent reproducible governance capacity assessments, the relation between water management performance and governance capacity can be scrutinised and the role of contextual factors may be understood so as to identify capacity-development priorities and understand the role of cities in the multi-level governance process to address water-related issues.

Third, the role of scientific validity is often emphasized, assuming that this alone is sufficient to feed the policy process (Holman 2009). However, in order to be useful for policymakers, departments and stakeholders across spatial scales and policy sectors, a shared knowledge frame is required that is credible, salient and appeals to multiple audiences with varying backgrounds (Cash et al. 2006; Hegger et al. 2012; Mostert and Raadgever 2008; Reed et al. 2005, 2006; Fraser et al. 2006). Such a shared knowledge frame may open up opportunities for a better exchange of knowledge, good practices and experiences between cities. Understanding their own water management performances, capacity-development priorities and city-to-city learning, may provide cities with action perspectives to better govern water-related challenges. Such an empirically-based frame of reference is largely lacking.

In the remainder of this chapter, answers to the five research questions are provided in section 8.2. Section 8.3 provides the overall conclusions, reflections and contribution to the literature. Section 8.4 provides action perspectives for cities on the road to achieve water-wise management.

8.2 ANSWERING THE RESEARCH QUESTIONS

The main research question is formulated as: *What factors account for water wisdom in urban areas across the globe?*

In order to answer the main question five sub-questions have been discerned.

SQ1 What are the characteristics of a comprehensive framework for assessing water cycle management in urban areas around the world?

In order to study differences in the management of the urban water cycle, it is necessary to consistently apply a coherent empirically-oriented assessment approach in cities with differing water management performances and in different contextual settings in different world regions. In doing so, the City Blueprint Framework (CBF) – an indicator framework assessing the urban watercycle – has been critically reviewed and revised based on the data analysis of 45 municipalities and regions in 27 countries. A distinction was made between water management performance and the broader social, environmental and financial pressures. As a result two separate framework were developed. First the Trends and Pressures Framework (TPF) consisting of 12 descriptive indicators that assessed the main social, environmental and financial pressures that may influence the ability of cities to improve their water management. Second, a purely performance-oriented framework allowed for a more action-oriented conceptualisation of urban water management through the 25 indicators that cover key aspects of the urban water cycle. The efforts necessary to apply a City Blueprint assessment was kept low for the participating cities in order to ensure the inclusion of a broad range of cities, their participation in interactive data collection and to obtain a sufficiently large pool of cities that reflect the global urban environment and its challenges. Accordingly the number of indicators was moderate, and the calculation method required simplicity with relatively low data requirements. It was found that data limitations greatly hampered possibilities to include sustainability components, especially for non-OECD member countries. In particular, indicators related to water quality were found to be largely inaccurate and underestimated water pollution in cities, though cities are generally large emitters of wastewater and solid waste. Therefore, indicators related to the management of wastewater and solid waste were introduced as proxies for urban water quality. Despite data limitations and the principle of only using publicly available data, it was possible to capture the key components of the urban water cycle into 25 performance indicators. The CBF includes elements such as, drinking water, sanitation, sewer infrastructure, and wastewater treatment, as well as indicators related to urban planning such as climate robust buildings, and blue and green areas to adapt to extreme weather. Furthermore, solid waste collection and management were accounted as key components to reduce water pollution and principles of reduction, reuse and recycling of resources was applied in the indicators throughout. In addition, the indicator accuracy and boundaries were improved to better highlight key differences in cities. Likewise, for the overall score of the indicators, the Blue City Index (BCI), the geometric mean of the 25 indicators was adopted as the calculation method to provide an incentive to improve the most urgent lowest scoring indicators. In this way, the differences in key characteristics between cities were better presented, more clearly showing the improvement priorities, opportunities to learn from other cities and solution pathways to improve the urban water cycle as a whole.

SQ2 What levels of water-wisdom can be identified based on empirical urban water cycle management assessments?

This dissertation provides a significant empirical contribution to our understanding of concrete categories of urban development towards achieving water-wise governance. Such developments are far-reaching and can take decades to take shape. However, by having a global scope on the urban watercycle, it was possible to identify urban development categories based on snap-shot City Blueprint indicator assessments. In this way, valuable insights are gained regarding the possible pathways of cities towards optimised water-wise management across the globe. Through this holistic assessment of the key characteristic of watercycle management in 45 municipalities and regions in 27 countries, it was possible to analyse patterns in the indicator scores. Based on a hierarchical clustering of the 25 CBF indicators it was possible to distinguish five categories that were each further described according to the indicator scores and rationale. The categories corresponded well with the overall score, i.e., the BCI, and were therefore interlinked. The following categories were identified: 1. cities lacking basic water services (BCI 0 - 2), 2. wasteful cities (BCI 2 - 4), 3. water efficient cities (BCI 4 - 6), 4. resource efficient and adaptive cities (BCI 6 - 8), and 5. water-wise cities (BCI 8 - 10). Interestingly, none of the 45 municipalities and regions were classified as water-wise. However, a combination of the best indicator scores from the cities assessed results in a BCI of 9.3 points, which is well within this category. It illustrates one of the most important conclusions of this thesis: the massive potential of city-to-city exchange of experiences and lessons learned with existing technologies and measures already applied. In fact the work may show that water-wisdom can be achieved if there is more emphasis on what cities already know and how this knowledge can effectively be shared and applied in other cities. It was possible to describe the key physical characteristics of a water-wise city based on the aggregation of good practices in 45 municipalities and regions. A water-wise city fully utilises resource and energy recovery in its wastewater treatment and solid waste treatment. Such a city fully integrates the element of water into urban planning with multi-functional and adaptive infrastructure, for example by encouraging climate adaptive building and by intertwining blue and green areas in their urban areas. Moreover, local communities are promoted to engage in decision-making and different water-related innitiatives. These cities are largely water self-sufficient, attractive, innovative and circular by applying multiple centralised and decentralised solutions. One could argue that the city of Singapore is perhaps closest to being water-wise.

SQ3 What are the characteristics of a comprehensive framework for assessing water governance capacity in cities around the world?

Each level of urban development towards becoming water-wise may have specific governance barriers and windows of opportunity that provide valuable lessons to enable cities to improve their capacity to better govern their water-related challenges. In order to understand these key governance conditions, a coherent diagnostic framework has been developed to consistently assess cities in multiple contexts. Urban water challenges generally transcend administrative boundaries and include many different organisations, each with different responsibilities and interests. Accordingly, an assessment of the governance capacity to become water-wise requires a focus beyond single institutions or policies and needs to assess the capacity of actors to collaborate and together govern a shared problem. Hence, governance capacity is trans-organisational by nature and requires a problem-oriented approach. In order to be able to compare the governance capacity of different cities, the water-related challenge in question should be relevant within the municipal boundaries. However, the actors involved are by no means limited to local actors, as multiple layers of governance are often involved. Within this context, governance capacity is determined by actors' interactions, which are shaped by social-institutional settings, allocation of resources and actors' frame of reference that includes their interests, values, and culture. As a consequence, the nature of actors' interactions is complex, unpredictable, and susceptible to external social-ecological developments. Therefore, it is concluded that the capacity to govern a water-related challenge is not determined by a single governance condition but rather by the interplay between different key conditions. We rationalised the key conditions according to three dimensions considered to be fundamental: knowing, wanting, and enabling. The "knowing" dimension refers to the need of the involved actors to be aware, understand, and learn about the risks and impacts of strategic choices and policy. In this dimension, the level of awareness (condition 1), existence of useful knowledge (condition 2) and the network's ability to continuously learn (condition 3) were found to be of critical importance. The "wanting" dimension relates to the necessity that actors commit, cooperate, act upon ambitions and use their skills to find solutions. Accordingly, the stakeholder engagement process (condition 4), management ambition (condition 5) and the role of agents of change (condition 6) were identified as key conditions for this dimension. Finally, the "enabling" dimension considers the network's potential to address water-related challenges (condition 7), the financial viability (condition 8), and the existing policy instruments that actors require to realise their ambitions (condition 9: implementing capacity), to be fundamental conditions.

SQ4 What contextual factors influence the development of governance capacity?

The nine governance conditions that are identified are the governance capacity framework are influenced by contextual at different levels. These contextual factors may form the root causes of differences in governance capacity profiles between cities. In order to better account for contextual differences, the role of contextual factors and their impact on capacity-development priorities has been investigated on the issue of flood risk. Based on two case study assessments in the United Kingdom and the Netherlands, three crosscutting contextual factors have been identified that may explain the root cause of the observed differences between their flood risk governance capacity: 1. flood probability and impact, 2. national imposed institutional setting, and 3. level of authority to secure long-term financial support. These contextual factors emphasize different elements of governance capacity in both countries. In the UK, the higher flood probability and decentralised institutional setting, with a recent political devolution and reduction of national funding, emphasizes the responsibility of individuals to pursue their own interests. Within this context, condition 1 awareness, 2 useful knowledge and 4 stakeholder engagement process appear to be essential to create the right conditions for local actors involved in flood risk in order to fulfil their responsibility. In particular, the role of individuals who gain access to resources, seek and seize opportunities, and influence decision-making becomes critical (indicator 6.1 entrepreneurial agents). In the Netherlands, the low flood probabilities, national coordination of flood safety and long-term financial continuation of flood safety programmes results in low awareness beyond the water authorities (condition 1). However, sea level rise, increased river discharges, storm events and soil subsidence necessitate alternative approaches focussed on flood preparedness and the reduction of flood impact (indicator 9.3 preparedness). This is challenging because these measures are often not cost-efficient due to low flood probabilities, and will prioritise condition 1 awareness. These contextual factors may also apply to flood risk governance in other European cities. We found that urban governance capacity is, to a large extent, a product of multi-level governance processes and therefore cities have to respond to broader national or international contextual factors in order to identify and seize available opportunities to improve their capacity to govern flood risk. The probability and impact of environmental risk, the national imposed institutional setting and financial structure may also provide an important structure to interpret the key priorities of capacity-development for other water-related challenges.

SQ5 How does water management performance relate to observed differences in governance capacity between cities?

The scientific literature, international programmes such as sustainable development goals, and cities themselves, consider capacity development as an important condition to improve their management performances. However, there is little research that actually measures governance capacity and management performance, and the relation between them, in particular for cities, is hardly studied. In order to address this knowledge gap the correlation between water management performance and governance capacities has been explored. Water management performances was measured by the 25 indicators that cover key aspect of the urban water cycle (i.e. the City Blueprint performance Framework (Figure 1.2; Chapter 2). The water management performance was assessed in seven cities in five continents. For the same cities, a governance capacity analysis was performed with respect to three of the greatest urban water challenges across the globe: flood risk, water scarcity and wastewater treatment. An in-depth insight into the capacity profiles of each city and how these profiles compare to one another, provided valuable insights regarding the barriers and enablers for improved water management. In particular, condition 3 *continuous learning* and condition 9 *implementing capacity* correspondended very well with water management performances, with a correlation coefficient of 0.89 and 0.93, respectively. Such an interaction between implementing capacity (condition 9) and the ability of local authorities to continuously monitor, evaluate and learn (condition 3) seems to be essential to achieve and maintain high water management performance. Cities with high water management performance seem to be well-prepared (indicator 9.3 *preparedness*) through their advanced policies and plans with clear allocation of resources and responsibilities. These policies and plans enable a high statutory compliance (indicator 9.2 *statutory compliance*). In addition, smart monitoring (indicator 3.1 *smart monitoring*) ensures that gaps in compliances may be better identified and can be addressed through a process of continuous evaluation (indicator 3.2 *evaluation*) and optimization of the use of policy instruments (indicator 9.1 *policy instruments*). The role of individuals who provide a long-term vision, promote initiatives, bring actors together, and mobilize the required local resources, seem to be important to achieve higher management performances (indicator 6.1 *entrepreneurial agents*; r=0.81). It was also observed that cities with higher water management performances seem to have a stakeholder engagement that was more embedded in the decision-making process. On the contrary, lower water management performances often result in more flood risk, higher water scarcity and water pollution and lead to higher community knowledge (indicator 1.1 *community* knowledge; r=-0.76) as people experience the direct consequences and have developed knowledge of how to cope with them. The overall geometric average of the 27 governance capacity indicators, the Governance Capacity Index (GCI) correlated well (r=0.83) with water management performances as expressed by the Blue City Index. The number of cities (n=7) is too small to extrapolate this trend and this correlation is not necessarily a cause-effect relation. However, it does seem to be a good indication that management performance results from a higher governance capacity.

8.3 OVERALL CONCLUSION

Unprecedented urban expansion and the impacts of climate change urge for an improved insight into which factors account for water wisdom in urban areas across the globe. These challenges are relevant and urgent. The main question of this dissertation is: *What factors account for water wisdom in urban areas across the globe?* This question can be divided into two simple though fundamental questions: *'what is water wisdom?'* and, *'which factors account for this water wisdom?'* In order to answer these two questions, it is essential to go beyond theoretical premises and empirically assess, compare and scrutinise actual urban water governance practices in a consistent and coherent manner.

Water-wisdom is understood as an ideal state of preparedness achieved through an optimised integration of institutions, scopes and short-term targets and long-term goals that intertwine with water. Accordingly, a key attribute of water-wisdom in cities is a high management performance in all relevant aspects of the urban water cycle as part of their integrated urban design. Hence, based on a literature review, an integrated indicator framework was developed and applied (see Fig. 8.1) which provides information about, and describes the current state of the urban water cycle, with a significance that extends beyond what is directly associated with the indicator scores. The resulting framework – the City Blueprint – has been applied in 45 cities in 27 countries and therefore provides a significant empirical contribution to our understanding of how cities develop towards water-wisdom. A cluster analysis of the 25 indicators identified five levels of water-wisdom: I cities lacking basic water services, II wasteful cities, III water efficient cities, IV resource efficient and adaptive cities. Although none of the assessed cities scored high on all components of the water cycle, their combined hypothetical achievement may be classified as water-wisdom (level V). Water-wise cities are cities that fully integrate the element of water into urban planning with multi-functional and adaptive infrastructure. These cities are largely water self-sufficient, attractive, innovative and circular, by applying multiple centralised and decentralised solutions together with engaged local communities. Beyond the scientific goal formulation, this holistic indicator approach also provides a clear 'mental image' for cities to help them to envision goals related to water-wisdom.. As such, a water-wise city is a city that scores high on all the water cycle management performance indicators (Fig. 8.1).

In order to identify the key factors that account for water-wisdom, this dissertation has made a strong effort to provide conceptual coherence to the existing literature related to social barriers and enablers to climate adaptation and good governance. Next, this conceptual frame was operationalized into measurable indicators and a standardized research approach that allowed for a high level of transparency and reproducibility. Accordingly, the resulting governance capacity framework enabled the accumulation of knowledge from a total of 15 different case studies that culminated in the identification of key overarching factors that account for water-wisdom. First and foremost, the level of water-wisdom, expressed as the integrated water management performance of a city, correlates strongly with the city's governance capacity (r=0.83; n=15). This correlation supports and substantiates the widely acclaimed notion that capacity-development is essential for improvements in urban water management. In fact, the developed methodology provides a unique opportunity to find a causal relation between governance factors that account for water-wisdom. In order to do so, a longitudinal study is necessary to test for covariance, to investigate whether the governance factors precede improvements in management performances, and to exclude alternative explanations.

This dissertation already provides important insights that improve our understanding of key factors for water-wisdom in cities worldwide. It was found that the interaction between implementing capacity and the ability of local authorities to continuously monitor, evaluate and learn, is essential to achieve and maintain water-wise practices. Cities that have advanced policies and plans with clear allocation of resources and

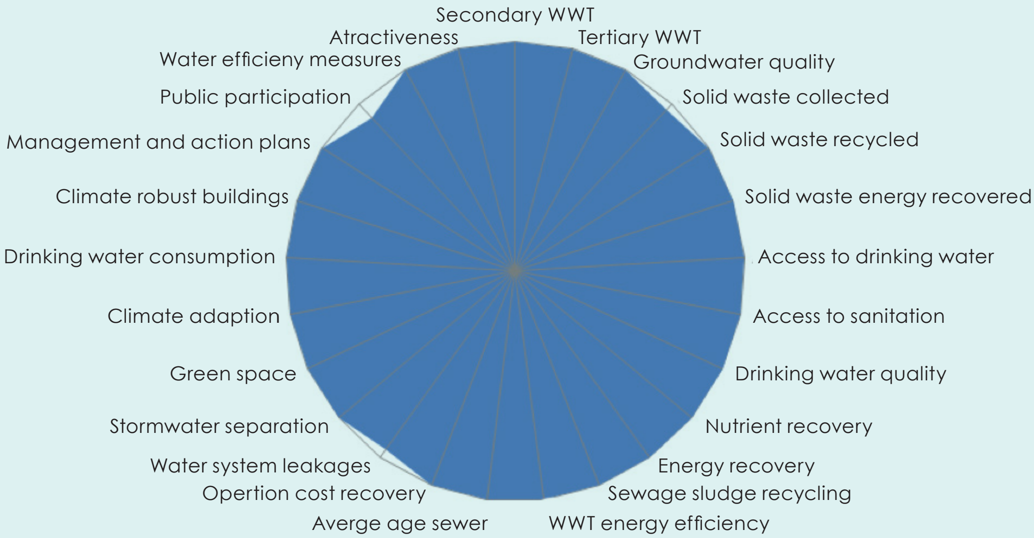

FIGURE 8.1 — Conceptualisation of water-wisdom by combining the highest City Blueprint indicator scores of the urban water cycle in 45 cities in 27 countries. No individual city is already water-wise.

responsibilities achieved a high statutory compliance. Through smart monitoring they were able to identify and address gaps in compliances by optimising the use of policy instruments. In addition, it was found that contextual factors are equalty important for understanding key factors that enable water-wisdom. The comparative assessment of flood risk governance indicates that for each individual case study, at least three crosscutting contextual factors should be considered: the probability and impact of environmental risk, the national imposed institutional setting, and the financial structure.

A key insight of this dissertation is that the identified levels towards water-wisdom are far from optimal and reveal a process of problem-shifting. This problem-shifting refers to a process where a management solution results in the creation of a new problem. Based on 45 urban water cycle assessments, overarching patterns of problem-shifting have been observed in cities across the full range of water management performances. First, cities that improve the access to basic water services often shift their problems towards strong pollution since sufficient treatment of the resulting waste streams is unaccounted for. Second, cities that invest in pollution control, tend to become path-dependent into a waste(water) treatment approach that does not account for the emerging scarcity of raw materials and energy that come along with a urban system that has no or low carbon emission. Third, many cities achieve full access to basic water services and improve their pollution control, but largely disregard the key role that water has in the spatial adaptation to climate change-related challenges of water scarcity, heat waves and water quality. The challenge to leapfrog this array of at least partly avoidable problems, requires a different set of key factors than is currently considered.

8.4 REFLECTIONS & CONTRIBUTION TO THE LITERATURE

8.4.1 REFLECTIONS

This paragraph provides a reflection with respect to the three frameworks developed and applied in this dissertation. With respect to the limited scope of the City Blueprint (chapters 3 and 4) three main points of reflection need to be considered. First, the main limitation in the development of the revised City Blueprint indicator assessment has been the limitations in data, in particular outside Europe. Consequently, important elements of the integrated urban water cycle - such as CO2-emissions, more specific indicators regarding sustainable asset management or modelling calculations about environmental risks - have not been included in the indicator composition (e.g. Hofman et al. 2011). It may therefore be important to emphasize that an integrated water cycle management assessment should not be limited by the City Blueprint indicators. In fact, it is urged that the City Blueprint indicators should be supplemented by other more detailed indicators whenever data is available. Such a '*City Blueprint Extended*' would provide the city with a more complete framework to facilitate their strategic decisions, whereas the City Blueprint indicators allow for international comparison with other cities that have completed a City Blueprint assessment. More advanced City Blueprint frameworks could be developed for specific areas such as the European Union, OECD countries or specific countries where more data is available. The second point of reflection is that the governance category within the City Blueprint performance framework could be removed since it overlaps with the governance category analysis. Such an adjustment would allow for a more accurate study regarding the relation between water management performances and governance capacity. Third, the City Blueprint assessments have a strong bias towards Europe whereas the most urgent urban water challenges are in Africa and Asia. Strong efforts are necessary to assess cities in other world regions. In doing so, it may be important to assess a subset of cities that more or less resembles the variety in size, demographics and water-related pressures of cities worldwide. In fact, since chapters 2 and 3 were published in 2015, 29 additional cities have been assessed with the City Blueprint, 19 of them from outside Europe. Hence, at the end of this dissertation (i.e., November 2018) a total of 74 municipalities and regions will have been assessed by the City Blueprint (see appendix 3).

An important reflection on the relevance of indicators of the governance capacity analysis is whether each condition is relevant in each specific institutional and social setting. In particular, condition 4 *stakeholder engagement process* may be of less relevance in countries with a strong top-down system such as in Singapore or China. Stakeholder engagement might be a western cultural perspective on governance capacity.

An important argument is that regardless of moral principles, many authors consider stakeholder engagement as a means to ensure effective policy implementation. In addition, the role of the researcher is restricted to providing knowledge through the governance capacity analysis. However, what will be done with the results is a political decision. Hence, cities are free to disregard parts of the analysis if they want to. However, for sake of consistency, this dissertation analysed all the framework's conditions in each city. Another important observation is that the framework may not account adequately for cities within social conflict situations or high levels of corruption. For this reason, the use of additional indicators such as the World Bank governance indicators might be essential in these contexts to provide the necessary representation of the main components that determine the capacity to govern water-related urban challenges. The analysis deliberately focusses on specific water challenges and not so much on the overall governance capacity of a city. The main reason to do so is that this focus enables more accurate results that may provide more concrete results for local actors to improve the capacity to govern their water-related challenges. In addition, adopting a specific scope increases the chances that cities will provide political support for the analyses results, since it is not so much perceived as a city rating but more as providing specific points of improvement that cities can implement.

8.4.2 CONTRIBUTION TO THE LITERATURE

Three main literature gaps that pertain to the path towards water-wise management in cities have been identified in chapter 1. First, a lack of empirically-based understanding was observed in the urban development towards water-wise management. Second, a lack of coherence was observed in the identification of governance conditions that may account for improved management performances. Third, the need to develop an empirically-based narrative was identified in order to improve the science-policy interface. In this paragraph, the scientific contribution to each of these three literature gaps will be discussed and some suggestions for further research are proposed.

Improving urban water management: providing an empirically-based understanding

Despite the huge challenges of managing and governing the world's urban water challenges, there is still little empirically-based understanding of concrete steps that cities can take to become *water-wise* (e.g. Brown and Farrelly 2009; Bos and Brown 2011; McCormick et al. 2013). In fact, the literature regarding transformation towards sustainability is an emerging and highly contested scientific debate where various approaches take a largely conceptual orientation towards the question of how trajectories of change unfold over time (Patterson et al. 2017; Geels 2002; Loorbach 2010; Walker et al. 2004; Folke et al. 2010; Chapin et al. 2009). However, much less effort is concentrated on simply measuring how cities, being at different levels of urban development towards water-wise management, are actually evolving. Indicators are a powerful tool to measure such a complex multi-faceted process because indicators are able to point to, provide information about, and describe the current state, with a significance that extends beyond what is directly associated with the parameter value (OECD 2003). However, there is no indicator framework that systematically measures the integrated urban water cycle across different world regions. This dissertation filled this knowledge gap by developing and refining an integrated indicator framework to assess urban water cycle management (chapter 3). The framework was applied in 45 municipalities and regions in 27 different countries and, based on the empirical results, different levels of urban development could be distinguished, and a definition of water-wisdom could be conceptualised (chapter 4). These observed levels of urban development towards water-wise management are far from optimal and cities in lower levels need to leapfrog their management practices. Since these trajectories of change are relatively unexplored with respect to urban water management (Brown and Farrelly 2009; Bos and Brown 2011; McCormick et al. 2013), the identified levels of water wisdom provide a solid basis for future empirical research.

Identifying barriers & enablers: providing a coherent, applicable & integrated diagnosis

The literature of water management, water governance and environmental governance contains a plethora of governance conditions that may account for adaptive or anticipatory management. However, these conditions tend to overlap, are sometimes contradictory and case-specific, and reflect disciplinary scopes (e.g. Biesbroek et al. 2013; Plummer et al. 2012; Measham et al. 2011; OECD 2015b). Definitions of these conditions are often not made explicit, neither is it clear how they are operationalized, measured, and how they relate to one another (Biesbroek et al. 2013; Eisenack et al. 2014; Plummer et al. 2012). Moreover, many conditions are applied within the context of individual case studies, often without considerable efforts to identify general patterns. However, conceptual definitions establish themselves through repeated testing, evaluations, and refinements (Ostrom 2009; Biesbroek et al. 2013; Eisenack et al. 2014). Accordingly, our notion of governance capacity can be considered as the product of a conceptual integration of knowledge from many different case studies and theoretical debates. Therefore, the concept of governance capacity is, in an implicit manner, a rationale that has to be derived from comparative analyses. By integrating the plethora of social barriers and enablers that determine the capacity to govern water-related challenges, the analysis provides a conceptual coherence to the term governance capacity. In doing so, a diagnostic framework has been developed that has been applied to assess existing governance capacities in different cities. Because the assessment consists of a coherent set of explicitly defined indicators that are scored through a standardized data gathering process, there is a large consistency in what is being measured. As such, the researcher's bias is minimized and inclusiveness of all relevant stakeholders and sources of information is ensured. In this way, a database has been developed that has been used to gain a better understanding of the relation with water management performances.

A positive correlation (r=0.83) between water management performance and governance capacity indicates that capacity development precedes good management performances. Although the number of cities (n=15) is too little to extrapolate this trend and although this correlation is not necessarily a cause-effect relation, it does provides an excellent start to explore this relation. In fact, both frameworks provide a reproducible frame that, with additional research efforts, may provide the unique opportunity to find cause-effect relations in the field of water governance. In order to achieve this, more city analyses are necessary that are repeated over time to test for covariance and investigate whether a change in governance capacity precedes a change in water management performances. Finally, the elimination of alternative hypotheses needs to be addressed. In order to do so, the role of contextual factors could be investigated in more detail. An in-depth insight into the capacity profiles of each city and how they compare with one another, has provided valuable insights regarding the barriers and enablers to improved water management (chapter 7). In particular, cities with high water management performance seem to be well-prepared for both gradual and sudden changes through their advanced policies and plans with a clear allocation of resources and responsibilities that enables a high statutory compliance. Smart monitoring ensures that gaps in compliances may be better identified and can be addressed through a process of evaluation and optimization of the use of policy instruments. Such an interaction between implementing capacity and the ability of local authorities to continuously monitor, evaluate and learn seems to be essential to achieve and maintain high water management performance in cities worldwide.

The standardized analyses of governance capacity allows for inter-city comparisons which may enable the identification of potentially relevant contextual factors. These contextual factor may facilitate cities in identifying capacity-development priorities. In fact, based on an analysis of the capacity to govern flood risk in Leicester, Milton Keynes, Rotterdam and Amsterdam, three crosscutting contextual factors have been identified in chapter 6. These contextual factors enable a better interpretation of how capacity can be developed given the sphere of influence of the city in the multi-level governance arena. Besides the identification of overarching patterns, statistically tested correlations and insights into the most determining governance conditions, the governance capacity analysis enabled a detailed understanding of cause-effect relations in individual case studies published for Sabadell (Šteflová et al. 2018), Ahmedabad (Aartsen et al. 2018), Seoul (Kim et al. 2018), Bandung (Rahmasary et al. 2018), Quito (Schreurs et al. 2017), New York City (Feingold et al. 2018) and Cape Town (Madonsela et al. 2018a,b). These studies show that the governance capacity analysis bridges two main bodies of literature that focus either on Europe and North America or on developing regions (e.g. Brown 2011; Brown et al. 2012; Ziervogel et al. 2010). Accordingly, this dissertation studied urban water governance from a global perspective.

Improving the science policy interface: providing an empirically-based narrative

In literature, the role of scientific validity is emphasized assuming that this alone is sufficient to feed information into the policy process (Holman 2009; Hanger et al. 2013). However, in this way valuable scientific knowledge is generally inaccessible for practitioners. In order to be useful in practice, scientific knowledge has to be reshaped into the right network, adopted by agents of change and scientific knowledge needs to be integrated with other local, operational and tacit knowledge. In this way, a wider support and understanding is ensured (Reeds et al. 2005,2006; Fraser et al. 2006; Holman 2009). Such a shared co-produced knowledge frame can function as a portal that opens up avenues of dialogue between tiers of government to broaden existing networks and emphasize the importance of long-term planning and integration (Astleithner et al. 2004; Holman 2009). This shared knowledge frame needs to be salient, credible and appeal to multiple audiences with varying backgrounds in order to enhance them to co-produce knowledge (Cash et al. 2006; Hegger et al. 2012; Mostert and Raadgever 2008). However, such an empirically-based frame of reference or narrative has been largely lacking, which leads to a poor science-policy interface that, in turn, hampers water-wise management. Both the City Blueprint and the Governance Capacity Analysis address this gap in literature.

The three assessment approaches (Figure 1.2) consists of clearly defined steps in which the role of the researcher is distinct and explicitly limited to a role as process facilitator and knowledge manager. Because the analysis is coordinated by independent researchers, an outside perspective or diagnosis is provided that may enable local actors to critically reflect their current practices and develop a deeper understanding of why things went well (the good practices) and what needs to be improved and how (desired improvements). In this way the Governance Capacity Analysis functions as a boundary object (Star and Griesemer 1989) because it provides a mediating frame that is flexible enough to co-produce context-specific narratives that merge different viewpoints, backgrounds and types of knowledge. The broadest possible set of actors is engaged through interviews, to test different arguments and create a wide support for the processes' results. The methods are transparent, publicly available and published in peer-reviewed journals. The procedure of scoring the indicators has been standardized in order to ensure the scope, level of depth and way of acquiring information is consistent and reliable. The database provides detailed substantiation for each indicator score referring to interviewee statements, reports, documents and literature, and explicitly showing the feedback that interviewees gave to the preliminary results. In this way, information can be checked in an easy, accessible and detailed manner by all actors involved in the analysis. This database is included in online software on the Watershare platform: http://beta.tools.watershare.eu/gca/$/. Through this tool, other researchers will be able to use the tool in a reproducible manner, which was done in the cities of Seoul and Cape Town.

Salience is strived for in multiple ways. Both approaches bundle existing knowledge from local authorities and stakeholders by explicitly involving them in the data gathering, processing and evaluation of the results. In this way, they become co-owners of the assessment results. The simple scoring system and graphical presentation of the results enable people to grasp the meaning of provided knowledge at a glance. Action priorities can be identified instantly, and indicators can be directly compared with other cities that may open up opportunities for city-to-city learning and policy-to-policy learning. The systematic reporting of the results enables people to look up information on specific indicators that are of particular interest or importance for them. The indicator scores are a result of the joint performance or capacity of several local actors. As a consequence, improving these indicators requires cooperation and a more holistic inter-organisational approach to find suitable solutions. Beyond the scientific contribution, the City Blueprint water management performance profile has a political and societal meaning because it shows the good intentions of cities that participate in such self-reflective analyses and provides citizens, professionals and politicians with a better mental image of the importance of water-related challenge in their city. The salience of this work is also strived for through active involvement within the European Innovation Platform on Water (EIP Water: https://www.eip-water.eu/), and through the '*Urban Water Atlas for Europe*' published by the European Commission: https://ec.europa.eu/jrc/en/publication/urban-water-atlas-europe. The atlas comprises 40 City Blueprint assessments and the mayors of all participating cities received a copy (Gawlik et al. 2018).

8.5 THE ROAD TO WATER-WISE CITIES

So far we have identified the differences in water management performances, analysed which governance capacities account for this, and explored how contextual factors may influence capacity development. However, beyond the main research question, the research objective is also related to the science-policy interface. More specifically, the potential of the knowledge developed in this dissertation will be discussed in the context of urban decision-making, with an emphasis on the potential of city-to-city learning.

Water-wise as a leading principle for goal-oriented strategies

In order to overcome fragmentation, overarching goals are required that operate through a synergistic set of measurable objectives and targets covering various sectors, policy fields and operations. The establishment of such a policy frame is a continuous political process of weighing a variety of interests. However, a holistic long-term perspective on how challenges of water, waste and climate change unfold and what kind of ambitions and resources a city requires in anticipating and adapting these challenges are essential to facilitate a well-informed inclusive weighing of interests. For practitioners, it is difficult to grasp the complexity of the urban system and how decisions, including the decision to linger in ‘business as usual’, impact the city. Communicating such information is further complicated, since people with varying backgrounds and expertise need to comprehend this information and relate it to their own actions. In order to measure, evaluate and communicate progress on desired targets, indicators are powerful tools. Accordingly, the set of City Blueprint indicators aim to communicate how well overarching goals - such as meeting basic human needs, reducing vulnerability and minimizing environmental impact - are pursued through various elements of the urban water cycle.

The two indicator frameworks developed in this dissertation are designed to meet two essential criteria in order to facilitate cities on their path to becoming water-wise. First, they are designed to communicate the key principles of water-wise management in a concise and effective manner to the diverse audiences involved. Second, these indicators provide sufficient room for cities to determine their own action priorities which are by definition a result of bargaining, negotiation and comprise. The developed indicators capture the progress towards achieving targets (key performance indicators: City Blueprint) and measure the conditions necessary to achieve these targets (process indicators: governance capacity analysis). Through these indicator assessment results, a clear mental image of what a water-wise city may look like can be developed. Such a mental image is considered indispensable for cities to take action.

Overcoming barriers on the road to water-wise cities

Based on the indicators scores and hierarchical clustering of the City Blueprint results of 45 municipalities and regions, five levels of water-wisdom have been identified: I *cities lacking basic water services*, II *wasteful cities*, III *water efficient cities*, IV *resource efficient and adaptive cities*, and V *water-wise cities*. These empirical insights are in fact a warning signal. These observed levels show an inefficient trajectory, costly and far from optimal trajectories and reveal a process of problem-shifting. A key challenge may be to leapfrog this array of at least partly avoidable problems related to urban infrastructure development (Monstadt 2009). Examples of leapfrogging situations include:

- **Access to sanitation requires connection to wastewater treatment**
  For cities in level I: *cities lacking basic water services*, it is a necessity to improve access to sanitation together with centralised or decentralised forms of wastewater treatment. Improved access to sanitation as a stand-alone measure leads to more efficient drainage of wastewater and strong water pollution. This situation is observed in level II *wasteful cities*. Moreover, for these cities the exposure to polluted water is generally high through polluted (private) drinking water wells, washing, bathing and monsoon flooding, leading to the spread of infectious diseases. In Africa and Asia, nutrient emissions are expected to double or triple in the next three decades, which further emphases the urgency to leapfrog towards systems that combine access to sanitation with wastewater treatment.
- **Reduce, reuse and recover resources from waste**
  Cities in level II: *wasteful cities* have much untreated wastewater and uncollected or poorly treated solid waste that both pollute the environment and result in many indirect costs. The adoption of standardized sectorial approaches applied in level III *water efficient cities*, do alleviate environmental pollution by better treatment but hardly address the root causes, namely the amount of waste that is produced. Since, treatment facilities require high investments and lead to a long-term lock-in of the chosen strategy, it is important for these cities to leapfrog towards a more holistic three-tier approach typified as '*reduce, reuse and recover*'. First *reduce*: by increasing water use efficiency and reducing the production of solid waste through policies such as restrictions for packaging materials, which may result in significant alleviation of pollution levels with moderate costs. Second *reuse*: by stimulating the use of products that can be reused, pollution can be further alleviated. For wastewater, greywater systems in domestic and industrial sites can reduce water consumption. Third *recover*: with well-tested treatment

techniques, it is possible to recover resources such as sparse materials, phosphate or freshwater. Such a strategy provides opportunities to achieve cost-effectiveness in the long term with only moderate additional investments in new treatment facilities. In particular, the reuse of treated wastewater poses a largely untapped resource for non-potable applications in water stressed regions.

- **Integrate urban planning to alleviate impacts of flood, heatwaves and densification**
  Water efficient cities (level III), are vulnerable to climate change and urban growth because of limited adaptation strategies, low share of green space and other spatial adaptation measures. For these cities it is important to leapfrog beyond a sectorial approach to address these issues in an attempt to take into account flood risk, heat risk, water pollution. In addition, also issues such as mobility, air pollution and social cohesion are key considerations for an optimised urban spatial planning. Such integrated spatial planning may also provide low hanging fruit for cities in level II *wasteful cities*, and level I *cities lacking basic water services*.
- **Continued learning for resource self-sufficiency in a changing climate**
  The highest performing cities belong to level IV *resource efficient and adaptive cities*. These cities apply promising initiatives with respect to resource and energy recovery from wastewater and solid waste. In addition, climate change adaptation is increasingly intertwined with mainstream urban planning. These cities are the living labs that foster water wisdom. However, in order to be fully water-wise, progressive efforts for water self-sufficiency, higher levels of resource recovery and increased adaptation to a changing climate are required with respect to each component of the urban water cycle.

Hence, it is essential that cities develop an integrated understanding of the current state of their water cycle and do not repeat the mistakes of other cities by leapfrogging towards higher levels of water wisdom. Such leapfrogging requires governance capacity to overcome issues of management fragmentation, to introduce self-reflective evaluation cycles, and to develop the necessary policy, human resources and expertise. Learning from other cities mistakes, inefficiencies and good practices, may be promising for cities to further reinforce each other's capacity development. In this process, it is essential to recognise that cities do not have to build capacity from scratch but already have good practices as well as individuals and organisations with good ideas and capacities that can be further supported and developed (Vallejo and Wehn 2015).

The role of city-to-city learning to achieve water-wisdom

In order to achieve meaningful city-to-city interaction cities, both the City Blueprint and the Governance Capacity Analysis provide a basis to identify desired improvements and good practices that can be shared with other cities. Mutual learning between cities requires an operable Transnational Municipal Network (TMN). There are three key motivations for cities to join TMNs (Bern and Bulkeley 2009). The first motivator is the exchange of knowledge, experiences and good practices. The second motivation to participate is that TMNs provide an excellent political platform and access to financial resources (Betsill and Bulkeley 2004). TMNs form a collective capacity to influence policy at the central level and member cities get access to first-hand information from central authorities such as new legislative requirements or funding opportunities (Fünfgeld 2015). The third motivator for cities to join a TMN is that it provides benchmarking or some form of certification that improves the city's reputation, visibility and recognition for innovations on the topic. Consequently, a membership can be politically exploited to attract additional funding (Heinrichs et al. 2013; Betsill and Bulkeley 2004) and put the projects or ambitions higher on the local, national or international political agenda.

Despite political and financial opportunities, the principle '*raison d'etre*' of TMNs is to share knowledge, experiences and good practices in order to strengthen each other's capacities. However, *what a good practice is*, *how it is defined*, and *how it can improve the capacity to govern* often remains largely unexplored. Because TMNs are fully horizontal non-authoritative organisations where cities are free to join or leave at any moment, good practices tend to be identified and described in a rather ad-hoc manner. Often ideas or cases are described together with member cities that primarily want to show-case their success stories. In this context, the quality, reliability and transferability of such examples are generally ill-considered. Therefore, it remains largely unknown how mutual learning opportunities are actually identified. Because local governance processes involve many organisations, multiple levels and sectors, most cities struggle to understand their own capacity-development priorities.

However, city-to-city learning requires some preconditions in order to be effective. It is widely acknowledged that successful implementation of innovative policies and projects requires larger administrative staffs with sufficient expertise and experiences (Collier 1997; Mathy 2007). In general, the larger and wealthier cities have the financial resources to meet these conditions (Rashidi and Patt 2018; Den Exter et al. 2014; Dannevig et al. 2012), and these cities are the ones that are actively engaged in TMNs (Hawkins et al. 2016; Krause 2012). Accordingly, TMNs are often primarily 'networks of pioneers for pioneers' (Kern and Bulkeley

2009; Aall 2012), attracting early adopters and organisations leading the sector. On the contrary, many predominantly smaller cities with less financial resources are passive. Their membership is largely a symbolic gesture of political support for the TMN's agenda (Kern and Bulkeley 2009). A key question for mainstreaming urban climate adaptation, seems to be: how can we actively engage the smaller municipalities that have limited financial resources to employ sufficient specialised staff?

A second important precondition for city-to-city learning is that TMNs provide more tangible results for its members through the support of national or transnational goals, policies, guidelines and financial stimuli that require local compliance (e.g. Gierst and Howlett 2013; Hakelberg 2011; Den Exter et al. 2014; Hawkins et al. 2016; De Villiers 2009). International high-profile city networks such as C40 do enhance international awareness and have substantial bargaining power for putting urban climate adaptation higher on the international political agenda. However, these global networks tend to have limited accountability due to a lack of a national or transnational enforcing body to ensure the compliance of member cities to goals and guidelines. In addition, the network's ambitions are often relatively detached from large plurality in national goals and policies. Moreover, language barriers also pose serious challenges (Kern and Bulkeley 2009). Accordingly, Hakelberg (2011) observed that regional networks such as CCP, the climate alliance and energie-cités provide more incentives for member cities to develop a climate action plan than the international high-profile C40 network. In addition, cities entering C40, either adopted a local climate strategy in the first year of their membership or became less and less active (Hakelberg 2011). The latter suggests prolonged membership of a high-profile TMN does not lead to significant climate adaptation efforts, but the implementation of a local action plan does. Moreover, many studies find that most cities that applied sustainability initiatives did that through many horizontal cooperations with private, public and non-profit regional actors (e.g. Dannevig et al. 2012; Zeemering 2012; Portney and Cuttlers 2010; Hanssen et al. 2013). Accordingly, cities active in regional networks tend to adopt more climate policies (Pitt 2010). Therefore, many authors argue that cooperation in functional regional areas, improves coordinated policy responses, reduces knowledge gaps, and builds enforcement structures that reduce transaction costs (Hawkins et al. 2016). The established trust-relations are also argued to improve governance of other environmental challenges.

A promising construction seems to be a combination of regional and global TMNs. Here regional networks can be formed around frontrunners. These front-running cities can share knowledge with neighbouring cities to stimulate them to improve (Den Exter et al.

2014). Since these cities operate in the same region, they face similar regulations and contextual factors, often speak the same language and can work towards a more cohesive strategy in the region. This may be the only option for smaller municipalities to get access to international funding schemes and address environmental challenges with their limited staff and financial resources. Moreover, these frontrunners are already active and have the ambition and capacity to actively engage in an international network where they can exchange knowledge, good practices and actively search for funding opportunities with other frontrunners. Twinning cities may also be important in such a city-to-city learning construction. Twinning is commonly referred to as a form of collaboration between similar institutions that have comparable responsibilities and tasks to execute and typically involves a peer-to-peer exchange of staff (Bontenbal 2013). Besides municipalities, twinning takes place between public services such as central government bodies, universities and hospitals (Jones and Blunt 1999). The direct interaction between like-minded people with similar professional backgrounds working together to address municipal challenges is considered key in city-to-city learning (Johnson and Wilson 2006; Bontenbal 2009; Baud et al. 2010). The level of similarity of these professionals is considered as a unique twinning feature that provides opportunities to create a shared understanding of policy and practices that is necessary for constructive dialogue and trust between participants (Johnson and Wilson 2006). Since research indicates that most adult learning occurs at the workplace and is rather self-directed (Brookfield 1987; Tough 1971), this exchange of professionals seems to be more promising to change work routines and organisational approaches than short-term training or exchange of experiences and knowledge.

In this way, capacity development may go beyond something that a donor city does for the recipient city, but rather a process undertaken jointly with the recipient in a long-term collaborative partnership (Vallejo and Wehn 2015). Because regional approaches may be difficult in the absence of clear regional frontrunners, lack of national support, regulations and guidelines, or limited enforcement of existing policy that reduces local compliance, twinning approaches may provide an interesting solution. Particularly when they are applied in a coherent international regional development strategy where not only municipalities but also other public services twin. In this way, the governance capacity of cities as well as regional or national climate adaptation strategies can be strengthened and can, in turn, reinforce each other. Such a multi-level twinning approach can foster regional development. Interestingly, a major challenge seems to be that the multi-level institutional fragmentation in frontrunner cities needs to be first overcome.

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APPENDICES

APPENDIX 1

OVERVIEW OF IN-DEPTH INTERVIEWS GOVERNANCE

CAPACITY ANALYSIS

In total, 220 in-depth interviews have been conducted and 15 cities have been assessed according to the Governance Capacity Framework. Below the interviewees are provided for each city. The interviewees are anonymised in order to protect the personal information and enable the interviewees to speak freely during the interviews. The full analyses, including the interviewees, consulted literature and justification of the indicator scores can be accessed on demand using the following link: http://beta.tools.watershare.eu/gca/$/

Ahmedabad

- PhD – Gujarat University
- Water scarcity expert – CEE Ahmedabad
- Sr Env Engineer – AMC Sewarage (STP)
- CEE Ahmedabad
- Two interviewees from MHT
- VIKSAT (rural water scarcity)
- Senior Geologist – GWSSB
- Senior Environmental Engineer – GPCB
- Professor – CEPT University
- City Engineer – AMC Drainage
- Spokesperson DPN wastewater treatment
- Engaged citizen / activist
- Director – Paryavaran Mitra
- Director – Urban management Centre
- Deputy Health Officer, New West Zone – AMC Health department
- IPHH

Amsterdam

- Strategic administrator at Water board Amstel, Gooi and Vecht. Portfolio manager of flood defences, spatial planning, ecology and freshwater.
- Strategic advisor at Waternet. Advisor on the implementation of the national Deltaprogram. Project initiator of Vital and Vulnerable and Water-resistant Westpoort as part of multi-level safety measure.
- Strategic advisor at Waternet. Advisor on organisation wide change and acceleration. Deals with strategy and process management, agents of change, transition and future exploration. Also project owner of Rainproof.
- Tactical employee at the Municipality of Amsterdam. Deals with Spatial planning and Sustainability, including Rainproof policy and continuation.
- Strategic administrator at Water board Amstel, Gooi and Vecht. Portfolio manager of freshwater resources management (among other things).
- Tactical advisor at Waternet. Head of the department of

Resource and Nature Conservation and Management.
- Tactical/operational employee at Waternet. Program manager of EU's "Kaderrichtlijn Water". Also team leader of the Water Control System.
- Tactical/operational employee at Waternet. Team leader water plans and projects as well as groundwater planning. Also government official at the Ministry of Environment and Infrastructure dealing with groundwater and the national Deltaprogram.
- Strategic administrator at Water board Amstel, Gooi and Vecht. Portfolio manager of wastewater treatment, Spatial planning and the "Water management plan" (Waterbeheerplan).
- Tactical employee at Waternet. Head of the department Asset Management of the Water Cycle: wastewater collection, purification and sludge treatment.
- Tactical/Operational employee at Waternet. Head of the department logistics and natural resources in the wastewater sector. Deals with the transport of sludge and the marketing channels and manages contracts for chemicals with purchasers.
- Strategic/Tactical employee at the Municipality of Amsterdam, South district. Manager of the business office of (solid) waste collection, previously employed in other districts as well and used to own a company called "Communiverse".
- Strategic advisor at the Waste-to-Energy company (AEB)
- Tactical/Operational (senior) advisor at Waternet. Employed at the department of Research and Advice on the topics of hydrology and ecology as well as ground- and surface water. Is responsible for networking with knowledge institutes. And participates in the Stowa's committee of urban water.
- Strategic advisor at Waternet. Deals with business economic issues, strategy development, benchmarking and the learning cycle within the Water sector
- Tactical employee at Waternet. Crisis manager and co-ordinator. Deals with crisis management, security and net centrical working.

Bandung
- Sub-division of General, staff, data and information – Bandung's Public Work Agency (Dinas Pekerjaan Umum Kota Bandung)
- PPK Operation and Maintenance WRI – Citarum River Basin Council (BBWS CItarum)
- Assistant Professor of SAPPK ITB and RDI's researcher – ITB & RDI
- Community founder & leader – Alingan
- Head of Solid Waste Division – Bandung's Environment and Cleanliness Agency
- Staff member of Legal and Public Relation Divisions – PD Kebersihan
- Lecturer/Researcher – ITB

- Communicty leader – Greeneration
- Head of Environmental Rehabilitation Division – Bandung's Environment and Cleanliness Agency
- Head of Parks (Green Space) Division – Bandung's Settlements, housing area, land and Parks Agency (DPKP3 Kota Bandung)
- Lecturer/Researcher – UPI Bandung
- Community leader – Earth Hour Bandung
- PPK – PIP Working Unit – Bandung's Settlements, housing area, Parks Agency (DPKP3 Kota Bandung)
- Head of Settlements Division – Bandung's Settlements, housing area, Parks Agency (DPKP3 Kota Bandung)
- Staffs of PDAM Tirtawening – R&D, PR, and Customer Service of Wastewater Division – PDAM Tirtawening
- Lecturer/Researcher – ITB
- Residents of RW02 Cijawura subdistrict – Residents
- Head of Settlement Division – Bandung's Settlement, housing area, Parks Agency (DPKP3 Kota Bandung)
- Staffs of PDAM Tirtawening – R&D, PR and Customer Service of Drinking Water Division – PDAM Tirtawening
- Lecturer/Researcher – UNPAD (Padjadjaran University)
- Community leader – Jagaseke

Cape Town

- City official Environmental Resource management – City of Cape Town
- Researcher climate change and urban sustainability – University of Cape Town. African Centre for Cities
- Research and former government employee – University of Cape Town
- Manager wastewater treatment – City of Cape Town
- Water Demand Management and Operational Implementation – City of Cape Town
- Water Programme Manager – GreenCape
- Climate change, energy and resilience manager – International Council for Local Government Initiatives
- Development Facilitation Enterprise and Investments – City of Cape Town
- Bulk water supply – City of Cape Town

Jerusalem

- CEO Water Policy – Hagihon
- Director Water Infrastructure – Hagihon
- Director of Water Measurements – Hagihon
- Project leader: Checking NRW-loss –Hagihon
- Director Water Meter Reading and Billing – Milgam
- Billing department – Hagihon
- Director Water Qulaity laboratories – Hagihon
- Director Repair and maintenance of water infrastructure – Hagihon

- Director of the GIS-System – Hagihon
- Educational programs – Hagihon
- Operation Manager Har Homa Wastewater Treatment Plant – Mavti
- East-Jerusalem Planner – Bimkom
- Researcher – Ir Amim
- Community garden coordinator Jerusalem – Society for nature Protection is Israel
- Founder (and former deputy mayor) – Sustainability Lobby Jerusalem and Jerusalem Green Fund
- Former project leader – NewTech Program
- Community Gardens Agricultural Coordinator – Jerusalem Municipality
- Initiator Rainwater Harvesting in Schools
- Volunteer – Community Garden at Museum of Nature History
- Volunteer – Muslala Rooftop Garden

Leicester
- National Flood Risk Expert – De Montfort University
- Project Officer River Soar – Trent Rivers Trust
- Flood Risk Manager – Leicester City Council
- Flood Warden
- Councillor – Leicester City Council
- Resilience Management – Leicester City Council
- Resilience Management – Leicester City Council
- Resilience Management – Leicester City Council
- Flood Risk Expert – Consultant
- Flood Risk Management Advisor East–Midlands
- Landscape Planner – Leicester City Council
- Landscape Planner – Leicester City Council
- Landscape Planner – Leicester City Council
- Parks and Open spaces volunteer leaders – Leicester City Council
- Parks and Open spaces volunteer leaders – Leicester City Council

Melbourne
- Flood specialist – Melbourne water
- Flood specialist – Clearwater
- Policy experts – Department of Environment, Land, Water and Planning
- Policy experts – Department of Environment, Land, Water and Planning
- Policy experts – Department of Environment, Land, Water and Planning
- Regulator – Essential Service Commission
- Expert water scarcity – Melbourne Water
- Expert water scarcity – Yarra Valley Water
- Expert water scarcity – Yarra Valley Water

- Expert water scarcity – City West Water
- Expert water scarcity – Manningham Council
- Specialist urban heat islands – Department of Environment, Land, Water and Planning
- Specialist urban heat islands – Melbourne Water
- Specialist urban heat islands – City of Melbourne
- Specialist urban heat islands – Monash University
- Wastewater treatment expert – Environmental Protection Authority Victoria
- Wastewater treatment expert – Environmental Protection Authority Victoria
- Wastewater treatment expert – Environmental Protection Authority Victoria
- Wastewater treatment expert – Melbourne
- Wastewater treatment expert – South East Water
- Wastewater treatment expert – South East Water
- Wastewater treatment expert – South East Water
- Wastewater treatment expert – Yarra Valley Water
- Independent environmental consultant
- Solid waste expert – Environmental Protection Authority Victoria
- Solid waste expert – Waste Management company
- Solid waste expert – Metropolitan Waste and Resource Recovery Group

Milton Keynes

- Town council member – Milton Keynes
- Lecturer in Water Governance – Cranfield University
- Strategy consultant – Highways Agency
- Waterbody governance – Environment Agency
- Planning Leader – Milton Keynes Planning Department
- Emergency Planner – Milton Keynes Council
- Director of Operations – Internal Drainage Board

New York City

- Climate Program Director – New York City Dep.
- Executive Director – New York Soil and Water Conservation District and member of the Stormwater Infrastructure Matters collation
- Staff attorney in green infrastructure and urban water issues – RiverKeeper New York City
- Senior attorney and NYC Environment Director specialized in solid waste reforms and drinking water protection – Natural Resources Defense Council
- Director of Recycling Outreach and Education – GROWNYC
- Chief of Staff – NYC Dept. of Sanitation
- Program director for policy – Science and Resiience Institute at Jamaica Bay
- Policy Advisor for coastal resilience – Mayor's Office of Recovery and Resilience

- Director of programs and policy – Waterfront Alliance
- Ecology Director for the Bronx River Alliance – NYC Bronx River Alliance/NYC Parks, Stormwater Infrastructure Matters collation
- Policy Coordinator Environmental Justice – WEACT
- Director of policy – Urban Green Council
- Board member of NYCH20 and director of operation
- Managing director of integrated water management – NYC DEP

Quito
- Six interviewees from EPMAPS
- Two University Students
- Three Citizen respondent
- Two interviewees from FONAG
- Two interviewees from Consorcio Cameren
- Accion Ecologica

Rotterdam
- Senior advisor strategy – Evides
- Researcher Teacher – Hogeschool Rotterdam
- Senior Advisor Flood risk – Municipality of Rotterdam
- Account manager Drainage – Municipality of Rotterdam
- Account manager flood risk – Municipality of Rotterdam
- Advisor Flood risk – Hoogheemraadschap van Schieland en de Krimpenerwaard
- Programme Manager – Rijkswaterstaat Deltaprogramma

Seoul
- Assistant professor – Seoul National University and Environmental Engineer – Integrated Research Institute of Construction
- General Manager – Seoul Water Institute, Bureau of R&D for Water
- Senior Researcher – Seoul Water Institute, Water Recycle Research Division
- Associate Professor – Hongik University, School of Urban and Civil Engineering
- Researcher – Seoul Water Institute, Water Recycle Research Division
- Deputy Director Ministry of Environment, International Cooperation Division – Research Professor Anyang University Department of Environmental Engineering
- Director – The Seoul Institute, Office of Planning and Coordination
- Associate Professor – University of Seoul, Department of Urban Planning and Design, International Urban Development & Climate Change Lab.
- Vice head of Songpa-gu, Seoul

Sabadell

- Simbiosy
- Director of planning and projects – General Society Water of Barcelona (SGAB)
- Director – CONGIAC Consortium of the Integrated Water Management of Catalunya.
- Consultant – Sabadell's water treatment plant Riusec (EDAR RIUSEC)
- Professor – University of Barcelona
- Director of sustainable development – CASSA
- Environmental technician – Barcelona Provincial Government
- Researcher – Institute of Environmental Assessment & Water Research (IDÆA), CSIC
- Professor at Polytechnic University of Catalonia
- Director of the Catalan Water Agency
- Director of the department of sanitation and new uses – CASSA
- Head of supply and reuse – Consortium of the Costa Brava Technical Services
- Councelor Water Cycle, Sabadell City Council
- Director of operational area – CASSA
- Coordinator of public space – Sabadell City Council
- Environmental technician – Figueres

Taipei

- Chief of Water Resources Department and River Basin Planning Division – New Taipei City Government
- Project-Appointed Assistant Researcher, Climate Change Division – National Science and Technology Center for Disaster Reduction
- Professor at Civil Engineering department – National Taipei Technology University
- Professor at Department of Bioenvironmental Systems Engineering – National Taipei University of Technology
- Hydraulic engineering – Sinotech Engineering Consultants
- Division director of the Hydrotech Division – Taiwan Typhoon and Flood Research Institute
- Division Chief of Public Works department – Taipei City Government
- Sub division Chief of technical Division – Taipei Water Department
- Researcher and division Chief climate change related problems – Water Resource Agency
- Senior Technical Specialist and Director Department of National Spatial Planning and Development and Deputy Director Department of National Spatial Planning and Development – National Development Council
- Ph.D. candidate at Department of Bioenvironmental Systems Engineering – National Taipei University of Technology
- Technical specialist and Environmental specialist –

Environmental Protection Administration
- Senior assistant Research fellow – Taiwan Research Institute
- Researcher – Ministry of Science and Technology
- Volunteer – Taiwan Youth Climate Coalition

Utrecht
- Groen-blauwe stad, klimaatadaptatie – Natuur en Milieufederatie Utrecht
- Stimulator at Winnet – Winnet (Water Innovation Network)
- Data analyst – Winnet (Water Innovation Network)
- Daily board member/finance – Regional Water Authority (HDSR)
- Policy consultant wastewater system – Winnet (Water Innovation Network)
- Climate adaptation – Coalition Spatial Adaptation, regional water authority
- Urban water management – Municipality of Utrecht
- Green policy (programme manager) – Municipality of Utrecht
- Climate adaptation/spatial adaptation – Province of Utrecht

APPENDIX 2

OVERVIEW KEY CONTACT CITY BLUEPRINT ANALYSIS

CITY	CONTRIBUTIONS FROM	INSTITUTION	PRIMARY CONTACT
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Reggio Emilia	Vittorio Di Federico	University of Bologna	vittorio.difederico@ unibo.it
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CITY	CONTRIBUTIONS FROM	INSTITUTION	PRIMARY CONTACT
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Stockholm	Misagh Mottaghi Lars Lindblom Kees van Leeuwen Luuk van Loosdrecht	Lund University Stockholm Vatten AB KWR Watercycle Research Institute KWR Watercycle Research Institute	misagh.mottaghi@ chemeng.lth.se lars.lindblom@ stockholmvatten.se
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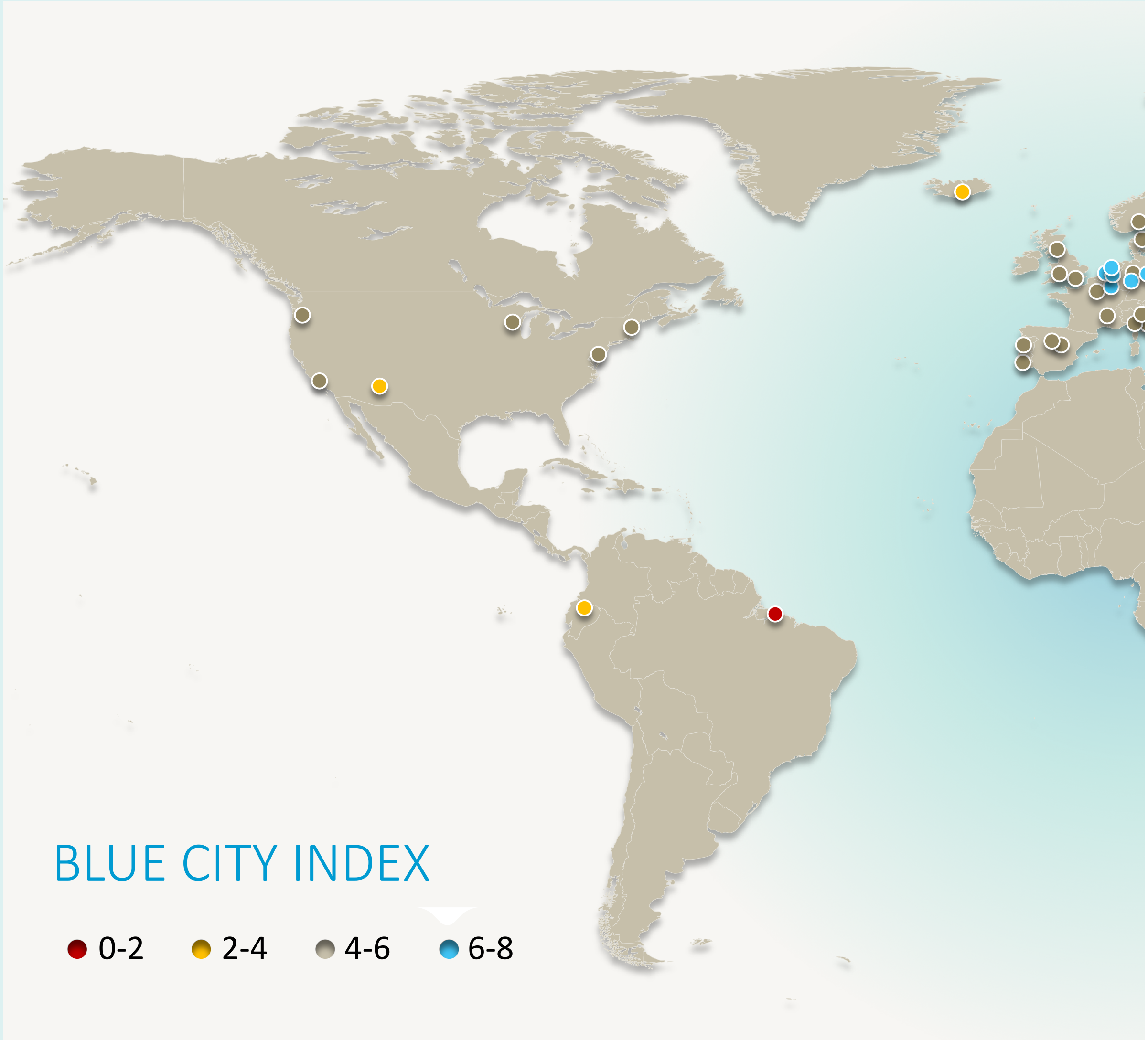
Venlo	Hedwig van Berlo, Patrick Lutgens, Jelle Roorda and Rob Beckers Onneke Driessen Leon Stelten Ruud van Weert Jos Frijns and Kees Van Leeuwen	WML WML WBL WPM City of Venlo KWR Watercycle Research Institute	Kees.van.leeuwen@ kwrwater.nl
Wroclaw	Alicja Lindert-Zyznarska Marisa Fernändez	Departament Klimatu i Energii Climate and Energy Department Wroclawskie Centrum Badan EIT+ Sp. z o.o. ul. Stablowicka 147 54-066 Wroclaw Tel: +48 71 734 70 08, +48 71 734 70 08, Tel. kom: +48 727 663 367 e-mail: alicja.zyznarska@eitplus.pl www.eitplus.pl	Zsoka.ardai@ gmail.com alicja.zyznarska@ eitplus.pl
Zaragoza		ZINNAE-Zaragoza Innova en Agua y Energía	marisa.fernandez@ zinnae.org

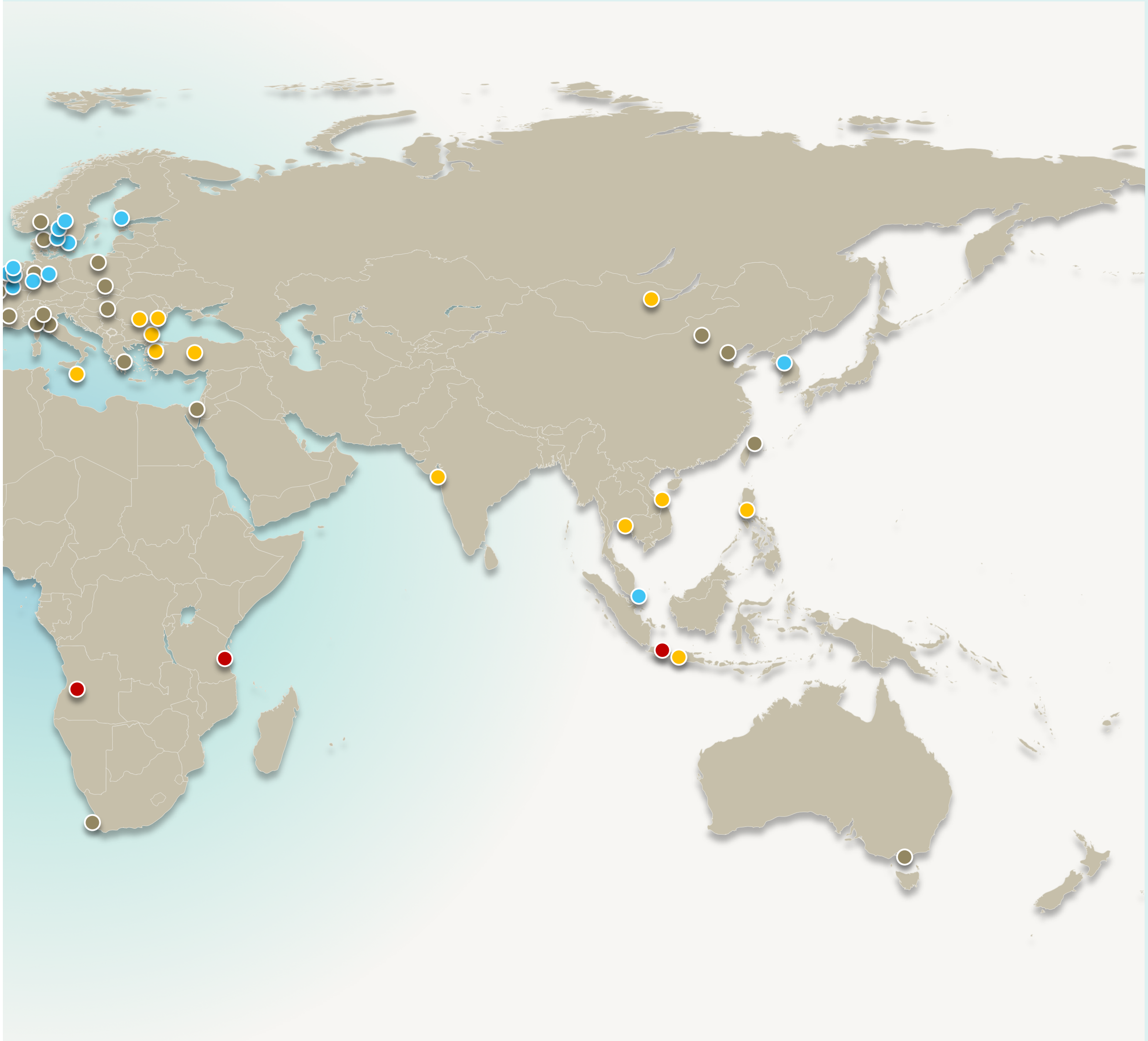
APPENDIX 3

EXTENSION OF THE CITY BLUEPRINT ASSESSMENTS

In chapter 2 and 3 the City Blueprint assessment frameworks have been improved and applied in 45 municipalities and regions in 27 different countries. These chapters have been published in 2015. By the end of this dissertation the number of City Blueprint assessments have increased substantially to 74 municipalities and regions across the world. The City Blueprint assessment is an ongoing activity that is aimed to continue after this dissertation trajectory. The table below provides an overview of the 74 municipalities and regions assessed at the time of the finalization of this dissertation (November 2018). The 29 new City Blueprint analyses are marked in seagreen. In addition, the figure on the next pages provides an overview of the global distribution of the cities.

NR.	CITY, COUNTRY
1	Algarve, Portugal
2	Ahmedabad, India ●
3	Amsterdam, The Netherlands
4	Ankara, Turkey
5	Athens, Greece
6	Bandung, Indonesia ●
7	Bangkok, Thailand ●
8	Bath, United Kingdom ●
9	Belem, Brazil
10	Berlin, Germany
11	Bologna, Italy
12	Boston, United States of America ●
13	Bristol, United Kingdom ●
14	Bucharest, Romania
15	Budapest, Hungary
16	Cape Town, South Africa ●
17	Copenhagen, Denmark
18	Dar es Salaam, Tanzania
19	Dordrecht, The Netherlands
20	Eindhoven, The Netherlands
21	Eslov, Sweden
22	Galati, Romania
23	Genova, Italy
24	Groningen, The Netherlands ●
25	Hamburg, Germany
26	Helsingborg, Sweden
27	Helsinki, Finland
28	Ho Chi Minh City, Viet Nam
29	Hohhot, China ●
30	Istanbul, Turkey
31	Jakarta, Indonesia
32	Jerusalem, Israel
33	Kilamba Kiaxi, Angola
34	Kortrijk, Belgium ●
35	Kristianstad, Sweden
36	Leeuwarden, The Netherlands ●
37	Leicester, United Kingdom ●
38	Ljubljana, Slovenia
39	Lodz, Poland
40	London, United Kingdom
41	Los Angeles, United States of America ●
42	Lyon, France
43	Maastricht, The Netherlands
44	Malmö, Sweden
45	Malta, Malta
46	Manila, The Philipines ●
47	Manresa, Spain
48	Maputo, Mozambique ●
49	Melbourne, Australia
50	Milton Keynes, United Kingdom ●
51	Milwaukee, United States of America ●
52	New York City, United States of America
53	Nieuwegein, The Netherlands
54	Oslo, Norway
55	Phoenix, United States of America ●
56	Portland, United States of America ●
57	Porto, Portugal ●
58	Quito, Ecuador ●
59	Reggio Emillia, Italy
60	Reykjavik, Iceland
61	Rotterdam, The Netherlands
62	Sabadell, Spain ●
63	Scotland, United Kingdom
64	Seoul, Democratic Republic of Korea ●
65	Singapore, Singapore ●
66	Taipai, Taiwan ●
67	Tianjin, China ●
68	Stockholm, Sweden
69	Ulaanbaatar, Mongolia ●
70	Utrecht, The Netherlands ●
71	Varna, Bulgaria
72	Venlo, The Netherlands
73	Wroclaw, Poland
74	Zaragoza, Portugal


BLUE CITY INDEX
0-2
2-4
4-6
6-8



APPENDIX 4

CASE STUDY DESCRIPTIONS CHAPTER 7

Bandung (BCI: 2.6)
Bandung is the capital city of West Java, and the third largest city in Indonesia after Jakarta and Surabaya. The city is located on a highland and has a population of about 2.4 million people. The wider Bandung agglomerate accounts for about 7.7 million people. The Bandung region is a growing mega-urban region (urbanization rate of 1.2% per year) with a mixture of rural and urban activities and blurred rural-urban distinction (Firman 2009). Together with the adjacent Jakarta metropolitan region it forms a 200 kilometer long urban agglomerate that is strongly urbanising. This urbanisation process also significantly contributes to the expansion of the slum population in Bandung, where around 30,281 slum households accounting for about 121.000 people, are scattered over more than half of Bandung's districts (Rahmasary et al. 2018; Tarigan et al. 2016). Bandung's Bojongsoang WWTP connects around 35% of population via sewerage networks (Hendrawan et al. 2013; OECD 2016). However, its performance is decreasing due to poor maintenance and because it receives considerable volume of non-domestic wastewater which disturbs the biological treatment process (Prihandrijanti and Firdayati 2011). Alternatively, more than 83% of the city's population uses septic tanks for storage and disposal of wastewater (Nastiti et al. 2017; Prihandrijanti and Firdayati 2011). Bandung's informal settlements are not connected to central WWTPs. For the slum population in Greater Bandung Area, only 16.8% collect their wastewater into septic tanks, 43.4% dispose their wastewater into drainage networks, while 39.6% discharge wastewater directly into rivers (Sofyan et al. 2016). Meanwhile, Bandung faces water scarcity as a result of an uneven distribution of drinking water. Despite an annual precipitation of 1700 mm (Afiatun et al. 2018; Abidin et al. 2013), the city struggles with water pollution and groundwater depletion due to private wells. Bandung city is densely populated with only 13% of its area covered by vegetation or water bodies which makes the city vulnerable to urban drainage flooding (Diskamtam 2015). This condition is worsened by frequent flash floods from intense rainfall with an under-dimensioned urban drainage system (Tarigan et al. 2016). Moreover, flood vulnerability of lower areas are aggregated by land subsidence which occurs at an annual average rate of 8 cm (Abidin et al. 2013). Flood events have increased in frequency and the worst seasonal floods can be stagnant for 2-4 weeks (Tarigan et al. 2016) which leads to, amongst others, large scale traffic congestion, air pollution and health risks.

Ahmedabad (BCI: 3.1)
With a population of 5.6 million, Ahmedabad is the seventh largest Indian city and the largest of the state Gujarat. The city's urbanisation rate of 3.4% implies strong urban growth and Ahmedabad is expected to grow with more than 2 million by 2025

(UN Habitat 2016). A considerable part of the population still lacks access to safe drinking water and sanitation, in particular in the slums areas. Here, the piped water distribution is defective with limited number of connections and an erratic supply. Moreover, the few connections in the slums are often shared amongst households (Aartsen et al. 2018). The city has a tropic monsoon climate with regular droughts and heat waves during the dry season, and water nuisance during the monsoon (Gupte 2011). The Sabarmati River can supply the city with water during the monsoon. For the rest of the year, freshwater is supplied through the Narmada canal. The rapid industrial growth, urbanization, intensive agriculture, and rising energy demands have led to alarming deterioration of the water quality in the Sabarmati river running through the city (Halder et al. 2014; Prajapati 2014; Shah and Joshi 2015). The river and most of its tributaries have in fact become sewage flowing drains leading to waterborne infectious diseases (Halder et al. 2014; Maheshwari 2016). Moreover, the state of Gujarat has a lot of pharmaceutical, petrochemical, textile, automotive, energy, chemical, and other industries. Many of these industries discharge partially treated or untreated effluents into the Sabarmati river. Moreover, the self-purification capacity of the river has been reduced considerably due to a lack of minimal flow induced by domestic, industrial and agricultural water withdrawals (Halder et al. 2014). Freshwater is already scarce in the region and climate change is expected to further reduce freshwater availability (Gupte 2011). In addition, unregulated groundwater abstraction through private wells is decreasing the groundwater table with several metres per year, deteriorating the quality of the remaining groundwater (Gupte 2011). Besides, water pollution and water scarcity, flooding forms a serious risk. In July 2017, Gujarat state and Ahmedabad city were affected by 200mm of rainfall within 24 hours which led to the evacuation of 54,000 people and a total of 123 people lost their lives due to rainfall-related havoc. Like other large cities, Ahmedabad is vulnerable to heavy downpours which seem to increase in frequency as examples in Chennai, Mumbai and Bengaluru indicate (Ranger et al. 2011; Chatterjee 2010). The rapid urban expansion leads to vast drainage of rainfall and river overflows that disrupt the urban infrastructure, lead to large economic losses and increases the risk to public health.

New York City (BCI: 4.8)
New York is with about 8.5 million inhabitants by far the largest city of the United States and the city is projected to have 9 million inhabitants by 2040 (World population review 2018). In 2008, Mayor Bloomberg convened the first New York City Panel on Climate Change (NPCC1; NPCC 2010). NPCC1 consisted of leading climate and social scientists and risk management experts and provided climate change projections, advised on

adaptation approaches, and examined suitable standards and regulations (Rosenzweig and Solecki 2014). The NPCC1 projected an increase in storm events, heatwaves and extended coastal floods in the New York metropolitan region in the coming decades (NPCC 2010). Moreover, projections also indicated that without reductions in greenhouse gas emissions, adaptation alone would fall short to maintain the urban system at an acceptable level of risk (NYC 2013; Aerts et al. 2017). In September 2012, the NPCC was codified in legislation in order to provide regular climate science updates and localized projections necessary to account for climate change in New York City's infrastructure developments. Two months later Hurricane Sandy hit the city. The continuous loss of coastal wetlands throughout the centuries, the old and obsolete infrastructure, and outdated flood projections that underestimated the flood impact, all contributed to heavy losses of Hurricane Sandy. Hurricane Sandy was a greater than a 1-in-100 year occurrence and had severe impacts. Although the impact and damage estimates were well estimated a week in advance (Hewson 2012), the mandatory evacuation was not completed in time. In particular, in Manhattan, Staten Island, Brooklyn, and Queens were affected. In total, 43 people died of which 80% from drowning, the other deaths were mainly due to falling trees and electrocution. The utilities were ill prepared, with electricity power outages that leaved almost 2 million people without power (SIRR 2013), some for several weeks. Transportation was heavily impeded with seven subway lines and three vehicular tunnels closed under the East River. Overall, estimated losses amounted to about $19 billion (SIRR, 2013). About 35,700 structures with 162,700 residences, were situated within high-risk flood areas (Dixon et al. 2013). However, just about 55% of these residences were insured, putting many people in great financial debt. It also became clear that many major infrastructure projects had not sufficiently included climate risks. For example, the renovation of the South Ferry Station in southern Manhattan that was completed in 2009. The construction required an investment of $530 million but the design poorly took into account the floods in this flood zone. As a consequence, it suffered huge damage and required three years of restoration. Hurricane Sandy revealed a lot of unforeseen or underestimated impacts such as an extensive gas shortages, the evacuation of several major hospitals, and fires due to gas line breaks. Because fire crews had great difficulty to navigate through flooded streets, damages were greatly exacerbated. Hurricane Sandy was a major turning point in New York's City's climate adaptation efforts (SIRR 2013; NPCC 2013). Amongst others, off-shore breakwaters, wetland construction and sand-nourished beaches were proposed to protect the city against the sea (SIRR 2013). Green infrastructure was identified as key priority in climate adaptation. Furthermore, affordable insurance for low-income groups was addressed, safety standards for existing buildings were determined, and awareness on proper insurance was increased through education programmes (Feingold et al. 2017). Besides flood risk, water scarcity too might play an important role in the next decades. New York City currently has a water supply surplus in its three major watershed systems: the Croton, Catskill, and Delaware watershed (NYC Department of Environmental Protection 2010). However, based on historical data of the past 500 years, the current water surplus is an anomaly (Pederson et al. 2012). Forecasts of future precipitation indicate continued wet winter conditions, but drier summers (Hayhoe et al. 2007). The city has already reduced its per capita consumption from 788.5 L day^{-1} in 1988 to 476.2 L day^{-1} in 2009 (NYC Department of Environmental Protection 2010). However, the city may need to improve water supply security through further water conservation and by facilitating watershed restoration in the Delaware and Catskill watersheds (Pederson et al. 2012). Water quality has improved significantly within the last century. Since 2002, $12 billion has been invested in wastewater treatment plant upgrades, sewer separation and sewer system upgrades, combined sewer overflow abatement, nitrogen reduction from wastewater, green infrastructure, and marshland restoration (NYCEP 2018). In recent years the City has committed $4.1 billion to further reduce combined sewer overflows (NYCEP 2018).

Cape Town (BCI: 4.9)
Cape Town is located in semi-arid region with a mean annual rainfall of only 348 mm and a high variability in rainfall over the years. The city relies strongly on surface water from mountain catchments in the region that are mainly supplied by winter rainfall (New 2002). From October to March is dry with high temperatures. The greater regions of Cape town has about 4 million inhabitants and an annual growth rate of 1.56% (Municipalities of South Africa 2017). Population growth and under-investments have resulted in overloaded wastewater treatment plants and insufficient treatment (CoCT 2007). The city consumes most water in the Greater Cape Town area, in its surrounding irrigation requires much water. In recent decades South Africa's economy has improved, but it is still a huge challenge to provide universal access to basic human needs, such as housing, basic health services and access to clean water (Ziervogel et al. 2010). As such, the city of Cape Town has considerable numbers of informal dwellers with restricted access to potable water and sanitation services and who are exposed to annual floods (Smith and Hanson 2003). In 1994, the first democratically elected government initiated efforts to improve basic needs of all its citizens after 60 years of apartheid regime. As a result, a policy was adopted in 2001 which dictates the free access of a minimum of 6 m^3 of potable water per

household per month (Gowlland-Gualtieri 2007). Nevertheless, the implementation of this policy remains challenging until today (Ziervogel et al. 2010). For Cape Town, the domestic and agricultural demands have grown over the past decades and make the city increasingly susceptible to rainfall anomalies increasing competition for freshwater between domestic, industrial and agricultural applications (Callaway et al. 2007; Jansen and Schulz 2006). In addition, a changing climate is leading to increased temperatures, evapotranspiration as well as reduced and more erratic winter rainfall (OWSI 2007; Midgley et al. 2007). These predictions pose imminent significant threats, in particular in the longer run. In 2018, the situation in Cape Town became desperate as despite stringent restrictions on water consumptions the city is in danger to completely run out of water, commonly referred to as '*day zero*'. Hence, the governance capacity to adapt and anticipate water scarcity of particular urgency for the city of Cape Town (Ziervogel et al. 2010; Madonsela et al. 2018a,b).

Melbourne (BCI: 6.1)
Melbourne is the state capital of Victoria and the second-most populous city in Australia and Oceania. With about 4.5 million inhabitants, Melbourne metropolitan area hosts almost a fifth of the Australian population. Over the past years the city has grown substantially with about 1.3% annually. Melbourne heavily relies on catchment water because it requires minimal treatment, little transportation and is therefore relatively inexpensive. However, catchment water supply is also sensitive to climatic conditions that can impose large fluctuations in water availability and water quality. Melbourne has been subjected to a decade-long drought period (1997-2009), generally referred to as 'the Millennium Drought' (CSIRO 2012). The Millennium Drought necessitated strong water conservation efforts. Through a series of policy and infrastructure innovations, the city was able to cut its per capita water consumption with almost 50% to a total annual water demand of 356 million m^3 in 2010 (Grant et al. 2013). In addition, the implementation of water recycling and the harvesting of rainwater and stormwater enabled Melbourne to reduce its drinking water consumption from respectively 21 million m^3 and 10 million m^3 a year (MACLM 2011; Low et al. 2015). Despite these efforts, the situation remained alarming. In fact, the water availability fell to a historic low of 25.6% of storage volume in June 2009, just before the Millennium Drought ended. The city achieved substantial water reductions through its Water Restrictions Guidelines consisting of a four-stage water restriction protocol which was implemented 2005 (Victorian Water Industry Association 2005). The stages range from minor restrictions on outdoor water use (Stage 1) to a complete ban on outdoor water use (Stage 4). In addition, a set of less stringent

water use rules was applied when reservoir storage volumes were sufficient. Melbourne's harvesting of rainwater and stormwater was boosted in order to replace drinking water. The percentage of households with a rainwater tank increased substantially and urban stormwater was collected and treated to irrigate gardens, sports fields and golf courses (State Government of Victoria 2014). Moreover, household greywater systems were implemented (Sinclair et al. 2011). Recycling of treated wastewater was applied to enhance both water conservation and improve surface water quality. In particular in the Port Phillip Bay, nutrient loads were reduced by water recycling practices (Harris et al. 1996). In 2008, Melbourne was reusing 23% of sewage inflows. However, the total recycled water use declined quickly when rain returned in late 2009 because of decreased water demand for crop irrigation. However, although modest in terms of volume, urban water reuse was much more persistent.

The Port Philip Bay area is also prone to floods. Due to high density developments and a limited drainage capacity, more than 100,000 properties are at risk of flooding of which 40% has an above floor level flood impact (Melbourne Water 2010). In particular a lack of knowledge regarding the flood probability and impact, as well as financial limitations, have been identified as factors limiting flood mitigation (Victorian Auditor-General's Office 2005). The causes of the Millennium Drought are largely unknown and it was uncertain how long the drought would last. Accordingly, the management initiatives were predominantly reactive. For example, the Wonthaggi Desalination Plant was constructed at a cost of $6 billion, with an annual capacity of 107 million m^3 which is about 70% of the city's achieved water reduction (Grant et al. 2013). The construction works were completed in 2012, right after the drought period had ended. Hence, the plant has not supplied water (Joint water conservation plan 2009). This is a huge financial loss. Nevertheless, Melbourne achieved a lot: the city was able to impose water use restrictions, implemented a water rebate programme, boosted rainwater and stormwater harvesting, increased the reuse of treated wastewater and strongly increased awareness through water conservation campaigns (Low et al. 2015). Without these efforts, estimates suggest that the city water reservoirs would be depleted by the end of 2009 (Office of Living Victoria 2013).

Seoul (BCI: 7.3)
Seoul, is the capital and largest metropolis of South Korea. The city of Seoul, a population of 9,776,305, is one of the dozens of megacities worldwide. Seoul's population grow exponentially from 1950 onwards. However since 1992, the population decreased slightly due to expensive housing and the high numbers of commuting cities (Son 2003, 2015). Today the city

with 17,200 inhabitants per square km is one of the most densely populated megacities (Demographia 2016). Accordingly, the land covered with impermeable heat absorbing surfaces such as roofs, roads and parking lots has increased dramatically from 7.8% in 1962 to 48.6% in 2014 (Kim 2012). The Han river runs through the city centre from east to west, which is also the sole source for the city's water distribution network (ME 2016). Seoul's annual precipitation has gradually increased over the past decades, however the city struggles with large and increasing variation in rainfall and an increase of extreme downpours (Lee et al. 2005; Kim et al. 2016). For example, 2014 was a dry year with 809mm of rainfall whereas the yearly average between 1955-2014 is 1407mm (Lee et al. 2018). The increase in extreme downpours limits gradual groundwater recharge and leads to land subsidence. Soil instability is further aggravated by leakages of old sewer pipes that erode fine particles of the surrounding soil which may lead to pipe cracking and groundwater pollution (SMG 2016; Davies et al. 2001). Because the city is locking into an old sewer system with 48.2% of the sewer pipes over 30 years old and 30.5% over 50 years old, sewer leakages occur frequently and are increasing (Kim 2004; Kim et al. 2018). In addition, underground infrastructure such as subway lines, tunnels for electrical and communication cables and high storied building constructions, require much groundwater pumping. Most of the water is discharged into the river without being reused. The lack of infiltration surfaces such as vegetation or water bodies greatly aggregates the declining groundwater table. It leads to urban heating that in turn increases thunderstorms and decreases groundwater, and hence further reduces soil instability (Kim et al. 2015a). Extreme downpours and the city's large share of impermeable surfaces also lead to much runoff and floods. An example is the July 2011 flood in the Seocho-gu district. In a single day 301.5mm of rainfall led to 147 landslides, 16 casualties, buried 30 houses, damaged 116 houses, and heavily disrupted traffic (Park et al. 2013; Yune et al. 2013). These heavy downpours lead to high concentrations of soil, solid waste and pollutants in the Han River. As a result, the city's tap water supply requires extra treatment and it is often interrupted (Lee 2008). On the other hand, prolonged drought trigger green algal blooms in the River, which also complicates water treatment (Kim et al. 2015b). Because of the many river contamination episodes, the quality of tap water is considered unreliable by the public (Ko et al. 2007; Sim et al. 2010). Despite substantial efforts to improve water treatment, issues of taste and odour are still unaddressed (Rosario-Ortiz et al. 2016; Lee et al. 2018). As a consequence only 5% of the population uses tap water directly for drinking water purposes. Many households boil or apply additional filtering of the tap water. Accordingly, bottled water sales have strongly increased. Remarkably this bottled water is about 961-2155 times more expensive and hardly affordable for low-income communities (Lee et al. 2012). The current dependence on a single source of water (i.e. river water) makes the city susceptible for increased rainfall anomalies in the face of the changing climate (Vrba 2016). Alternative water sources such as bank filtration, rainwater harvesting, and groundwater, including the reuse of seepage from underground constructions, are considered. Moreover, several measures may be promising to tackle water challenges in the densely populated megacity. In particular, the restoring of river tributaries to their natural meandering flow, the use of permeable surface materials, green roofs, and transforming the sewers system to a dual network that separately collects rainfall, seem to be most promising. These integrated measures together seem adequate to address Seoul's interconnected challenges related to flood risk, water quality, groundwater over-abstraction and soil instability (e.g. McGrane 2016; Su 2016; Hasenmueller and Robinson 2016).

Amsterdam (BCI: 8.3)
Amsterdam is an old city with a relatively high and increasing population density of 5,042 inhabitants per square km (Municipality of Amsterdam 2018). The city is protected from the North sea, the *Lek* river, lake *Markermeer*, and regional water bodies through a complex system of dikes, dams and sluices. Amsterdam is also connected to the North Sea via a canal running through the city centre. Due to climate change, the discharges of the major rivers Rhine that feed the city and its surroundings, are expected to show a greater variety in seasonal extremes (De Bruijn and Mazijk 2003; Doomen et al. 2006). An increase in storm events is also expected (KNMI 2014). The city therefore has to cope with more extreme dry and wet periods as well as increased frequencies and magnitude of extreme rainfall while the city's population density is increasing substantially.
The city was one of the first to adopt the national Multi-layer Safety Approach (MSA; Van den Brink et al. 2011) to better address its flood risk. The first MSA layer focusses on reducing flood probabilities through revised safety standards and flood defence infrastructures. The second MSA layer is about reducing the impact of flood risk through adaptive spatial planning. The third MSA layer focusses on adequate flood response strategies. Amsterdam's spatial planning is suboptimal because vital infrastructure such as electricity supply, chemical industry and the city's wastewater treatment facilities are situated in flood prone areas. Hence, several measures taken including efforts to raise the area, construct small dikes around the area and implementation of crisis management (Koeze and Van Drimmelen 2012a). Flood safety standards are very high. However, the flood response strategy was found to be insufficiently equipped (Koeze and van Drimmelen 2012b). Cost-efficiency of spatial adaptation is low due to the low flood probability (Koop et al. 2018a). However, the

city is pioneering with a strategy that combines flood adaptation with projected infrastructural refurbishments and with measures to reduce heat stress, air pollution or water nuisance due to extreme rainfall (Dai et al. 2018). Due to the city's on-going densification, infiltration is reduced leading to higher runoff volumes as a consequence of increased impervious surfaces (City of Amsterdam 2010). In order to address this challenge, Amsterdam is implementing a real-time sewer control system that optimizes the storage capacity of the sewer to ensure a constant flow to the wastewater treatment plant (De Korte et al. 2009). Moreover, new gutters and storm water collection systems are constructed to temporarily store rainwater (Van der Hoek et al. 2014). About 75% of Amsterdam's sewers collects stormwater separately which strongly reduces water pollution through combined sewer overflows during storm events. Nevertheless, due to an expected increase in temperature, surface water quality, in particularly Dissolved Oxygen (DO) levels, are expected to deteriorate. During these periods with very low DO levels, the canals in Amsterdam are flushed with water from regional water bodies from the lake IJssel and lake Marken (Korving et al. 2012). In addition, surface water quality has improved substantially over the past years due to improved wastewater treatment and by moving the emissions of the wastewater treatment plant downstream the city's canal system. Historically, Amsterdam used groundwater from the dunes for its drinking water supply. However, over-abstraction led to salinization now the Amsterdam's drinking water is provided by Dune plant (70% of provision) and a lake plant (30% of provision). For the Dune plant, water from the river Rhine is transported about 60 km to the dune area for artificial recharge. After the dune filtration, the water requires only moderate post-treatment. In order to anticipate reduced water supply from the river Rhine, the city is experimenting with an innovative system that applies reverse osmosis to exploit the brackish groundwater. The membrane is placed in the groundwater well and the concentrate is returned at great depth in an aquifer with a similar natural salt concentration. The pressure required to apply reverse osmosis is naturally present at the depth of the membranes. This technique has the advantage that it exploits water that is free of anthropogenic substances, is relatively energy efficient and with low environmental impact (EEA 2018; Timmer et al. 2011).

SUMMARY & CURRICULUM VITAE

SUMMARY

INTRODUCTION

The magnitude of challenges related to water, waste and climate change is intensifying and calls for improved water management and water governance in cities. The challenges concern too much, too little and too polluted water. Within 30 years, cities will grow with 2.7 billion people and will make up 66% of the 9.7 billion people on earth. About 15% of the global population is already threatened by the combined impacts of sea-level rise, river flooding and urban expansion in flood-prone areas, while storm events are expected to increase in frequency and magnitude. In addition, the world is projected to experience an estimated 40% freshwater shortage by 2030, along with heatwaves that increase in frequency, length and severity. Cities are the largest water polluters through the emissions of solid waste, poorly treated or untreated sewage and polluted stormwater runoff that leads to biodiversity loss, and threatens drinking water, fisheries and economic activities. The pressure exerted on cities is projected to increase in the 21st century, thus emphasizing the intensifying urban challenges of water, waste and climate change, which in turn make strategic efforts towards sustainability ever more important. This message is emphasized by the United Nations Sustainable Development Goals. Nevertheless, the prevailing water governance systems are often still rooted in inflexible, fragmented and short-term conventional approaches. Nevertheless, in the last few decades a transformation can be observed towards more horizontal intra-sectorial decision-making that deliberately includes private actors, leading to the emergence of two key approaches. First, Integrated Water Resource Management, which recognizes water as a key element of integration. Second, Adaptive Management that embraces the inherent uncertainty, complexity and risk involved in environmental governance. Within these contexts, cities emerge as focal areas of integration. Although both approaches are widely aspired to by international organisations such as UNDP, OECD or EU Mayors Adapt initiative, their concrete application to facilitate water governance in cities is still largely undiscovered. The urban water cycle consists of many inter-related elements; amongst others, water infrastructure to secure basic water services, pollution control through wastewater treatment and blue-green spatial adaptation to alleviate extreme rainfall or heatwaves, and enhance groundwater recharge. An integration of these elements into an optimal management performance can be typified as water-wise management.

Despite these challenges, there is still little empirically-based understanding of how well cities perform with respect to integrated water management, which concrete steps can be observed on the path towards water-wise management, and which governance capacities account for water management improvements. In order to obtain such an empirical understanding, it is necessary to overcome a lack of coherence in the theoretical definitions and their operationalization by developing a unifying, comprehensive framework of measurable indicators. Accordingly, the objective of this dissertation is:

Increasing our understanding of what water-wisdom is and which governance conditions cities require to achieve it, by consistently analysing the water management performance and governance capacity of cities across the globe.

In order to fulfil this objective, three integrated assessment frameworks are developed; one to measure the main social, environmental and financial challenges that a city may have, that impact their ability to address water-related challenges (i.e., the Trends and Pressures Framework). Based on 12 descriptive indicators, these key challenges are quantified and expressed as a score of concern in 45 municipalities and regions across the world. The second framework – the improved City Blueprint performance Framework - measures the performance of urban water management practice. As such, a cohesive set of 25 indicators has been developed that covers key aspects of the urban water cycle such as drinking water, infrastructure, wastewater treatment and climate adaptation. The framework has been consistently applied in 45 municipalities and regions in 27 countries. The third framework analyses the governance conditions that account for increased water management performance. Based on the improved City Blueprint indicator assessment, the integrated water management performance of 45 municipalities and regions across 27 countries is analysed and used as a basis to identify tangible steps towards water-wise management. The data are obtained through an interactive questionnaire that is completed together with local authorities in cities. Next, a governance capacity analysis is developed, comprising nine conditions and 27 indicators that together are considered as a precondition for improvements in water management performances. The analysis has been applied in 15 cities with respect to the five most prevailing water-related challenges experienced in cities worldwide: flood risk, water scarcity, wastewater treatment, solid waste treatment and urban heat islands. The information for each city assessment has been gathered through 1) the study of literature, policies, reports and grey literature, 2) interviews with representatives of all relevant stakeholders, and 3) including constructive feedback from the interviewees. In total, 220 interviews have been conducted in 15 cities, and in these cities a total of 41 separate governance capacity analysis have been performed with respect to specific water-related challenges.

RESULTS

In order to address the overall research objective, the chapters of this dissertation are structured according to five complementary research questions that together answer the main question: What factors account for water wisdom in urban areas across the globe? First, *chapter 2* sets the scene by describing the challenges of water, waste and climate change in cities. *Chapter 3* is concerned with the question: what are the characteristics of a comprehensive framework for assessing water cycle management in urban areas around the world? Based on the developed framework results, *chapter 4* is concerned with the question: What levels of water-wisdom can be identified based on empirical urban water cycle management assessments? Next, *chapter 5* scrutinizes social barriers and enablers in order to form a framework, answering the question: What are the characteristics of a comprehensive framework for assessing water governance capacities in cities around the world? Although such a framework may be able to find overarching factors for water-wisdom, the local contextual factors also play an essential role. Hence, *chapter 6* aims to answer the question: What contextual factors influence capacity development? Finally, based on the empirical results of water management performances (chapter 3) and governance capacity (chapter 5), the relation between the two is investigated in *chapter 7*. Based on the study of respectively seven and 15 cities the last research question is addressed: How does water management performance relate to observed differences in governance capacity between cities?

Chapter 2 provides an introduction to the most prevailing urban water-related challenges and sets the scene for the other chapters in this dissertation. In particular, the chapter discusses the role of cities with respect to the governance of major challenges of water, waste and climate change. Furthermore, the importance of transforming water management through city-to-city learning alliances is emphasized by stressing the high learning potential emerging from the large differences in water management performances between cities.

Chapter 3 is concerned with the development and refinement of a framework of indicators that assess the integrated urban water cycle management performances. In 2011, a methodology to assess the urban water cycle has been developed, named the City Blueprint. Apart from the City Blueprint, there is no internationally standardized indicator framework focused on the integrated management of the urban water cycle. The City Blueprint methodology is critically reviewed according to three steps. Firstly, a distinction is made between water management performances and the social, environmental and financial trends and pressures that a city may be subjected to and that pose limitations and windows of opportunities for improved water management. Through a set of 12 descriptive indicators, these social, environmental and financial elements are represented in the Trends and Pressures Framework (TPF). Secondly, only the purely performance-oriented indicators are selected for the City Blueprint performance Framework (CBF) which forms a comprehensive set of 25 indicators that cover the key elements of the urban water cycle. The accuracy and boundaries of these indicators are critically assessed. In total, six indicators are removed because of insufficient accuracy, overlap or lack of focus on integrated urban water management. Seven indicators are added, i.e., secondary and tertiary wastewater treatment, operation cost recovery, green space and three indicators concerning solid waste treatment. In particular, data quality turned out to be an issue affecting the accuracy of indicators. For example, the indicators regarding water quality had to be removed for this reason and are replaced by indicators that assess the main sources of urban water pollution, namely the collection and treatment of wastewater and solid waste. Thirdly, based on the indicator scores in 45 municipalities and regions, basic statistics such as correlations and variances are applied to rearrange the indicators, so as to ensure a proportional contribution of all indicators and categories to the overall score, i.e., the Blue City Index® (BCI). Finally, for the BCI, the geometric mean is applied instead of the arithmetic mean because it better emphasized the need to improve the lowest scoring indicators. The newly established TPF and CBF indicators better include the key characteristics of the integrated urban water cycle in an operational indicator framework that can assess cities across the world.

Chapter 4 analyses the water cycle management in 45 municipalities and regions in order to identify levels of urban development towards water-wise management, including the characterization of what a water-wise city may look like. Transformative change or urban climate adaptation is an emerging and contested scientific debate where various approaches take a largely conceptual orientation towards the question of how trajectories of change unfold over time. However, much less effort is concentrated on simply measuring how cities, being at different stages of development, are evolving. In particular, with respect to global urban water management, such an empirical foundation is lacking. Accordingly, the City Blueprint indicator assessments (chapter 3) is used to address this literature gap. In doing so, five levels of water management performances are conceptualized based on a hierarchical clustering of the CBF results of 45 municipalities and regions as well as considering the indicator scores and their meaning. The levels are linked to the BCI scores, ranging from 0 (low performance) to 10 (high performance). The identified five levels include: I cities lacking basic water services (BCI: 0 – 2), II wasteful cities (BCI: 2 – 4), water efficient cities (BCI: 4 – 6), resource efficient and adaptive cities (BCI: 6 – 8), and water-wise cities (BCI: 8 – 10). The levels of water-wisdom are far from optimal and reveal a process of problem-shifting. This problem-shifting refers to a process where a management solution results in the creation of a new problem. The underlying cause of problem-shifting seems to be that management solutions are too restricted in both time and intersectoral scope. Hence, problem-shifting may lead to inefficient and ineffective paths towards water-wise cities. Based on 45 urban water cycle assessments, overarching patterns of problem-shifting have been observed in cities across the full range of water management performances. First, cities that improve access to basic water services often shift their problems towards strong pollution, since sufficient treatment of the resulting waste streams is unaccounted for. Second, cities that invest in pollution control, tend to become path-dependent into a waste(water) treatment approach that does not account for the emerging scarcity of raw materials and energy that ensure with an urban system that has no or low carbon emission. Third, many cities achieve full access to basic water services and improve their pollution control, but by largely disregarding the key role that water has in the spatial adaptation to the climate change-related challenges of water scarcity, heat waves and water quality. The challenge of leapfrogging this array of at least partly avoidable problems, requires a different set of key factors than is currently considered. Through these indicator assessment results, a clear mental image of what a water-wise city may look like is developed. Such a mental image is considered indispensable for cities to take action. Water-wise management is a state in which all 25 City Blueprint performance indicators score well (8 to 10 points). Accordingly, water-wise management may be described as: Cities that apply full resource and energy recovery in their WWT and solid waste treatment, fully integrate water into urban planning, have multi-functional and adaptive infrastructures, and local communities that promote sustainable integrated decision-making and behaviour. Cities are largely water self-sufficient, attractive, and innovative and circular by applying multiple (de) centralized solutions.

Chapter 5 involves the development of a comprehensive framework to measure the governance conditions that may account for improvements in water management performances. Water governance challenges typically feature fragmented scopes, viewpoints, and responsibilities. As there are many causes leading to this uncertainty and disagreement, there is no single best approach to solve these challenges. The literature on environmental governance contains a plethora of governance gaps, barriers, and capacities, which sometimes overlap, are contradictory and case-specific, thus reflecting a strong difference in disciplinary scopes. Moreover, conceptual rationales and individual case studies provide many plausible suppositions that are, however, not sufficiently tested in a more general setting. Accordingly, the definitions of identified barriers, enablers, and conditions are often not made explicit, neither is it clear how they are operationalized, measured, and how they relate to one another. Since conceptual definitions generally establish themselves through repeated testing, evaluations, and refinements, the Governance Capacity Framework (GCF) is designed to be a coherent, empirically-based diagnostic framework that assesses existing governance capacity in cities across the world. In this way, a database can be developed that can be used to identify overarching patterns and transferable lessons across a range of case studies, while, at the same time, it can improve our understanding of cause-effect relations in individual case studies. The GCF consists of nine conditions divided into three dimensions: knowing, wanting, and enabling. The "knowing" dimension refers to the level of awareness (condition 1), existence of useful knowledge (condition 2) and the network's ability to continuously learn (condition 3). The "wanting" dimension concerns the stakeholder engagement process (condition 4), management ambition (condition 5), and the role of agents of change (condition 6). Finally, the "enabling" dimension analyses the network potential to address water challenges (condition 7), the financial viability (condition 8), and existing policy instruments and action plans that actors can use to implement policies (condition 9). The frameworks application is illustrated in the city of Amsterdam with respect to the five most prevailing water-related challenges in urban areas worldwide: 1) flood risk, 2) water scarcity, 3) wastewater treatment, 4) solid waste treatment and 5) urban heat islands.

Chapter 6 aims to identify contextual factors and how they prioritise different elements of governance capacity. In order to get the necessary insights to identify overarching patters and recognize important starting points for city-to-city learning activities, a large database has to be developed through the consistent assessment of governance capacity in cities across the world. However, the contextual background of a city may be a determining factor in identifying feasible capacity-development priorities. Hence, insight into the key contextual factors may be indispensable to identify overarching patterns across a range of case studies, and, at the same time, to understand cause-effect relations in individual cases. In order to investigate these contextual factors, the GCF (developed in chapter 5), is applied in two Dutch cities and two cities in the United Kingdom. Based on their governance capacity profiles and the study of local, regional, national and EU policy and water management histories, three crosscutting contextual factors are identified: (1) flood probability and impact; (2) national imposed institutional setting; and, (3) level of authority to secure long-term financial support. It is observed that the institutional setting in the UK and recent political devolution and national austerity measures enlarged differences in flood safety standards throughout the country. In this context, the role of citizen awareness, useful knowledge, stakeholder engagement process, and entrepreneurial agents of change become critical components of governance capacity. On the contrary, the Dutch focus on flood safety through centralised public coordination with long-term financial continuity has resulted in high flood safety standards. However, this approach also inhibits incentives to reduce flood impacts and lowers awareness, as most citizens take flood protection for granted. The three crosscutting contextual factors that have been identified provide a useful narrative for cities in the UK and the Netherlands to understand their feasible capacity-development opportunities and priorities to better govern flood risk. These contextual factors can be also applicable in other European cities. More research is necessary to gain a deeper understanding of governance capacity development in other world regions and for other urban environmental challenges.

Chapter 7 investigates the relation between water management performance (as measured by the CBF) and governance capacity (as measured by the GCF). Although the necessity of capacity-development is widely recognised and emphasized as an important precondition for good water management, there is little empirical research scrutinising the relation between water management and governance capacity. Consequently, most cities struggle to understand their own water management performances and capacity-development priorities. In this chapter, seven cities are analysed with respect to their capacity to govern flood risk, water scarcity and wastewater treatment challenges. Through the GCF analysis (chapter 5) in each city, an in-depth insight into the main barriers and enables for improved water management is obtained. The scores of the 27 governance indicators have been compared to the overall management performance score, i.e., the Blue City Index (BCI). In doing so, a high positive correlation efficient was found between high management performance (i.e. BCI) and *prepared* (r=0.89) for both gradual and sudden events through the existence of policy and plans with clear allocation of resources and responsibilities. In addition, high correlation coefficients were found between the BCI and *smart monitoring* (r=0.87) which indicates that gaps in *policy compliance* (r=0.94) can be identified and addressed accordingly. Moreover, the high correlation coefficient with *continuous evaluation* (r=0.82) and *policy instruments* (r=0.87) indicate that high performing cities tend to continually optimization their policies through a joint evaluation and learning process. Such interaction between implementing capacity (condition 9) and the ability to continuously monitor, evaluate and learn (condition 3) seems to be essential to achieve and maintain high water management performance and ultimately achieve water-wise management. On the contrary, community knowledge was negatively correlated (indicator 1.1; r=-0.76). Arguably a lower capacity to govern water challenges leads to more exposure to water-related hazards and people may develop more knowledge on how to cope with it. In addition to the seven cities that have been analysed with respect to their capacity to govern flood risk, water scarcity and wastewater treatment, the analysis has been broadened to include eight other cities that are assessed with respect to either one or two of the previously mentioned water challenges. Based on this extension, a positive correlation is found between water management performances and governance capacity (r=0.81). The number of cities (n=15) is too small to statistically extrapolate this trend and this correlation cannot be attributed to a cause-effect relation. Nevertheless, it does seem to be a good indication of the intuitive link between good management performance and high governance capacity. In order to find a cause-effect relation, more city analyses are necessary that are repeated over time in order to test for covariance, investigate whether capacity-development precedes improvements in management performances, and to exclude alternative explanations. Further research is important here to seize a unique opportunity to identify causal relations and better understand capacity-development priorities for cities to improve their water management performances in a world of unprecedented change, as described in chapter 2.

CONCLUSIONS

Chapter 8 provides the main conclusions that culminate from the previous chapters. In order to meet the dissertation's objective – namely to understand what water-wisdom is and which governance conditions cities require to achieve it – empirically-based insight into the key characteristics of how well the urban water cycle is managed is much needed. Through the development, refinement and assessment of the City Blueprint indicator in 45 municipalities and regions, such insight is provided. In particular, the levels of water-wisdom indicate that the observed trajectory reveals a process of problem-shifting in which the applied solutions are too confined in both their time horizon and inter-sectorial scope, leading to the creation of new problems.. Hence, this problem-shifting leads to an inefficient and ineffective development towards water-wise cities. Based on 45 urban water cycle assessments, overarching patterns of problem-shifting include three major observations. First, cities that improve the access to basic water services often shift their problems towards strong pollution since sufficient treatment of the resulting waste streams is unaccounted for. Second, cities that invest in pollution control, tend to become path-dependent into a waste(water) treatment approach that does not account for the emerging scarcity of raw materials and energy that come along with a urban system that has no or low carbon emission. Third, many cities achieve full access to basic water services and improve their pollution control, but by largely disregarding the key role that water has in the spatial adaptation to climate change-related challenges of water scarcity, heatwaves and water quality. The challenge to leapfrog this array of at least partly avoidable problems, requires a different set of key factors than is currently considered.

Based on the empirical study of 41 specific governance assessments in 15 cities, an overall correlation between water management performance and governance capacity is found. More specifically, the capacity to implement policy and continuously monitor, evaluate and learn may be the key determinants for water-wise management due to their high observed correlations with water-wise management. In order to go beyond correlations and find causal relations, more city analyses are necessary that are repeated over time. In such an exercise, three crosscutting contextual factors may be key to identify feasible capacity-development priorities in different urban contexts. These three conditions include: 1) probability and impact of environmental risk; (2) national imposed institutional setting; and, (3) level of authority to secure long-term financial support. Finally, the CBF and GCF may be an important approach to knowledge coproduction that enables cities to develop a strategic understanding of their own water management performances and governance capacity profile, and accordingly identify desired improvements and good practices which provide the concrete starting point for meaningful city-to-city learning.

SAMENVATTING

INTRODUCTIE

Klimaatverandering veroorzaakt of droogte of korte perioden met een te veel aan water. Samen met de afvalverwerking en de waterkwaliteit stelt dit steeds hogere eisen aan een beter waterbeheer en het bestuurlijk vermogen van steden. Het gaat hierbij over te veel, te weinig en zeer verontreinigd water. Binnen 40 jaar groeit de wereldbevolking met 2,7 miljard en gaan steden 66% van de 9,7 miljard mensen huisvesten. Ongeveer 15% van de wereldbevolking is al kwetsbaar voor de gecombineerde effecten van een stijgende zeespiegel. Rivieren treden buiten hun oevers en steden breiden zich uit in overstromingsgevoelige gebieden. Hierbij komt dat extreme weersomstandigheden naar verwachting toenemen in omvang en frequentie. Schattingen tonen aan dat wereldwijd het zoetwatertekort zal oplopen tot 40% in 2030. Ook nemen hittegolven toe in frequentie, duur en hevigheid. Steden zijn ook de grootste watervervuilers door hun productie van afval, gebrekkige afvalwaterbehandeling en vervuiling door afspoeling na regenbuien. Dit leidt samen tot biodiversiteitsverlies, bedreigingen van de volksgezondheid, landbouw, visserij en economische groei. Deze omvangrijke problemen en tegelijkertijd ook het potentieel van steden om door innovaties aan de oplossingen bij te dragen, zullen een belangrijke stempel drukken op de eenentwintigste eeuw. Deze ontwikkelingen benadrukken het belang van onderzoek en duurzaamheidsinspanningen op het gebied van water, afvalbeheer en klimaatverandering in steden zoals ook verwoord in de duurzame ontwikkelingsdoelen van de Verenigde Naties. De gangbare bestuurlijke systemen voor wateruitdagingen zijn echter vaak nog geworteld in inflexibele, gefragmenteerde en traditionele korte termijn benaderingen. In de laatste decennia zijn grote verandering waar te nemen in de richting van meer horizontale, intersectorale besluitvorming waarin private actoren nadrukkelijk worden betrokken. Deze trend komt tot uitdrukking in twee belangrijke benaderingen. De eerste is ‘Integrated Water Resources Management’ dat water beschouwt als het essentiële element voor integratie in bijvoorbeeld de stedelijke omgeving. De tweede is ‘Adaptive Management’ dat onzekerheid, complexiteit en risico omarmt als onlosmakelijke eigenschappen van het besturen en beheren van milieuvraagstukken. In de context van deze veranderingen vragen steden steeds meer om een integrale aanpak. Beide benaderingen worden breed nagestreefd door internationale organisaties zoals UNDP, OESO en het EU Mayors Adapt initiatief, maar het ontbreekt aan een concrete toepassing. Steden worden daardoor niet goed geholpen in het besturen van deze complexe watervraagstukken. Een stedelijke watercyclus bestaat uit verschillende samenhangende elementen. Naast de waterinfrastructuur om in de eerste waterbehoeften te voorzien bestaat de stedelijke watercyclus uit de adequate afvalwaterbehandeling om watervervuiling te voorkomen.

Daarnaast is blauwgroene ruimtelijke adaptatie essentieel om de gevolgen van extreme regenval te verminderen, hittegolven te verzachten en grondwater en oppervlaktewater aan te vullen. De integratie van al deze elementen in een optimaal waterbeheer kan worden getypeerd als 'water-wise management'.

Ondanks deze uitdagingen is er maar weinig proefondervindelijk onderbouwd onderzoek over hoe goed steden in relatie tot integraal waterbeheer presteren. Het is daarom nodig om op basis van een veelvoud aan stedenbeoordelingen een stapsgewijze ontwikkeling richting 'water-wise management' te vinden. Een belangrijke opgave hierbij is het in kaart brengen van bestuurlijke capaciteiten die verbeteringen in de watermanagementprestaties mogelijk maken. Om dit empirisch te beantwoorden is het nodig om het gebrek aan coherentie in de theoretische definities en hun operationalisatie te overbruggen. Hiervoor is het nodig om een concrete set meetbare indicatoren te ontwikkelen die de prestaties op het gebied van integraal stedelijk waterbeheer en het bestuurlijk vermogen kunnen beoordelen. Derhalve is het doel van dit proefschrift:

Het vergroten van ons begrip van 'waterwijsheid' en het aangeven van bestuurlijke condities die steden nodig hebben om waterwijsheid te bereiken, door het op een consistente wijze analyseren van de prestaties op het gebied van watermanagement in en het bestuurlijk vermogen van steden over de hele wereld.

Om aan deze doelstelling te voldoen zijn drie integrale beoordelingskaders ontwikkeld.

Eén meet de belangrijkste sociale, ecologische en financiële uitdagingen die steden kunnen beperken in hun vermogen om water gerelateerde uitdagingen aan te pakken (het *Trends and Pressures Framework*). Op basis van 12 beschrijvende indicatoren zijn deze belangrijkste uitdagingen gekwantificeerd in 45 gemeentes en regio's wereldwijd.

Het tweede beoordelingskader – de verbeterde *City Blueprint* – meet de managementprestaties van de stedelijke watercyclus. Zo is er een samenhangend geheel van 25 indicatoren ontwikkeld die de belangrijkste aspecten van de stedelijke watercyclus karakteriseren waaronder drinkwatervoorziening, infrastructuur, afvalwaterzuivering en klimaatadaptatie.

Het derde beoordelingskader – het *Governance Capacity Framework* (GCF) – analyseert de bestuurlijke condities die zorgen voor betere managementprestaties binnen de stedelijke watercyclus. De resultaten van de *City Blueprint Assessment* in 45 gemeenten en regio's vormen de basis voor het benoemen van stappen richting waterwijsheid. De benodigde gegevens zijn verkregen door middel van een interactieve vragenlijst die is ingevuld samen met lokale autoriteiten in de steden. Het *Governance Capacity Framework* bestaat uit negen condities en 27 indicatoren die samen beschouwd kunnen worden als voorwaarden voor verbeteringen in het stedelijk watermanagementprestaties. De analyse is toegepast in 15 steden met betrekking tot de vijf meest voorkomende water gerelateerde uitdagingen die steden wereldwijd ervaren: 1) overstromingsrisico, 2) waterschaarste, 3) afvalwater-behandeling, 4) afvalbeheer en 5) stedelijke hitte-eilanden. De informatie die nodig is voor het beoordelen van steden zijn verzameld door middel van 1) het bestuderen van literatuur, beleidsdocumenten, rapporten en grijze literatuur, 2) interviews met vertegenwoordigers van alle relevante belanghebbende groeperingen en 3) door constructieve feedback van deze geïnterviewde personen te verwerken. In totaal zijn er meer dan 220 interviews afgenomen in 15 steden met betrekking tot 41 aparte analyses van het bestuurlijk vermogen nodig voor specifieke wateruitdagingen in deze steden.

RESULTATEN

De hoofdvraag *Welke factoren zorgen voor waterwijs management in stedelijke gebieden over de hele wereld?* wordt in de afzonderlijke hoofdstukken van dit proefschrift opgesplitst in vijf complementaire onderzoeksvragen.

Hoofdstuk 2 geeft een beeld van de uitdagingen op het gebied van water, afval en klimaatverandering in steden.

Hoofdstuk 3 behandelt de vraag: *Wat zijn de kenmerken van een breed raamwerk voor het beoordelen van managementprestaties binnen de stedelijke watercyclus wereldwijd?* Het resulterende raamwerk en de toepassing daarvan vormt het uitgangspunt voor *hoofdstuk 4*.

Hoofdstuk 4 behandelt de vraag: *Welke niveaus van waterwijs management kunnen worden onderscheiden op basis van de empirische beoordelingen van de stedelijke watercyclus?*

In *hoofdstuk 5* wordt aandacht besteed aan sociale barrières en mogelijkheden om een raamwerk te vormen dat de volgende vraag beantwoordt: *Wat zijn de kenmerken van een breed raamwerk voor het toetsen van de bestuurlijke capaciteiten van waterbeheer in steden over de hele wereld?* Een dergelijk raamwerk geeft inzicht in de sleutelfactoren voor waterwijs management. Er zijn echter ook lokale context factoren die een belangrijke rol kunnen spelen die in dit raamwerk niet kunnen worden meegenomen.

Hoofdstuk 6 is daarom gericht op het beantwoorden van de vraag: *Welke contextuele factoren beïnvloeden de ontwikkeling van bestuurlijk vermogen?* Gebaseerd op de beoordeling van 7 van de in totaal 15 onderzochte steden komt de laatste onderzoeksvraag aan de orde: *Hoe verhouden de prestaties op het gebied van watermanagement zich tot waargenomen verschillen in bestuurlijke capaciteit tussen steden?*

Hoofdstuk 2 geeft een introductie van de belangrijkste stedelijke water gerelateerde uitdagingen en zet daarmee de toon voor de andere hoofdstukken in dit proefschrift. Dit hoofdstuk zoomt in op de bestuurlijke aspecten van steden bij de grootste uitdagingen op het gebied van water, afvalbeheer en klimaatverandering. Verder wordt het belang van een transformatie van het stedelijk waterbeheer door middel van stedelijke kennisuitwisselingsnetwerken benadrukt. Deze kennisuitwisseling is veelbelovend gezien de grote verschillen in de huidige prestaties van steden.

Hoofdstuk 3 gaat in op de ontwikkeling en verbetering van het indicatorenraamwerk dat de stedelijke watercyclus beoordeelt.

Op dit moment ontbreekt het aan een internationaal gestandaardiseerd indicatorenraamwerk dat het integraal beheer van de stedelijke watercyclus beoordeelt.
De bestaande *City Blueprint* methodologie is in drie stappen kritisch doorgelicht.

1. Er is een onderscheid gemaakt tussen aan de ene kant prestaties op het gebied van waterbeheer en aan de andere kant de sociale, ecologische en financiële aspecten waaraan steden onderhevig zijn. Deze aspecten bieden kansen of zijn juist beperkend voor verbeterde watermanagementprestaties. Daarvoor is een raamwerk van 12 beschrijvende indicatoren ontwikkeld – het *Trends and Pressures Framework* (TPF) dat de sociale, ecologische en financiële omstandigheden beoordeelt.
2. Er zijn indicatoren die zuiver de prestatie meten geselecteerd – het *City Blueprint performance Framework* (CBF). Dit vormt een breed raamwerk van 25 indicatoren dat de belangrijkste elementen van de stedelijke watercyclus representeert. De nauwkeurigheid en grenswaarden van de indicatoren zijn kritisch geëvalueerd en nieuwe indicatoren zijn toegevoegd. Zes indicatoren zijn verwijderd omdat ze onvoldoende nauwkeurig bleken, overlapten of onvoldoende betrekking hadden op stedelijk waterbeheer. Zeven indicatoren zijn toegevoegd te weten: secondair en tertiair afvalwaterbehandeling, operationele kostendekking, groene ruimte en drie indicatoren op het gebied van afvalbeheer. Vooral de kwaliteit van de beschikbare data bleek een complicerende factor die de nauwkeurigheid van de indicatoren bepaalt. Zo bleken de indicatoren die de waterkwaliteit weergeven onnauwkeurig te zijn. Daarom zijn deze vervangen door de inzameling en behandeling van afvalwater en huishoudelijk afval als indicatoren die de voornaamste stedelijke vervuilingsbronnen in kaart brengen.
3. Op de gegevens van 45 gemeenten en regio's is basisstatistiek toegepast zoals correlatie- en variantietesten. Op basis hiervan is de indicatorsamenstelling aangepast waardoor er een meer evenwichtige indeling van de verschillende categorieën kon worden gerealiseerd. Voor de berekening van de totaalscore – de *Blue City Index* (BCI) – is gekozen voor het geometrisch gemiddelde van de indicatoren. Op deze manier wegen laag scorende indicatoren zwaarder en hebben daarmee een grotere invloed op het gemiddelde.

Met deze drie stappen zijn de nieuwe TPF en CBF indicatoren ontwikkeld. Deze twee raamwerken kunnen het beheer van de stedelijke watercyclus in verschillende wereldregio's beter karakteriseren.

Hoofdstuk 4 analyseert het beheer van de watercyclus in 45 gemeenten en regio's om zo categorieën van stedelijke ontwikkeling naar waterwijs management te identificeren. Hierbij hoort ook de karakterisering van hoe een waterwijze stad er daadwerkelijk uit ziet. Transformatieve verandering vormt een belangrijk wetenschappelijk vraagstuk. Er bestaan verschillende benaderingen met een vooral conceptuele oriëntatie over de vraag hoe trajecten van verandering zich ontvouwen in de tijd. Er is echter veel minder onderzoeksinspanning gericht op het eenvoudig meten van hoe steden, die zich in verschillende stadia van transformatie bevinden, zich daadwerkelijk ontwikkelen. Vooral voor het mondiaal stedelijk waterbeheer ontbreekt een dergelijke empirische basis. De *City Blueprint* indicatorbeoordelingen (hoofdstuk 3) kunnen een belangrijke bijdrage leveren om deze kennisleemte in de literatuur aan te vullen. In dit hoofdstuk is een conceptuele indeling in vijf fasen van voortschrijdende prestaties op het gebied van watermanagement gemaakt. De basis hiervoor is een hiërarchische clustering van een CBF indicatoranalyse van 45 gemeenten en regio's. Daarbij is ook het scoreprofiel en de betekenis van de indicatoren meegenomen. De verschillende niveaus zijn gekoppeld aan de BCI-scores, variërend van 0 (lage prestatie) tot 10 (hoge prestatie). De vijf geïdentificeerde niveaus zijn: (I) steden zonder primaire watervoorzieningen (BCI:0-2), (II) verspillende steden (BCI: 2-4), (III) waterefficiënte steden (BCI: 4-6), (IV) grondstof-efficiënte en adaptieve steden (BCI: 6-8), en (V) waterwijze steden (BCI: 8-10). De geobserveerde niveaus van stedelijke ontwikkeling richting waterwijze steden onthult een proces van probleemverschuiving. Zo ondervinden steden die de toegang tot primaire watervoorzieningen verbeteren vaak sterke vervuiling omdat er onvoldoende rekening wordt gehouden met een adequate behandeling van de toenemende afval(water) stromen. Steden die investeren in de beheersing van de vervuiling hebben de neiging om onvoldoende rekening te houden met de centrale rol van de watercyclus in het verminderen van klimaatkwetsbaarheid of met het goed omgaan met toenemende grondstof schaarste.

De uitdaging is om deze reeks van mogelijk vermijdbare problemen te ontlopen. De indicatoren analyse geeft een duidelijk beeld van hoe een waterwijze stad er uit zou kunnen zien. Deze beeldvorming is onmisbaar om steden te stimuleren in actie te komen. Er is sprake van waterwijs beheer wanneer alle 25 City Blueprint indicatoren goed scoren (8 tot 10 punten). Vanuit deze redenering kan 'waterwijs beheer' beschreven worden als:

- Steden die potentiele grondstoffen en energiestromen terugwinnen uit hun vast afval en afvalwater.
- Steden die water volledig integreren in hun stedelijke planning en multifunctionele en adaptieve infrastructuren hebben.

• Steden waarin lokale gemeenschappen duurzaam geïntegreerde besluitvorming en gedrag bevorderen.

Deze steden zijn grotendeels water zelfvoorzienend, aantrekkelijk en innovatief en circulair door het toepassen van meerdere (de) centrale oplossingen.

Hoofdstuk 5 omvat de ontwikkeling van een raamwerk voor het meten van de bestuurlijke condities die bijdragen aan verbeterde watermanagementprestaties. Oplossingen binnen het stedelijk waterbeheer hebben vaak beperkingen met betrekking tot het afwegingskader en een fragmentatie in standpunten en verantwoordelijkheden. Omdat er veel oorzaken zijn die tot deze onzekerheid en onenigheid leiden, kan er geen sprake zijn van één alomvattende aanpak die alle verschillende uitdagingen kan oplossen. De literatuur over milieubeheer bevat een overvloed aan bestuurlijke uitdagingen, barrières en capaciteiten, die elkaar soms overlappen, tegenstrijdig zijn en meestal context-specifiek zijn. De verscheidenheid aan voorgestelde factoren komt voort uit uiteenlopende benaderingen vanuit verschillende wetenschappelijke disciplines. De verschillende concepten en verscheidenheid aan casussen zorgen voor veel aannemelijke veronderstellingen die echter niet voldoende zijn getest op generaliseerbaarheid. Ook de definities van deze factoren zijn vaak niet expliciet geformuleerd. Het is ook niet duidelijk hoe ze geoperationaliseerd zijn in meetbare indicatoren en hoe verschillende factoren zich tot elkaar verhouden. Conceptuele definities ontwikkelen zich op basis van herhaaldelijk testen, evalueren en herformuleren. Daarom is ook het *Governance Capacity Framework* ontworpen als een coherent, empirisch gebaseerd diagnostisch kader. Het kan gebruikt worden om de bestaande bestuurscapaciteit in steden over de hele wereld te beoordelen om zo tot voortschrijdend inzicht te komen. Op deze manier kan een database worden ontwikkeld die kan worden gebruikt om overkoepelende patronen en algemene lessen te vinden in een reeks van case studies. Tegelijkertijd kan het ons begrip van causale relaties in individuele casussen verbeteren. Het *Governance Capacity Framework* bestaat uit negen condities verdeeld over drie dimensies: *weten, willen en kunnen*. De dimensie ''weten'' verwijst naar het niveau van bewustzijn (conditie 1), de beschikbaarheid van bruikbare kennis (conditie 2) en het vermogen van het netwerk om voortdurend te leren (conditie 2). De dimensie ''willen'' gaat over de betrokkenheid van stakeholders (conditie 4), managementambitie (conditie 5) en de rol van 'agents of change' (conditie 6).

De dimensie ''kunnen'' analyseert het netwerkpotentieel om wateruitdagingen aan te pakken (conditie 7), de financiële haalbaarheid (conditie 8), en het gebruik van beleidsinstrumenten en toepassing van actieplannen om beleid goed uit te kunnen voeren (conditie 9). De toepassing van de GCF wordt geïllustreerd in de stad Amsterdam door vijf belangrijke water gerelateerde uitdagingen te analyseren, namelijk: 1) overstromingsrisico, 2) waterschaarste, 3) afvalwaterbehandeling, 4) behandeling van vast afval en 5) stedelijk hitte-eilanden.

Hoofdstuk 6 richt zich op het identificeren van contextuele factoren die de prioriteit van verschillende elementen van bestuurlijk vermogen (*governance capacity*) bepalen. Om inzicht te krijgen om overkoepelende patronen te herkennen en belangrijke aanknopingspunten voor ''city-to-city'' leren te identificeren, moet een grote database worden ontwikkeld waarmee op wereldschaal consistent het bestuurlijke vermogen van steden kan worden beoordeeld. De contextuele achtergrond van een stad kan echter een bepalende factor zijn bij het vaststellen van haalbare prioriteiten voor de ontwikkeling van bestuurlijk vermogen. Vandaar dat inzicht in de belangrijkste contextuele factoren onmisbaar is om overkoepelende patronen te identificeren en tegelijkertijd inzicht te verschaffen in de oorzaak-gevolg relaties in specifieke situaties. Om deze contextuele factoren nader te onderzoeken is het *Governance Capacity Framework* (ontwikkeld in hoofdstuk 5) toegepast in twee Nederlandse steden en twee steden in het Verenigd Koninkrijk met betrekking tot overstromingsrisicobeheer.

Op basis van hun bestuurlijke capaciteitsprofielen, de studie van lokale, regionale, nationale en EU-beleidskaders en de voorgeschiedenis van dit beleid zijn drie algemene contextuele factoren geïdentificeerd: 1) overstromingskans en impact; 2) nationale institutionele setting; 3) het niveau van bevoegdheid om financiële ondersteuning op lange termijn veilig te stellen. Dit onderzoek observeert dat de institutionele situatie in het Verenigd Koninkrijk, de recente decentralisering van politieke bevoegdheden en de nationale bezuinigingsmaatregelen leiden tot grote verschillen in veiligheidsnormering. In deze context hebben burgerbewustzijn, bruikbare kennis, proces van stakeholderbetrokkenheid en entrepreneurs de hoogste prioriteit voor het verder vergroten van het bestuurlijk vermogen.

In Nederland daarentegen is een sterke focus op overstromingsveiligheid. Deze wordt voornamelijk nationaal gecoördineerd waarbij financiële continuïteit heeft geleid tot strenge veiligheidsnormen. Deze benadering schept een gevoel van veiligheid dat de prikkels ontneemt om de gevolgen van een mogelijk niet te voorkomen overstroming in te dammen. Daarmee wordt dus het maatschappelijke overstromingsbewustzijn belemmert omdat de meeste burgers bescherming tegen overstromingen als vanzelfsprekend beschouwen. De drie geïdentificeerde contextuele factoren bieden een bruikbaar kader die steden in het Verenigd Koninkrijk en Nederland kunnen gebruiken om hun bestuurlijk vermogen verder te ontwikkelen en de beheersing van overstromingsrisico's te verbeteren. Deze contextuele factoren kunnen ook van toepassing zijn in andere Europese steden. Aanvullend onderzoek is nodig om meer inzicht te krijgen in de ontwikkeling van bestuurlijk vermogen in andere regio's in de wereld en in relatie tot andere stedelijke milieu-uitdagingen.

Hoofdstuk 7 onderzoekt de relatie tussen prestaties op het gebied van watermanagement (gemeten door de CBF) en het bestuurlijk vermogen (gemeten door de GCF). Hoewel de noodzaak van bestuurlijke capaciteitsontwikkeling algemeen onderkend en benadrukt wordt als een belangrijke voorwaarde voor goede watermanagementprestaties, is er weinig empirisch onderzoek verricht dat de relatie tussen watermanagementprestaties en bestuurlijk vermogen onder de loep neemt. Daarom worstelen de meeste steden met het inschatten van hun eigen prestaties en het stellen van prioriteiten op het gebied van waterbeheer om hun bestuurlijk vermogen kunnen vergroten. In dit hoofdstuk zijn zeven steden geanalyseerd met betrekking tot hun vermogen om overstromingsrisico, waterschaarste en afvalwaterzuiveringsuitdagingen te beheersen. Door de toepassing van het *Governance Capacity Framework* (hoofdstuk 5) in ieder van deze zeven steden wordt inzicht verkregen in de belangrijkste bestuurlijke barrières en mogelijkheden voor verbeterde watermanagementprestaties. Vervolgens zijn de correlatiecoëfficiënten berekend tussen ieder van de 27 governance-indicatoren en de watermanagementprestaties die is uitgedrukt in een totaalscore van de 25 City Blueprint indicatoren, de *Blue City Index* (BCI). Op basis van een studie van 41 aparte Governance Capacity-analyses in 15 steden (met betrekking tot verschillende wateruitdagingen) is vastgesteld dat steden met hoge managementprestaties (i.e. steden met een hoge BCI) over het algemeen goede beleids- en implementatieplannen hebben met daarin een duidelijke toewijzing van middelen en verantwoordelijkheden. Dit blijkt uit de hoge correlatiecoëfficiënt tussen de BCI en de governance-indicator die de mate van *goede voorbereiding* voor zowel geleidelijke als plotselinge gebeurtenissen meet (r=0,89). Ook de zijn correlatiecoëfficiënten hoog voor de indicatoren *slimme monitoring* (r=0,87) en *beleidsnaleving* (r=0,94). Het lijkt erop dat hiaten in de beleidsnaleving sneller worden geïdentificeerd en aangepakt door slimme monitoring. Dat gebeurt middels een proces van voortdurende evaluatie en optimalisatie van het gebruik van beleidsinstrumenten. Dit is terug te zien in de hoge correlatiecoëfficiënten tussen de BCI en de indicatoren *evaluatie* (0,82) en *beleidsinstrumenten* (r=0,87). Een dergelijke interactie tussen de implementatiecapaciteit (conditie 9) en het vermogen om voortdurend te monitoren, te evalueren en daarvan te leren (conditie 3) lijkt essentieel te zijn om goede watermanagementprestaties te bereiken en in stand te houden om uiteindelijk waterwijs te worden. In steden met een relatief hoge watermanagementprestaties was het kennisniveau van lokale gemeenschappen en burgers lager (r=-0,76). Mogelijk leidt een lagere watermanagementprestatie tot meer blootstelling aan water-gerelateerde gevaren en ontwikkelen mensen daarom meer kennis over hoe zij daarmee om moeten gaan.

Naast de zeven steden die zijn geanalyseerd met betrekking tot hun vermogen om overstromingsrisico, waterschaarste en afvalwaterzuivering te beheersen, is de analyse uitgebreid met acht andere steden. Deze additionele steden zijn beoordeeld met betrekking tot een of twee van de genoemde wateruitdagingen. Op grond van deze uitbreiding is er een positieve correlatie gevonden tussen watermanagementprestaties en bestuurlijk vermogen (r=0,81). Het aantal steden (n=15) is te klein om deze trend statistisch te extrapoleren. Ook kan een correlatie niet worden geïnterpreteerd als causaal verband. Toch lijkt een positief verband tussen goede managementprestaties en een hoge bestuurlijk vermogen aannemelijk. Om een oorzaak-gevolg relatie te bevestigen zijn meer stedenbeoordelingen nodig die in de loop van de tijd herhaald zouden moeten worden. Op deze manier zou onderzocht kunnen worden of een stijging in bestuurlijk vermogen voorafgaat aan verbeteringen in managementprestaties (i.e. covariantie). Alternatieve verklaringen zouden daarmee kunnen worden uitgesloten. Aanvullend onderzoek naar causale verbanden is belangrijk omdat hiermee prioriteiten voor bestuurlijke capaciteitsontwikkeling beter kunnen worden begrepen. Hiermee kunnen steden hun watermanagementprestaties gericht verbeteren. De urgentie is hoog gezien de ongekende veranderingen in een wereld zoals beschreven in hoofdstuk 2.

CONCLUSIE

Hoofdstuk 8 trekt de belangrijkste conclusies uit de voorgaande hoofdstukken. De doelstelling van het proefschrift is te begrijpen wat waterwijsheid is en welke bestuurlijke condities steden nodig hebben om dit te bereiken. Daarvoor is op empirisch niveau veel inzicht nodig in de belangrijkste kenmerken van hoe goed de stedelijke waterkringloop wordt beheerd.

Door de ontwikkeling, verfijning en beoordeling van de City Blueprint-indicatorraamwerk in 45 gemeenten en regio's is dit inzicht verschaft. In hoofdstuk 4 zijn vijf niveaus van voortschrijdende prestaties binnen de stedelijke watercyclus geïdentificeerd: (I) steden zonder primaire watervoorzieningen (BCI:0-2), (II) verspillende steden (BCI: 2-4), (III) waterefficiënte steden (BCI: 4-6), (IV) grondstof-efficiënte en adaptieve steden (BCI: 6-8), en (V) waterwijze steden (BCI: 8-10). De geïdentificeerde niveaus van waterwijsheid laten zien dat het de geobserveerde verduurzaming van de stedelijke watercyclus in feite een proces van probleemverschuiving is. Op basis van 45 evaluaties van de stedelijke watercyclus en de geobserveerde niveaus zijn er drie belangrijke waarnemingen die dit proces van probleemverschuiving typeren.

1. Steden die de toegang tot basiswatervoorzieningen verbeteren houden onvoldoende rekening met een goede behandeling van de toegenomen afvalstromen. Hiermee wordt het probleem verschoven van een gebrekkige basisvoorziening (drinkwater) naar grootschalige vervuiling van bodem en water.
2. Steden die investeren in beheersing van de vervuiling worden meestal pad-afhankelijk in een aanpak van afval(water) behandeling die geen oplossing biedt voor de opkomende schaarste aan grondstoffen en energie. Vooral in de context van de zoektocht naar betrouwbare hernieuwbare energiebronnen en grondstoffen is dit een gemiste kans.
3. Veel steden die een volledige toegang tot watervoorzieningen bereiken en de verontreiniging verminderen, gaan grotendeels voorbij aan de sleutelrol die water in de ruimtelijke ordening speelt om klimaat-gerelateerde uitdagingen zoals hittegolven, waterschaarste en waterkwaliteit het hoofd te bieden. De uitdaging om deze reeks van tenminste deels vermijdbare problemen te voorkomen vereist een aantal sleutelfactoren die soms onvoldoende worden meegenomen. Hierbij kan gedacht worden aan het creëren van randvoorwaarden voor een verbeterde samenwerking tussen verschillende organisaties (Governance Capacity-indicatoren) en het integraal meewegen van verschillende componenten van de stedelijke watercyclus in de beleidsvorming en uitvoering (de City Blueprint-indicatoren). Een nulmeting is daarbij cruciaal om de juiste prioriteiten te stellen.

Op basis van de empirische studie van bestuurlijk vermogen in relatie tot 41 specifieke wateruitdagingen in 15 steden is een algemeen verband gevonden tussen watermanagementprestaties en bestuurlijk vermogen om deze uitdagingen aan te pakken. Het vermogen om beleid te implementeren en continu te monitoren, te evalueren en daaruit lering te trekken kan gezien de hoge waargenomen correlaties beschouwd worden als de belangrijkste determinant voor goed watermanagement. Om verder te gaan dan correlaties en ook causale verbanden te vinden zijn meer stadsanalyses nodig die in de loop van de tijd worden herhaald. In een dergelijk onderzoek zijn drie algemene contextuele factoren van cruciaal belang om haalbare prioriteiten voor capaciteitsontwikkeling in stedelijke ontwikkeling vast te stellen. Deze drie contextuele factoren zijn:

1. Waarschijnlijkheid en impact van milieurisico's;
2. Nationale bepaalde institutionele setting;
3. Het bevoegdheidsniveau om financiële ondersteuning op lange termijn veilig te stellen.

Het City Blueprint performance Framework en Governance Capacity Framework kunnen een belangrijke instrument vormen voor een gezamenlijke kennisvergaring en informatie-uitwisseling als concreet startpunt voor een zinvol leerproces tussen steden. Het stelt de steden in staat strategisch sneller en beter inzicht te verwerven in eigen watermanagementprestaties en bestuurlijk vermogen. Op grond daarvan zijn zij beter in staat doelen te stellen, goede methoden toe te passen en de resultaten effectief en efficiënt te implementeren.

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