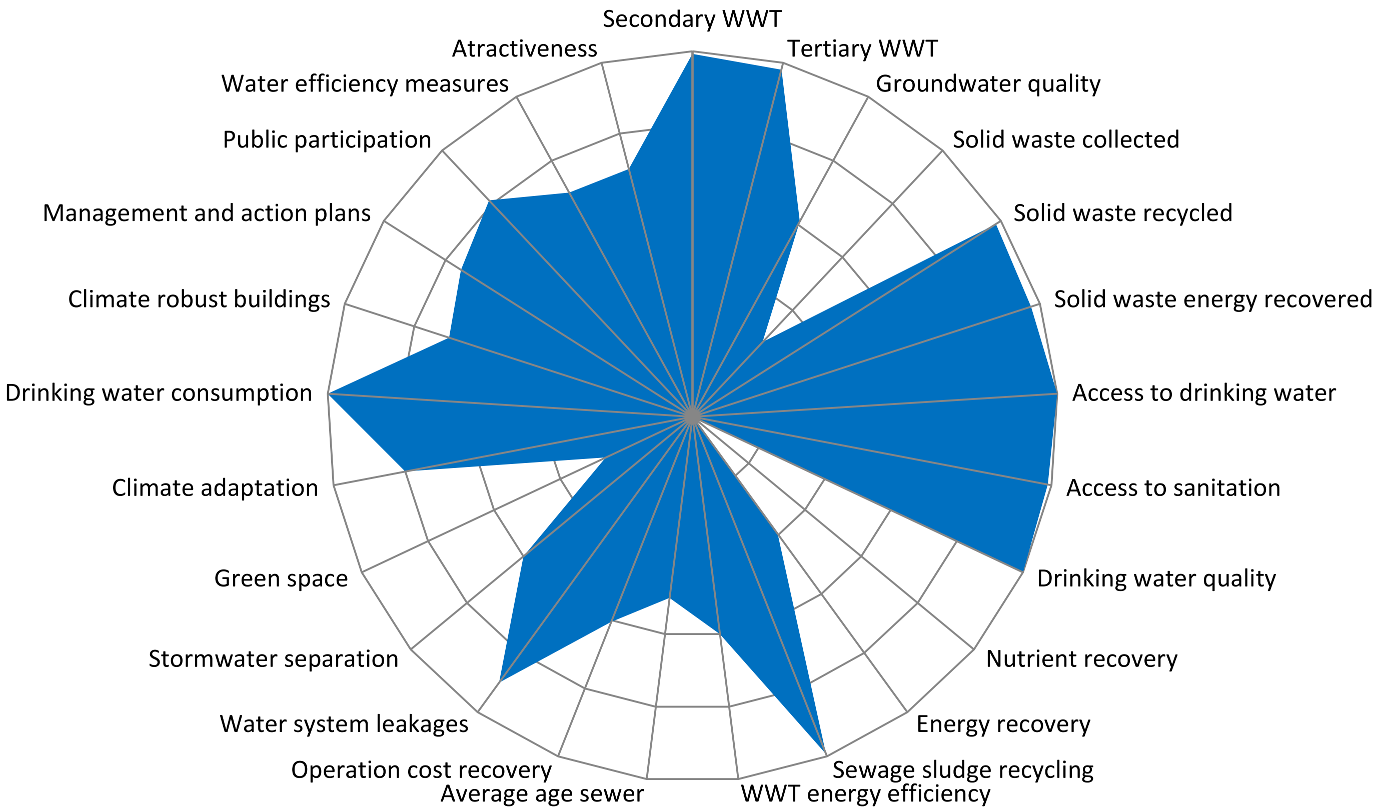
Master thesis

Towards sustainable Water Resources Management
Improving the City Blueprint assessment framework



S.H.A. Koop (3481859) University of Utrecht

Supervision: Kees van Leeuwen

Glossary

BCI	Blue city index
BCI*	Alternative blue city index
CB	City blueprint
CB*	Alternative city blueprint
BOD	Biological oxygen demand
ES	Ecosystem services
EEA	European environmental agency
EPI	Environmental performance index
EU	European Union
GDP	Gross domestic product
EGCI	European green city index
GHG	Green house gas
IWRM	Integrated water resource management
IPCC	International panel on climate change
OECD	Organization for economic co-operation and development
SSI	Sustainable society index
UHI	Urban heat island
UM	Urban metabolism
UN	United nations
UNEP	United nations environmental program
UWCS	Urban watercycle services
WF	Water footprint
WWT	Wastewater treatement
WQI	Water quality index

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Summary

The impact of climate change, urbanization and water pollution due to urban waste and wastewater, may cause flooding, water scarcity, adverse health effects, and rehabilitation costs that can exceed the carrying capacity of cities. Currently, there is no internationally standardized indicator framework for integrated water resources management (IWRM) at the city level. The City Blueprint (CB) is a first attempt of such a framework. It is also a first step in enhancing the transition towards water wise cities. In this thesis, a four step revision of CB indicator framework has been executed based on data for 32 cities: 1) A distinction has been made between *trends and pressures* (on which the city's IWRM has a negligible influence) and *IWRM performances.* Therefore, a separated framework has been developed that indicates the most prominent trends and pressures; 2) The CB data accuracy has been assessed and new indicators have been selected; Moreover, the performance framework has been reconstructed to arrive at an approximately proportional contribution of all indicators and categories to the overall score, i.e. the Blue City Index (BCI). This was done by analyzing correlations and variances, as well as by balancing and regrouping the different indicators of the CB; 3) Next, a suitable aggregation method has been selected for the performance framework; 4) Finally, correlation coefficients have been calculated between the improved BCI (BCI*) and other city descriptors. Six indicators have been removed because of data inaccuracy, overlap / redundancy, 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 belonging to the category *solid waste treatment*. Furthermore, the geometric aggregation method has been selected and applied because it emphasizes the integrative nature of IWRM by penalizing unbalanced indicator scores. The BCI* showed high correlations with ND-GAIN climate readiness index (r=0.89), GDP (r=0.86), environmental awareness (r=0.82) and the World Bank governance indicators. The *trends and pressure* framework has been developed to provide a context to the IWRM performance of cities and is centered around the social, financial and environmental trends and pressures for each city. The variance of the BCI* is a factor 2.35 higher than the BCI because it is more performance-oriented. Hence, the potential gain in the sustainability of urban IWRM by sharing best practices, is better emphasized.

Samenvatting

Klimaatsverandering, verstedelijking en watervervuiling door emissies van afval en afvalwater leidt onder andere tot overstromingen, waterschaarste, gezondheidsschade en kosten die kunnen uitstijgen boven de (financiële) draagkracht van steden. Bovendien zijn er geen gestandaardiseerde indicatoren voor het benchmarken van stedelijk integraal waterbeheer. De City Blueprint (CB) is een eerste stap voor een dergelijke benchmark en kan worden toegepast in het transitieproces naar 'water wise cities'. In deze thesis wordt de CB in vier stappen aangepast, waarbij data van 32 steden zijn gebruikt: 1) Er is een onderscheid gemaakt tussen enerzijds trends en spanningen (waarop stedelijk integraal waterbeheer geen noemenswaardige invloed kan uitoefenen) en anderzijds prestaties. Daarom is er een apart raamwerk ontwikkeld dat de meest prominente trends en spanningen aangeeft; 2) De CB data accuraatheid is geanalyseerd en mogelijkheden voor nieuwe indicatoren zijn verkend. Verder is het CB kader aangepast met als doel om alle indicatoren en categorieën een evenredige bijdrage te laten leveren aan de Blue City Index (BCI). Dit is gedaan door het analyseren van correlaties en varianties; 3) Vervolgens is er een passende aggregatiemethode geselecteerd; 4) Tot slot is de verbeterde BCI (BCI*) gecorreleerd met andere stedelijke indicatoren. Zes indicatoren zijn verwijderd omdat de data niet accuraat waren, of omdat er overlap was, of omdat de indicatoren niet prestatie georiënteerd waren. Zeven indicatoren zijn toegevoegd: secondaire en tertiaire afvalwaterbehandeling, operationele kostendekking, groene ruimte, en drie indicatoren voor afvalbeheer. Ook is de geometrische aggregatiemethode toegepast. De aangepaste BCI (BCI*) correleert sterk met ND-GAIN indicator voor klimaatgereedheid (r=0.89), GDP (r=0.86), de milieubewustzijnsindex (r=0.82) en de Wereld Bank governance indicatoren. Het '*trends and pressures'* raamwerk verschaft het sociale, economische en milieu kader van steden. De BCI* vertoont 2,35 maal meer variantie dan de BCI omdat het meer prestatiegerichte indicatoren heeft, waarmee ook de potentiële winst die haalbaar is door het uitwisselen van 'goede praktijken' beter benadrukt wordt.

1. Introduction

1.1 Water challenges in cities

The majority of the world's population live in cities (Figure 1; UN DSA, 2009). Because by far most resources are consumed here, the current and future challenge to achieve human well-being, sustainable use of natural resources and economic growth is particularly large for 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 consumed in cities as well (UNEP, 2013). The pressure and potential for innovation by sharing of knowledge amongst cities will only increase due to vast urbanization and urban sensitivity to climate change. The urban watercycle has an essential role in this process.

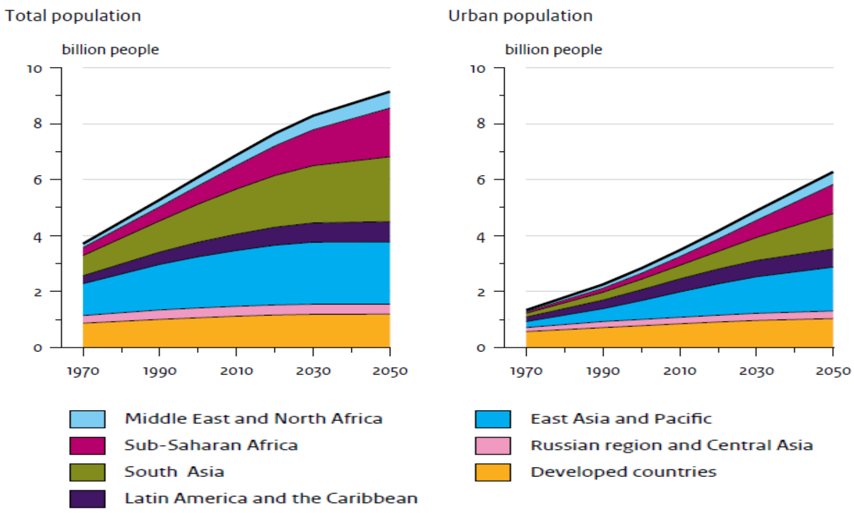

Figure 1 World's population and urbanization projections according to the baseline scenario of the United Nations Department of Economic and Social Affairs (2009). Source: Ligtvoet *et al.,* 2014.

Currently, over half of the word population lives in cities, in flood prone areas along the coast and major rivers (Figure 2). In the coming 40 years urbanization is projected to increase with more than 2 billion people, meaning that two third of the world population will live in cities by 2050 (Figure 1). This rapid urban growth will mostly take place in developing countries where it causes immediate water-related challenges. Currently, basic needs are insufficiently met since over 600 million people still do not have access to safe drinking water and 2.5 billion people lack improved sanitation facilities (UNEP, 2012). Diseases related to unsafe water caused by inadequate sanitation and hygiene lead to an estimated 1.7 million deaths a year (WHO, 2002). Furthermore, costs of climate change are in general high and will further increase, although they will differ per region. For example, Europe is expected to be only moderately impacted by climate change (IPCC, 2013), still the calculated damage of 240 billion US$ by 2080 (JRC, 2014) is significant. Large investments in urban climate adaptation and mitigation are therefore necessary.

Flooding

Rapid urbanization leads to urban developments in flood prone areas, large scale surface water pollution and depletion of freshwater resources. Most cities are vulnerable to flooding and sweater intrusion because they are located in the vicinity of rivers and seas. Sea level rise and the increase in extreme river discharges poses a projected 15% of the global population at risk of flooding. This is mainly in urban areas including almost all worlds' mega-cities (Ligtvoet *et al.,* 2014). Importantly, cost-effective urban flood protection can often be attainable because of high concentrations of people and assets. Furthermore, impacts of floods by extreme rainfall will become more severe due to global warming. Often urban soil is largely sealed by buildings and paved infrastructure. Hence, rainwater cannot infiltrate which results in reduced groundwater recharge, and increased risk of urban drainage flooding (Shuster *et al.,* 2005). This affects many cities around the world including unexpected places such as the city of Copenhagen (EEA, 2012A).

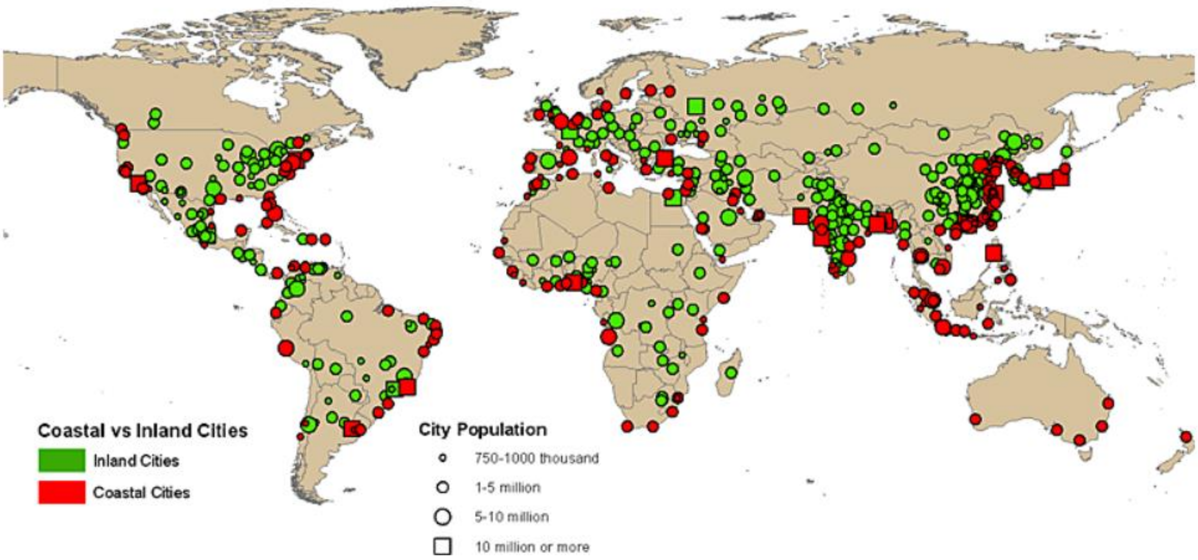

Figure 2 Coasts and deltas are the world's most densely populated areas. Freshwater resources are scarce and pollution, including seawater intrusion often occurs. Moreover, these regions are vulnerable to flooding and climate change (UN DESA, 2011).

Water scarcity

Approximately 30% of the megacities' population lives in arid areas (Sekovski *et al.,* 2012). By 2030, the world will experience an estimated 40% fresh water shortage (2030 WRG, 2009). Global water demand will increase by 55% between 2000 and 2050 and over 40% of the world's population is projected to live in river basins under severe water stress (Sekovski *et al.,* 2012). Furthermore, water withdrawals are estimated to increase by 50% in 2025 in developing countries, and by 18% in developed countries (WWDR, 2006). Climate change will cause increased droughts, limit freshwater availability, groundwater recharge and will amplify the spread of water-borne diseases (IPPC, 2013).

Water pollution

Access to clean water is a precondition for life, human activity and sustainable development. Cities are large emitters of nutrients and contaminants that reduces biodiversity and human health (Finotti *et al.,* 2014). The 'urban stream syndrome' describes a consistently observed degradation of streams fed by urban areas (Walsh *et al.,* 2005A; Gressner *et al.,* 2014). Key mechanism explaining this ''urban stream syndrome'' is an efficient drainage system together with large urban waste production (Walsh *et al.,* 2005B). Untreated sewer discharges, combined sewer overflows, solid waste pollution and stormwater runoff are the largest causes of urban water pollution. Stormwater runoff from sealed surfaces such as asphalt and concrete hinder infiltration and generates runoff peaks (Shuster *et al.,* 2005). This water is polluted with e.g. oil, grease and toxins from motor vehicles, road salts and heavy metals from roofs (Batten and Totten, 2012; EPA, 2014). These pollutants cannot be adequately purified by vegetation or processes in the soil (Grimm *et al.,* 2008). Secondary wastewater treatment (WWT) is a prerequisite for sufficient water quality (Grimm *et al.,* 2008). Hence, improved access to sanitation has to be combined with WWT in order to avoid enlarged wastewater drainage efficiencies (Ligtvoet *et al.,* 2014). Furthermore, nutrients such as phosphate are on the EU list of critical raw materials (European Commission, 2014). Combined sewer overflows are still frequent and will increase as a result of the increase in extreme weather events (Abdellatif *et al.,* 2014). Moreover, nutrient emissions in Asia and Africa are projected to double or triple within 40 years. This will enhance eutrophication, biodiversity loss, threaten drinking water, fisheries, aquaculture and tourism (Ligtvoet *et al.,* 2014). Cities generate vast amounts of solid waste which release hazardous substances and nutrients. Especially plastics easily enter rivers and ultimately oceans. Weathering processes reduces these plastics into small particles that are not biologically degradable and toxic. The plastics form a 'soup' in the Pacific ocean that covers twice the area of United States and affects many marine animals by ways of ingestion (Zarfl *et al.,* 2011; McFedries, 2012).

Heat risk

Global warming exacerbates heat waves that poses serious health risks especially for elderly. Recent heat waves have caused many fatalities e.g. in 2003, 70.000 Europeans died. Cities are vulnerable for extreme heat because of the 'urban heat island effect' (UHI) that describes higher temperature in cities, which can be up to 10°C. The solar energy that is absorbed and transferred into heat is higher in cities because the cooling effect of vegetation is low (EEA, 2012A). The UHI will amplify the severity of heat waves occurring more frequently and intense due to climate change (Baccini *et al.,* 2008).

Infrastructure refurbishment

Infrastructural and urban planning are key for sustainable Integrated water resource management (IWRM) but require large investment and long term planning. An estimated 41 trillion US$ (41 x 10^{12} US$) is needed to refurbish the urban infrastructure in the period between 2005-2030. Over 50%, 22.6 trillion US$ of these investments 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 and McKinsey, 2013). Yearly expenditures on water infrastructure for developed countries are currently around 1% of the GDP. For developing countries this is about 3.5% with extremes up to 6% or more (Cashman and Ashley, 2008).The widespread need to accelerated investments in infrastructure are exacerbated by increased climate change related adaptation costs to combat weather anomalies, extreme rainfall and water scarcity (Gessner *et al.,* 2014). Some of these challenges in cities are summarized in Figure 3.

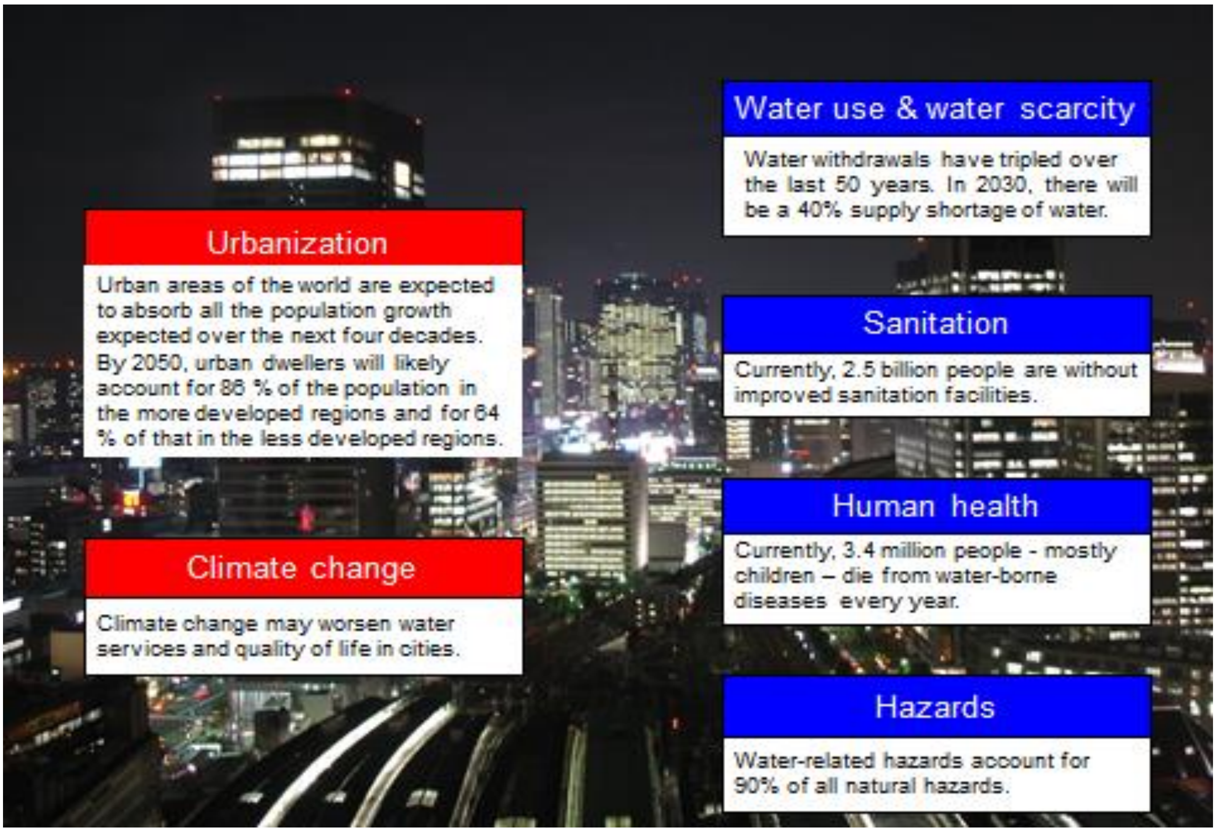

Figure 3 Megatrends pose urgent challenges in cities (Van Leeuwen, 2013).

1.2 The City Blueprint

Rapid urbanization, flooding, heat risks, water scarcity, infrastructure investment deficit, pollution and climate change all pose serious threats on cities worldwide. Cities need to become more resilient and resistant against these threats. Knowledge and technologies to do this are available and applied in a few cities, but much can be gained if best practices are shared. City Blueprints are quick scans for the evaluation of the actual situation in cities. The approach involves all stakeholders and is a first step in the strategic understanding and addresses the challenges concerning UWCS (Figure 4).

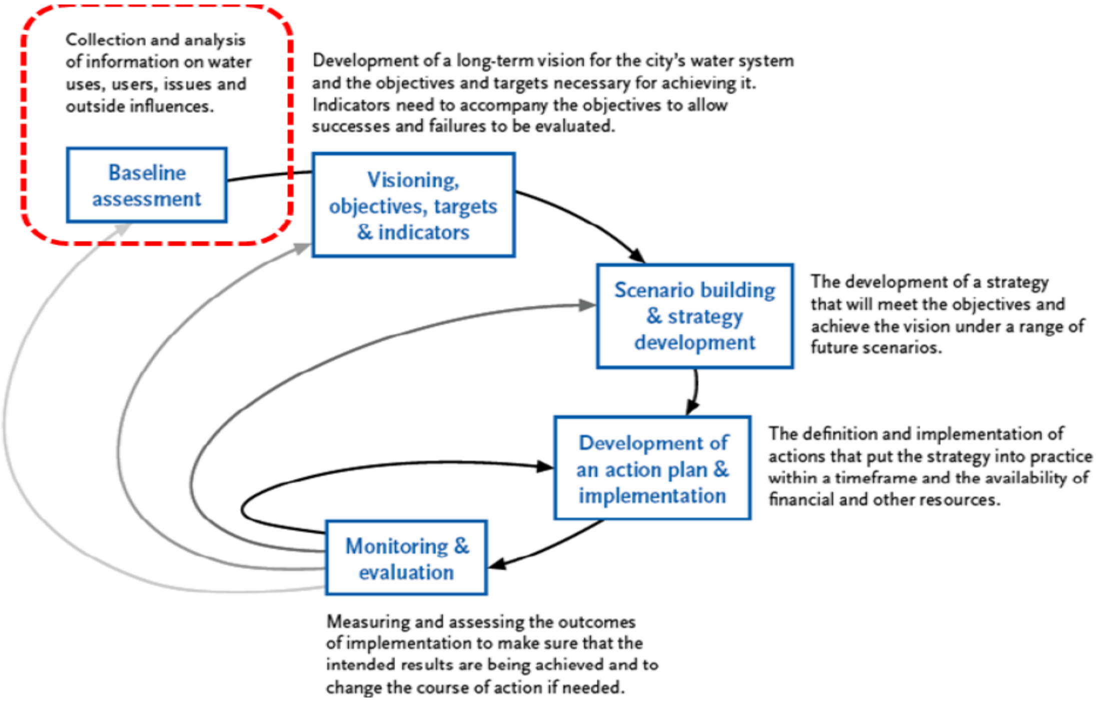

Figure 4 The strategic planning process for IWRM according to SWITCH (Philip *et al.,* 2011).

The City Blueprint (CB) process strives to promote best practices by stimulating the sharing of knowledge and experiences. This can be described as a city learning alliance and/or as city to city learning. The first step is that all relevant stakeholders provide information for a baseline assessment of 24 indicators presented in a spider diagram (Figure 5) and a final grade, the Blue City Index (BCI). Hereafter, exchange of best practices amongst stakeholders is promoted and long-term goals and priorities are set resulting in follow-up actions leading to measures that promote sustainable IWRM.

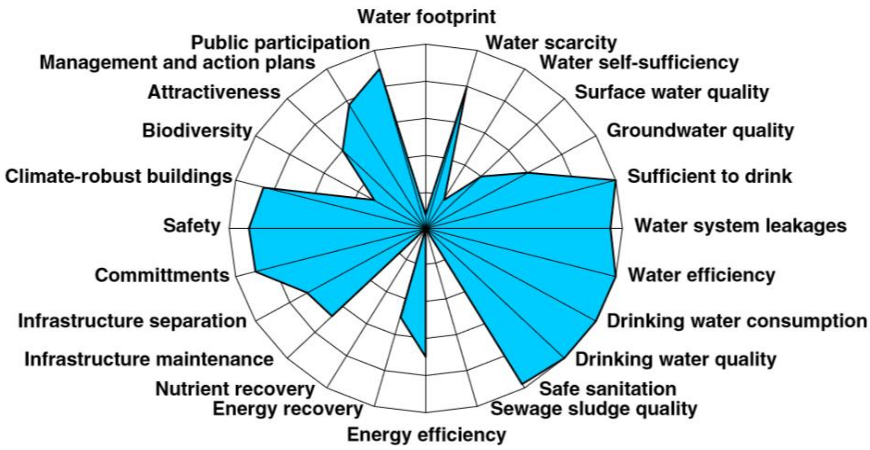

Figure 5 Right: The CB of Rotterdam. A score of 0 (center of the cycle) implies that further attention is needed and 10 points means an excellent score. The arithmetic mean of all indicators represents the BCI-score, for Rotterdam this is 7.03 (Van Leeuwen *et al.,* 2012).

This approach has been developed by KWR Watercycle Research Institute in collaboration with Deltares (Van Leeuwen *et al.,* 2012). After this, KWR has refined the approach (Van Leeuwen, 2013) and applied it to 30 cities (Van Leeuwen and Sjerps, 2014). The main objective of the CB approach is to create awareness amongst decision makers and resource managers that helps them envisioning, developing and implementing stepwise measures to transform towards water wise and water sensitive cities (Figure 6). Simplicity, transparency and ease of communication are key elements of the CB (Van Leeuwen *et al.,* 2012). Each indicator receives a score between 0 and 10 points (where 0 points means that further attention is needed and 10 points is an excellent score). The CB indicators have to be: 1) easy to access, 2) easy to understand, 3) timely and relevant, 4) reliable and consistent, 5) credible, transparent and accurate and 6) developed with the end-user in mind (Van Leeuwen *et al.,* 2012).

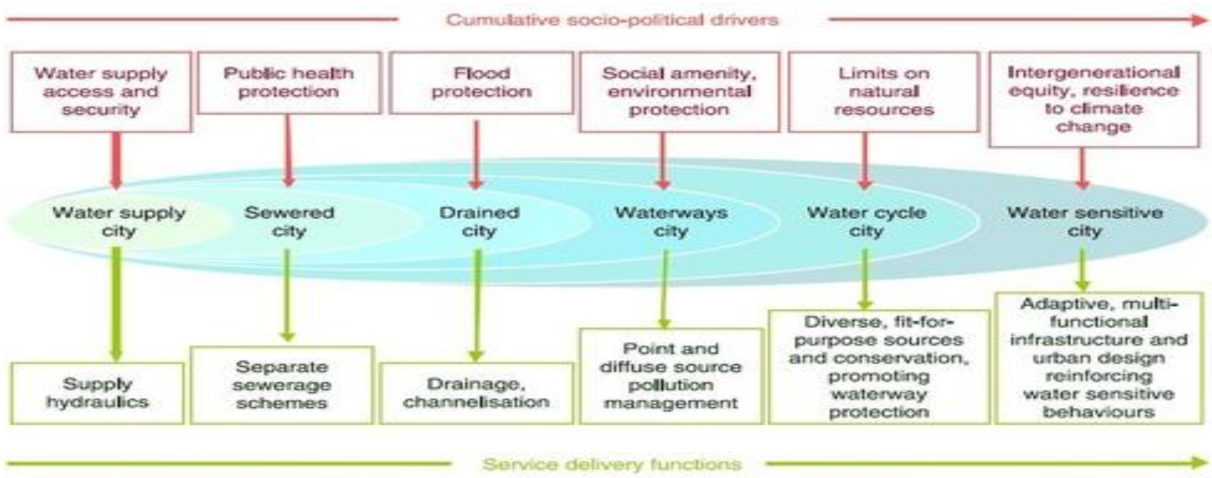

Figure 6 The different stages that can be distinguished in the transition process of cities towards water wise and sensitive cities (Brown and Farrelly, 2009).

There are many sustainability indices with elements of either water or cities, mostly at the country level. Indices that address water issues are, e.g. sustainable society index (SSI), Notre Dame Global Adaptation Index (ND-GAIN), Water footprint (WF), environmental performance index (EPI), OECD environmental indicators and the UN set of water indicators (SDS, 2014; ND-GAIN, 2014; Hoekstra *et al.,* 2009; Yale university, 2014; OECD, 2013; UN Water, 2014), Most important sustainability indices that address issues on the city scale are, e.g. European green cities, the Dutch municipal sustainability index, innovation cities index and European smart cities (Siemens, 2009; Vienna University, 2014). Abundant scientific literature is available on urban water technologies including best practices, innovative modeling approaches and case studies. Acknowledgement that urban water problems urge for an integrated approach is generally recognized (Ligtvoet *et al.,* 2014; Patterson *et al.,* 2013). However, only the CB provides an integrative indicator approach for policy makers that fully addresses urban IWRM issues. Knowledge to tackle these problems is present in the scientific community and best practices are successfully applied in a few cities, yet many cities show unsustainable IWRM. The CB is therefore essential to bridge the gap between scientific knowledge and local authorities, and provides an innovative and fully integrative urban water framework to support decision making.

1.3 City Blueprint revision

The CB followed a learning by doing approach and, at this stage, a critical revision of the indicator choice, methodology and framework as well as a revision of the indicator scaling and aggregation method is desired. This revision is based on (A) critical feed-back from the cities, (B) the need to better separate *trends and pressures* from the IWRM performances, (C) the omission of solid waste issues in CB framework, and (D) developments in the accuracy, availability and accessibility of data for the calculation of the indicators. Moreover, it is argued if (E) arithmetic or geometric is the most appropriated aggregation method to calculate the BCI. In fact, the CB aims to measure only the city's performance in order to set priorities and to show as clearly as possible the potential gain that can be attained by improving urban IWRM. An indicator that includes the environmental, financial and social setting may result in an unfair comparison between cities performances and fail to show the potential gain of improved IWRM. For instance, currently water scarcity is incorporated in the performance index. A water scarce city during the millennium Drought in Australian, such as Melbourne, would score low while it has implemented many measures and has gained enormous experience and knowledge about water efficiency, i.e., water sensitive management. On the other hand, the environmental, financial and social setting is key in identifying the key urban IWRM challenges. Therefore a distinction between the city's *performance* and (*external) trends and pressures* is desired. In this way, the specific setting, which is vital for understanding the local context, is not disregarded while cities IWRM performance is measured. All CB indicators are critically assessed on data reliability, scoring method and only time-series are used to ensure that the indicators are and will be up-to-date. Currently, the CB has adopted the sustainability definition of Brundtland: *Meet the needs of the present generation without compromising future generation to meet their own needs.* In this CB revision this definition is extended using the *people, planet, profit* concept. Three principles are guiding in the CB revision i.e. 1) Full cost recovery, 2) Equitable services, and 3) Ecosystem service (ES) preservation (Figure 7).

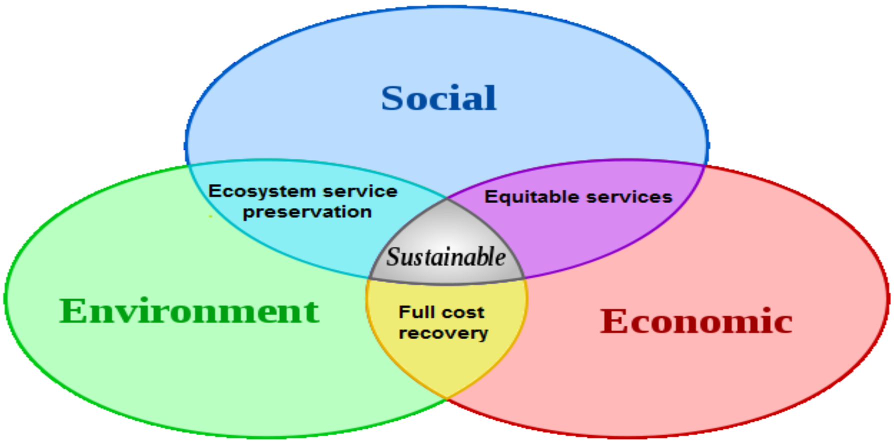

Figure 7 Conceptualization of sustainable development in urban IWRM. From the people, planet, profit concept three interfaces are identified which are guiding principles in this CB revision. Figure adjusted from UN (1992).

Full cost recovery: Important is that the price of water services includes all costs including prevention/compensation of negative impacts on the environment and future generations. For example WWT costs prevents water pollution. Moreover, if the water price includes costs that re necessary to prevent adverse environmental impacts, a balance can establish between water price and demand that would promote sustainable water consumption (EEA, 2012A; EEA, 2013). Full cost recovery also includes cost for long term UWCS preservation. If these costs are not fully covered, future generation pay the price.

Equitable services: UWCS should be accessible and affordable for every citizen. Especially the fulfillment of basic water-related needs, i.e. access to basic water services, are essential. Furthermore, adverse effects of improper water management such as surface water pollution, flood risk and effects of climate change should be prevented and, if they happen, it should not disproportionally affect the poor or future generations.

Ecosystem service preservation: An integrative ES approach should be addressed in the CB because key factors causing urban water threats are closely related to the well-functioning of ecosystems. Currently about one-third of the global population experiences moderate to high water stress, and pressures on water resources are increasing, due to the deterioration of ecosystems e.g., depletion and contamination. If current water consumption and pollution patterns continue to affect ecosystems, about two-third of the world’s population may experience water-stressed conditions by 2025 (UNEP, 2007). Besides fresh water, ecosystems provide food, energy and other life-sustaining resources such as cooling water for power supply and water for industry (UNEP, 2007). Especially fish which provides 2.6 billion people with at least 20% of their protein intake, is often indispensable. Ecosystems also provide regulating services such as flood control, climate regulation, water and air purification, water storage capacity and disaster prevention. Supporting ES maintain the conditions for life on Earth, conditions cities heavily depend on, such as biodiversity and a balanced nutrient cycle (Van Leeuwen *et al.,* 2012; UNEP, 2007). Finally ES also provide cultural services, i.e. spiritual and recreational value. Urban pressures such as waste flows leading to (water) pollution will increasingly disturb the ecosystems (UNEP, 2013). The CB focusses on the preservation of these ES by using the concept of urban metabolism (UM) which describes the inward and outward flow of energy and materials. As an organism, cities metabolizes ecosystem products e.g. fuels and water into the built environment, heat and waste (Decker et al, 2000). Resources such as freshwater, phosphorus and valuable metals are increasingly scarce because the abstraction is far beyond the ecosystems regenerating capacity (Cordell and White, 2011; Agudelo *et al.,* 2013). Moreover, the vast inflow of nutrients and hazardous substances released by untreated urban wastewater has a detrimental effect on ecosystems. In a sustainable city, waste(water) is considered as a resource by means of reusing and recycling, while energy consumption is as low as possible. The pressure on supporting ecosystems can be reduced if the urban watercycle transforms its metabolism from a linear towards a circular system (Figure 8).

Linear metabolism

Circular metabolism

Figure 8 Linear and circular urban metabolism (UM) (Rogers, 1996). In a city with linear UM, fresh water and resources flow in, much energy is used and polluted wastewater flows out. In a city with circular metabolism wastewater is a resource that is reused and recycled. Circular UM is vital for the CB ES preservation.

1.4 Research questions

Aim of this master thesis is to critically assess and improve the CB methodology, indicator selection and data provision. By doing this the CBs comprehensiveness, transparency and ease of use for policy makers, decision makers and water managers should be warranted. Furthermore, the set of indicators should be applicable on at least the European (EU) level and preferably on the global level, with data that is freely available on internet. With the findings of the CB revision a new alternative CB (CB*) is proposed and compared with other city descriptors. Therefore the following research question and sub-questions are formulated:

Which improvements in the set of indicators, assessment method, data use and graphical representation can be made in the City Blueprint sustainability assessment?

Sub-question 1: *How can a distinction be made in the City Blueprint framework between (1) IWRM descriptors in terms of trends and pressures and (2) the cities' performances on sustainable IWRM, and how should this be graphically presented?*

Sub-question 2 : *Which improvements in the City Blueprint set of indicators and categories are desired and attainable given the available public data and sustainability principles?*

Sub-question 3: *Which adjustments in the City Blueprint scaling and aggregation methodology are useful?*

Sub-question 4: *How does the alternative BCI and the trends and pressures score relate to the other city descriptors?*

2. Methodology

In order to get acquainted with the CB framework, the city of London has been assessed and the results have been used in this thesis. The first step in the revision of the CB was splitting of the current set of indicators into *trends and pressures* and *performances* indicators. Next, the *trends and pressures* framework has been set up. This is done by checking the data quality and providing a consistent indicator scaling method. Based on scientific literature and international indexes, e.g. World Bank and UN, a new framework was chosen and relevant new indicators were selected or developed to support this approach. The *trends and pressure* indicators were calculated for 32 cities including London and a presentation format has been selected. This was followed by the development of the *performance* framework. This begun with a statistical analysis of the CB indicator variance, correlations between indicators and the indicator correlations with reference to the category averages. The Pearson correlation coefficient is used throughout the report. These correlation are able to estimate the relation between two variables but do not prove causality. Next, the data quality of the indicators was evaluated as well as the indicator scaling methods. Decisions concerning the scaling method were supported by the results from the statistical analysis. Furthermore, based on literature research, gaps and insufficiencies in the coverage of urban IWRM (Figure 7), in the current CB set of indicators were identified. Importantly, additional indicators were developed based on the availability of public data with the aim to further improve the framework. Together with the results from the statistical analysis, a new set of indicators was proposed falling within different categories aimed at a better and more balanced representation of the most important urban IWRM performances in a city. This alternative CB (CB*) has been applied to 32 cities. As for the CB, the CB* has been statistically analyzed and refined as a result of the outcomes of the statistical analyses. After this iterative process, an improved CB* has been proposed. Subsequently, the CB* aggregation method has been selected by comparing the BCI* for the 32 cities calculated with an arithmetic and a geometric aggregation approach. Finally, the BCI* has been compared by calculating the Pearson correlation with other city descriptors e.g. GDP, environmental awareness index. *Etcetera.* All city descriptors and the BCI* are tested to meet the requirements for testing the Pearson correlations, i.e. being an interval or ratio level, a linear relation is assumed, significant outliers are removed and the descriptors and BCI* are tested to assure a normal distribution by applying the Shapiro-Wilk test using SPSS software (assumption of normal distribution rejected if significance is 0.02).

Results

3.1 Analysis of the City Blueprint approach

3.1.1 Descriptors of external trends and pressures

Every city has its own social, financial and environmental setting. This context may result in different priorities for IWRM in cities and their ability to attain sustainable urban water management. For example, a city situated in an (semi)arid area does not necessarily experience water stress due to overconsumption but simply due to the low natural availability of fresh water. Social and financial components are also essential. For example, financial resources are necessary for investments in urban water systems and, enough skilled labor force is crucial for running the water utilities. Therefore a distinction needs to be made between '*trends and pressures*' and the cities '*performances*' related to IWRM. To make sure that the major IWRM components are balanced, an equal number of indicators for social, environmental and financial classes is preferred (Table 1). Each indicator is scaled from 0 to 4 points, where a higher score represents a higher urban pressure or concern. In this way, the *trends and pressures* are identified that may hamper sustainable IWRM or, on the contrary, pose opportunity windows. Annex 7.2 describes the scaling method and data sources of the (sub-)indicator that will be proposed in this section 3.1.1.

Each indicator is scored from 0 to 4 points:
0) No concern
1) Little concern
2) Medium concern
3) Concern
4) Great concern

Table 1 Conceptual framework for the CB descriptors of external trends and pressure (Annex 7.2).

Categories	Indicators	Sub-indicators
Social pressures	**1. Urbanization rate**	
	2. Burden of disease	
	3. Education rate	
	4. Political instability	
Environmental pressures	**5. Flooding**	Urban drainage flood River peak discharges Sea level rise Land subsidence
	6. Water scarcity	Freshwater scarcity Groundwater scarcity Salinization and seawater intrusion
	7. Water quality	Surface water quality Biodiversity
	8. Heat risk	Heat island effect
Financial pressures	**9. Economic pressure**	
	10. Unemployment rate	
	11. Poverty rate	
	12. Inflation rate	

Social pressures

Key indicators that are chosen to represent the main social stress factors in a city are: urbanization rate, burden of disease, education rate and political instability. As explained, urbanization worldwide will increase rapidly, especially in developing countries where local authorities face large numbers of people that are often poor and low educated. This causes a host of problems such as water, soil and air pollution, urban heating, climate change, poor governance and strongly delayed investments in infrastructure (SWITCH, 2011). Health is essential for human and societal well-functioning (WHO, 2014). The burden of disease indicator is a well-established, easy accessible and intelligible indicator that represents human well-being and social stability. This indicator makes use of age-standardized disability-adjusted life years (DALY) per 100.000 people. DALY is the quantification of premature death, burdens of disease and disability in life years (WHO, 2004; Annex 7.2). Education rate is expressed as percentage of children completing their primary education and is selected because it is an important measure of the human capital in the city. The indicator political instability includes many forms of the presence of violence, tension, conflicts and instability (World Bank, 2014). Political instability is by definition unsustainable because it decreases the human capital but may also hamper long-term investments and attention towards sustainable development.

Environmental pressures

In the introduction four water-related pressures have been described which strongly related to the geographic setting and climatological factors affecting urban areas, i.e. flooding, water scarcity, water pollution and heat risk. These are also the 4 indicators in the environmental category. Each environmental indicator is the arithmetic average of the associated sub-indicators.

Flooding

Many people live in flood prone urban areas along the coast and rivers often due to vast urbanization (Figure 2). The most important types of urban floods which are coastal flooding, riverine flooding, urban drainage flooding and flooding due to land subsidence, are selected to be indexed as sub-indicators (EEA, 2012A; Table 1). Coastal floods occur during storm surges and river floods are mainly triggered by heavy rainfall and/or snow melt in upstream areas. Decrease in upstream storage capacity due to a decrease in vegetation typically leads to quick runoff, soil erosion and downstream flood vulnerability. Loss of human life, property and land are examples of the severe consequences of flooding (EEA, 2012A). To score both the external pressures of coastal and of riverine flooding, the percentage of land that is inundated due to a 1 meter rise in sea or river level are both taken as a sub-indicator. For these sub-indicators, the effects of flood protection works is disregarding in order to only measure *trends and pressures* instead of water defense performances (Annex 7.2). During extreme precipitation events the piped system capacity can fall short because of the high runoff created by a high share of imperviously sealed urban soil, leading to urban drainage flooding. Therefore, the percentage of the soil that is sealed is taken as a sub-indicator for the vulnerability of urban drainage (Annex 7.2). Finally, land subsidence is often caused by groundwater overexploitation or peat oxidation (Hoogland *et al.,* 2012) and may lead to flooding in low lying urban areas. Land subsidence is regarded a sub-indicator of flood vulnerability in low lying areas (Annex 7.2).

Water scarcity

Freshwater and groundwater scarcity are the most common water scarcity issues and are therefore chosen to be indexed as most relevant *trends and pressures* for water scarcity. Both sub-indicators represent the water abstraction as percentage of the total renewable water resource. Furthermore, salinization and seawater intrusion is indexed because seawater intrusion is closely linked to water overexploitation (Mtoni *et al.,* 2013) and because urban growth stimulates unsustainable irrigation practices salinizes the soil (Merchán *et al.,* 2014). Salinization and seawater intrusion affect urban food security, fresh water availability and ES. These sub-indicators are selected because they measure local human pressure on water resources in a direct way. It is chosen to leave out the water footprint (WF) concept from Hoekstra et al, (2009) which describes the volume of water over the full supply chain, that is needed to produce a product or that is used by a country. The WF considers all water use in the full global supply chain, making it a strong tool to describe global water usage as a consequence of a certain standard of living. Because this supply chain is global, the WF is not particularly suitable to describe local water scarcity *trends and pressures*. For example, a country that imports all their goods that require much water use in their supply chain, will have a high WF but local water scarcity is alleviated and can be low.

Water quality

Cities are often situated along major rivers and delta regions where upstream water pollution is an important trend or pressure for the city's surface water quality. Pollution such as agricultural run-off, irrigation, industrial discharges and upstream municipal discharge of solid waste and sewerage cause high levels of e.g. pesticides, nutrients, salts and heavy metals concentrations in downstream cities. Both the WQI (water quality index) and the (aquatic) biodiversity are chosen to represent *trends and pressures* of water quality (Yale University, 2014). Section 3.1.3 (*indicator improvements*) provides an argumentation why the WQI index is recommended to be excluded from CB (performances). Importantly, the WQI uses national data which leads to overestimations of the urban water quality, since cities are large emitters of pollution (Van Leeuwen *et al.,* 2013; Finotti *et al.,* 2014). However, this country averaged WQI can be suitable as a measure for the external pressure of pollutants that can enter the city. Furthermore, the WQI is, until now, the only index that assesses water quality worldwide. Aquatic biodiversity is also an indication of surface water quality. For instance, biodiversity is used to report the status of water quality in European water framework directive (WFD) (EEA, 2014B). Data that is used to describe this sub-indicator is used in the current CBs biodiversity indicator. Section 3.1.3 (*indicator improvements*), provides an argumentation why it is recommended to exclude biodiversity from the CB**.** As for the WQI, biodiversity data represent national averages and thus may lead to a strong overestimations of aquatic biodiversity in cities because cities are large emitters of pollution (Van Leeuwen, 2013; Finotti *et al.,* 2014). However, this sub-indicator is useful for quantifying the state of aquatic ES on which the cities depend, e.g. fish population. Although the design of urban waterfronts can partially mitigate the negative impact of urbanization on aquatic biodiversity (Dyson and Yocom, 2014), the country average aquatic biodiversity level largely measures the external pressure of the water quality entering and affecting cities.

Heat risk
As described in the introduction, cities are vulnerable for heat waves which will be exacerbated by climate change. The urban heat island (UHI) effect leads to higher temperature of urban air compared to the rural surrounding. Most urban soil is sealed by dark concrete and as a consequence all incoming radiation is transformed into heat. A higher share of green and blue space counteracts the UHI-effect strongly (EEA, 2012A). The average temperature of a city largely determines the comfort temperature or heat threshold. Below these heat thresholds mortality due to heat is minimal (Baccini *et al.,* 2008). Therefore the indexation of the UHI-effect takes into account two important components: Firstly, the share of green and blue area, and secondly, future temperature increase measured as the number of tropical nights >20°C and hot days<35°C between 2070-2100 (EEA, 2012A).

Financial Pressures
In order to attain full cost recovery that includes cost of negative impacts on ES and achieving equitable service of UWCS (Figure 7), the degree of wealth should be sufficient. If this is not the case, full cost recovery is difficult and/or people cannot afford water services resulting in e.g. illegal groundwater withdrawal. Illegal housing is often a result of poverty and in many cases this leads to settlements in flood prone areas where water safety cannot be guaranteed (Ligtvoet *et al.,* 2014). Furthermore, the necessary investments in e.g. water infrastructure or flood prevention cannot be made as well. In order to determine the financial strength, the Gross Domestic Product (GDP) per capita is taken as an indicator. Also poverty rate expressed as the percentage of the population which has less than 2 US$ to spend a day, is incorporated. Furthermore, the unemployment rate (%) is selected because it is an important measure of the trend of economic development and paying for water serves requires a sufficient disposable income. Finally, the inflation rate (% year^{-1}) is taken. Urban IWRM deals with large investments spread over long time periods. High inflation rates decrease the opportunities to reserve for future investments (UNEP, 2013).

Indicator scaling
In order to ensure accurate indicator scaling, existing standardization methods have been applied which are often widely used. However, such a scaling method is not available for indicator 3 (*education rate*), 10 (*unemployment rate*), 11 (*poverty rate*) and 12 (*inflation rate*). For these indicator, the scorings of all countries are ranked and divided into five groups of equal size. Cities belonging to the lowest group received 4 points (great concern), cities belonging to the second lowest group received 3 points (concern) *etcetera*. However, this scaling method is not applied for indicators 8 (*heat risk*), 11 (*economic pressure*) and sub-indicator 6.1 (*urban drainage flooding*) because the relation between the country/city values show an insufficient proportional relation to the ranking. Hence, the average of the lowest and highest 10% values of all ranked city or country has been taken as the minimum and maximum for standardization of the indicators according to the min-max method (equation (1)). For more detail concerning the indicator scaling see annex 7.2.

Putting together the social, environmental and financial *trends and pressures*, provides an indication of how much sustainable IWRM is affected by these external trends and pressures (Figure 9). Annex 7.1 shows examples of *trends and pressures* for the following cities: Dar es Salaam, Kilamba Kiaxi, Ho Chi Minh City, Istanbul, Bologna, Melbourne and Amsterdam.

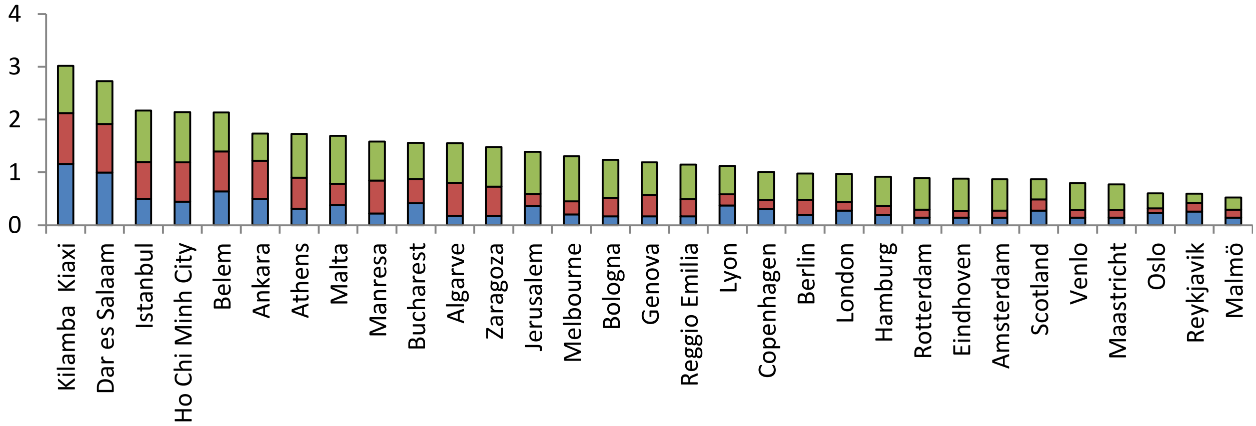

Figure 9 The arithmetic average of all 12 indicators. Green is the share of environmental concern to the overall score. Likewise, red is the share of financial concern and blue is the share social concern of the overall score.

3.1.2 Statistical framework analysis City Blueprint

Figure 10 shows the differences between the average top and bottom 25% scores together with the variance depicted in red. There is a high variation for indicators such as 14 (*energy recovery*), 15. *(nutrient recovery)* and 12 (*sewage sludge recycling*). It means that most improvements in UWCS can be attained by sharing of knowledge and experiences for these indicators. Differences in variance amongst indicators are acceptable because differences between the 32 analyzed cities actually can by larger for some indicators, e.g. indicator 6 (*sufficient to drink*) has low variance because most cities that are analyzed are situated in developed countries. However, variances that are unlikely to represent reality but are a result of the scaling method, are undesirable and the scaling methodology has to be improved.

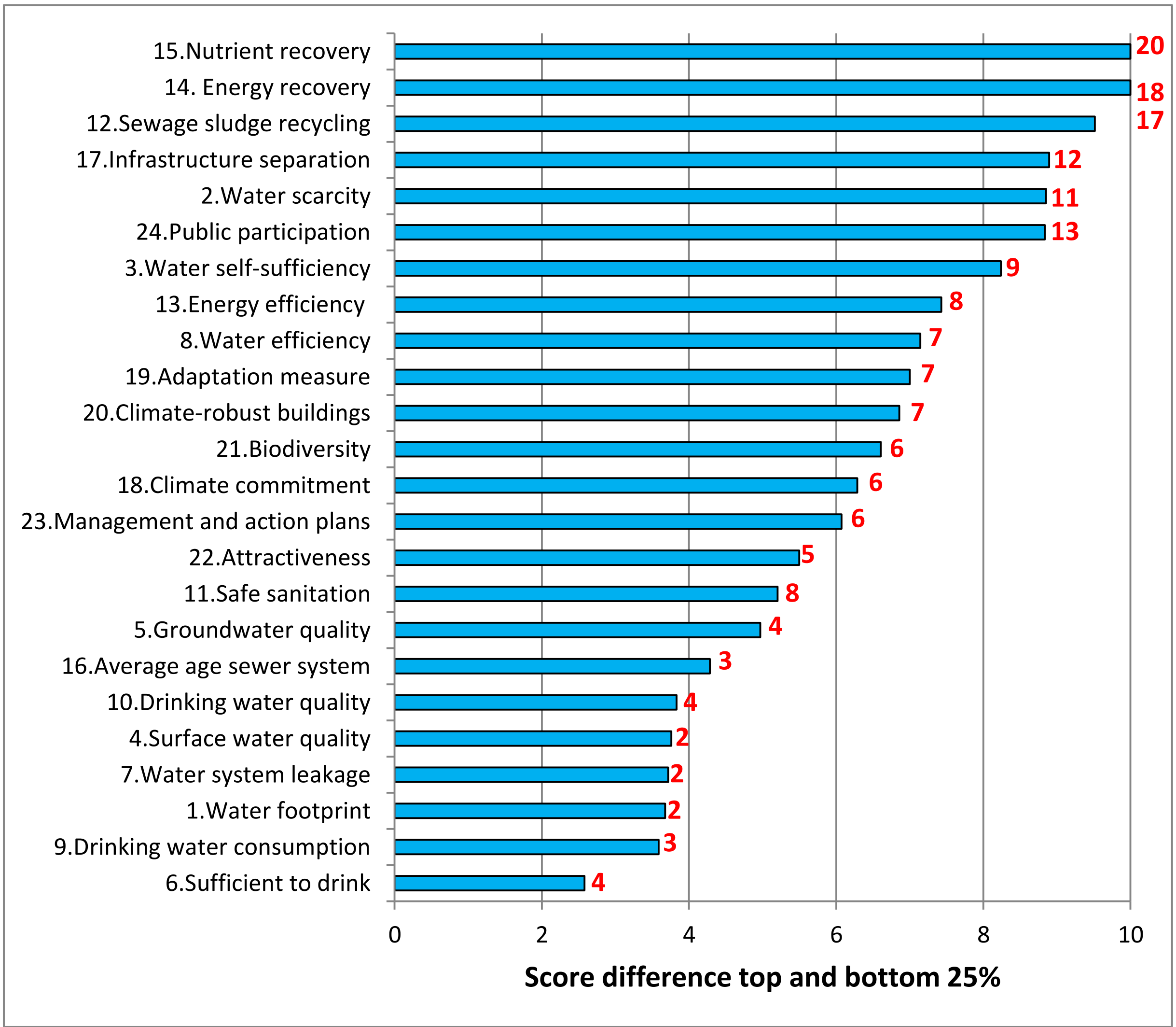

Figure 10 Space for improvement and sharing of knowledge and experience. Difference between average score of top 25% and bottom 25% per indicator. Red number is the variance within each indicator for 32 cities that are analyzed.

The scaling of indicators amongst the existing categories should be done in such a way that the indicators best represent the category. A supportive tool to measure if the indicators are adequately scaled is testing the correlation between the indicator score and the category average. Preferably the correlation coefficient is higher between indicators and their own category average than with other categories averages (Table 2). It is important to realize is that the smaller the number of indicators per category the more likely it is that a single indicator is higher correlated to its own category. This is simply because the indicator has a relatively larger contribution to the category average.

Table 2 The 24 CB indicators (x-axis) and their Pearson correlation r with each category (y-axis). The white boxes highlight the r of the indicators with their own category. Because the indicators constitute the category, it is desirable to have a higher r with their own category average. In orange are the indicators that correlated higher to another category average.

Categories	Indicator	I	II	III	IV	V	VI	VII	VIII
I Water security	1. Total water footprint	0,61	0,03	-0,01	-0,21	-0,08	0,13	-0,11	0,16
	2. Water scarcity	0,81	0,41	-0,31	-0,41	-0,14	-0,21	-0,13	0,03
	3. Water self-sufficiency	0,61	-0,07	-0,70	-0,48	-0,20	-0,67	0,25	-0,58
II Water quality	4. Surface water quality	0,31	0,91	-0,03	0,17	0,08	0,00	-0,05	0,20
	5. Groundwater quality	0,12	0,95	0,18	0,36	0,13	0,18	-0,07	0,46
III Drinking water	6. Sufficient to drink	-0,53	0,19	0,78	0,61	0,51	0,58	-0,03	0,54
	7. Water system leakages	-0,38	0,30	0,83	0,59	0,49	0,72	-0,23	0,82
	8. Water efficiency	-0,65	0,00	0,84	0,54	0,21	0,71	0,08	0,60
	9. Consumption	0,16	-0,24	0,21	-0,18	0,05	0,14	-0,17	0,19
	10. Quality	-0,44	0,15	0,81	0,59	0,45	0,58	-0,04	0,51
IV Sanitation	11. Safe sanitation	-0,63	0,23	0,79	0,71	0,42	0,57	-0,04	0,61
	12. Sewage sludge recycling	-0,55	0,27	0,51	0,87	0,32	-0,38	-0,38	0,41
	13. Energy efficiency	-0,38	0,19	0,69	0,82	0,47	0,65	-0,26	0,57
	14. Energy recovery	-0,48	0,12	0,48	0,82	0,46	0,46	-0,03	0,41
	15. Nutrient recovery	-0,23	0,34	0,15	0,68	0,23	0,12	-0,21	-0,03
V Infrastructure	16. Maintenance	-0,22	0,16	0,39	0,21	0,43	0,44	0,06	0,37
	17. Separation of wastewater and storm water	-0,13	0,05	0,33	0,42	0,90	0,19	-0,11	0,23
VI Climate robustness	18. Local authority commitments	-0,45	0,02	0,77	0,50	0,43	0,97	0,10	0,78
	19. Safety	-0,46	-0,03	0,77	0,59	0,40	0,95	-0,03	0,75
	20. Climate-robust buildings	-0,37	0,32	0,68	0,51	0,21	0,90	0,10	0,70
VII Biodiversity and attractiveness	21. Biodiversity	0,28	-0,03	-0,59	-0,57	-0,31	-0,60	0,63	-0,52
	22. Attractiveness	-0,28	-0,04	0,56	0,35	0,26	0,74	0,51	0,56
VIII Governance	23. Management and action plans	-0,38	0,19	0,81	0,54	0,41	0,89	0,12	0,80
	24. Public participation	-0,12	0,42	0,55	0,31	0,27	0,56	-0,10	0,92

Table 3 List of indicators with the high correlation coefficients (r>0.75). On top, the highest correlation coefficients between indicators of different categories which may point out that it is more valid to put these indicator together in one category. Below are the correlations coefficients of indicators belonging to the same category.

Between categories		r
18. Climate commitments	23. Management and action plans	0.86
23. Management and action plans	19. Adaptation measures	0.83
23. Management and action plans	20. Climate-robust buildings	0.82
11. Safe sanitation	6. Sufficient to drink	0.82
11. Safe sanitation	10. Drinking water quality	0.76
23. Management and action plans	8. Water efficiency	0.76
18. Climate commitment	22. Attractiveness	0.75

Within categories		
18. Climate commitment	19. Adaptation measures	0.95
18. Climate commitment	20. Climate-robust buildings	0.79
10. Drinking water quality	6. Sufficient to drink	0.75

In addition to Table 2, Table 3 shows the indicators with the highest correlation coefficients. Indicators can correlate strongly in an indicator framework, as long as both indicators do not measure the same underlying principle. Furthermore, high correlation coefficients between indicators of different categories may point out that it is more valid to sort these indicator together in the same category. However, note that indicators can correlate without any causal relation.

In Table 4 correlation coefficients between the categories are shown. Category 3 (*drinking water*) correlates highly with category 6 (*climate robustness*) (r= 0.79) and category 8 (*governance*) (r= 0.75). Category 8 (*governance*) is highly correlated with category 6 (*climate robustness*) (r= 0.79). As for indicators, high category correlations may point out that the categories measure the same underlying component. However, categories can correlate while they measure very different components.

Table 4 Pearson correlations between categories[1] . Especially category 3 (*Drinking water*) correlates highly with Category 6 (*Climate robustness*) and 8 (*Governance*). *Climate robustness* and *Governance* show the strongest correlation.

	1	2	3	4	5	6	7	8
1	1,00	0,22	-0,57	-0,57	-0,22	-0,46	0,03	-0,25
2		1,00	0,10	0,30	0,12	0,11	-0,06	0,38
3			1,00	0,62	0,47	0,79	-0,08	0,75
4				1,00	0,47	0,57	-0,24	0,46
5					1,00	0,37	-0,07	0,37
6						1,00	0,06	0,79
7							1,00	-0,01
8								1,00

[1] The Pearson correlation coefficient is used throughout the report. Correlation estimates the relation between two variables. Correlation does not prove causality.

3.1.3 Indicator improvements

All CB indicators have been critically assessed on data reliability, scoring method and whether the used data are time-series in order to ensure that the indicators are and will be up-to-date. First, indicators 4 (*surface water quality*) and 21 (*biodiversity*) were discussed and alternative indicators have been provided to replace them. Hereafter indicators 12 (*sewage sludge recycling*), 14 (*energy recovery*) and 15 (*nutrient recovery*) were assessed and improved methods were recommended. Finally indicators 7 (*water system leakages*), 16 (*average age sewer system*), 24 (p*ublic participation*) and 18 (*climate commitment*) have been assessed.

Surface water quality

For indicator 4 (*surface water quality*), the Yale University's water quality index (WQI) is used. The WQI consist of 5 basic features, i.e. electrical conductivity, pH, dissolved oxygen and total phosphorus and nitrogen concentrations because these are most frequently reported and relevant for eutrophication, acidification and salinization (Emerson *et al.,* 2010). The WQI is the only global database of water quality for inland waters. Insufficient spatial and temporal coverage of measurements, poor reporting and inconsistent sampling design pose serious issues concerning data reliability and representativeness (Srebotnjak *et al.,* 2012). Given these issues, the Yale University stopped using the WQI after the year 2010. Moreover, the WQI is a national average which leads to serious overestimations of water quality in the CB because cities in general are large emitters of pollution (Van Leeuwen, 2013; Finotti *et al.,* 2014; Gressner *et al.,* 2014). Rapidly growing cities such as Ho Chi Minh City, Dar es Salaam, Kilamba Kiaxi and Belém are good examples where the WQI is seriously underestimating local water pollution (Dan and Viet, 2009; Lyimo, 2009; Colombo *et al.,* 1993; Siqueira and Aprile, 2013). If these cities are plotted against an important determinant of urban water quality, i.e. secondary WWT, the discrepancy is obvious. Moreover, the variance of WQI is low while the differences in water quality between cities is expected to be large (Figure 10; Figure 11).

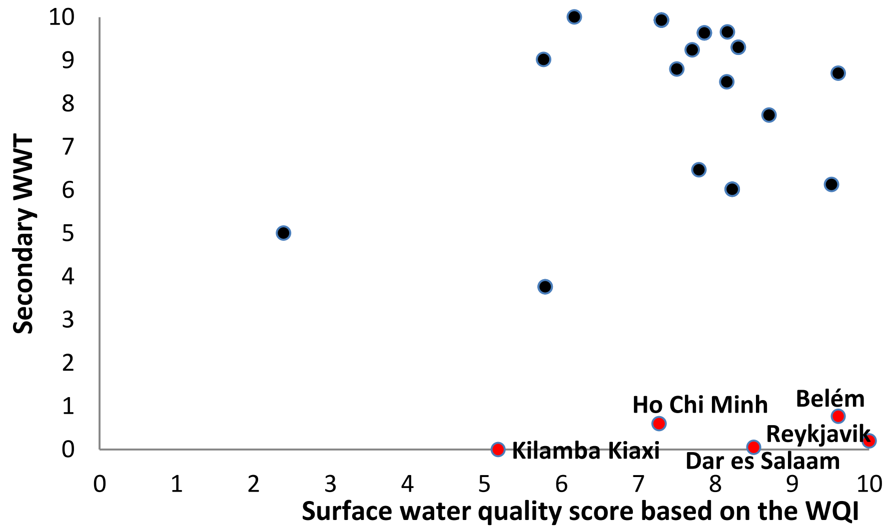

Figure 11 Secondary WWT coverage plotted against surface water quality as used in the CB. Because sewage treatment is an important determinant of urban surface water quality most scores are similar for both indicators. However, surface water qualities are clearly overestimated for the named cities.

Biodiversity

Aquatic biodiversity is closely linked to and often used to measure surface water quality e.g. in the EU water framework directive (WFD). Data that is used for indicator 21 (*biodiversity*) in EU cities, are from the WFD (EEA, 2014A) and for non-EU cities from the EPI water (effects on ecosystems) (EPI, 2010).

The latter is an aggregate of the WQI, water stress index and water scarcity index (Emerson *et al.,* 2010). The WFD's ecological status is an accurate description of solely aquatic biodiversity, and takes into account different ecological reference conditions per water type and local geographical setting (EC, 2014). The EPI water (effects on ecosystems) on the other hand is a rough estimate. Besides data quality issues, this indicator assumes that water scarcity has the same impact on water quality regardless of local circumstances. For non-EU cities, the WQI is used twice (i.e. in indicator 21 *biodiversity* and 4 s*urface water quality*) which makes the WQI weighing in the CB relatively high while it has considerable data reliability issues. Figure 12 shows the score for the EU cities if they are scored according to the EPI water (effects on ecosystems) (red + blue) and WFD (only blue).

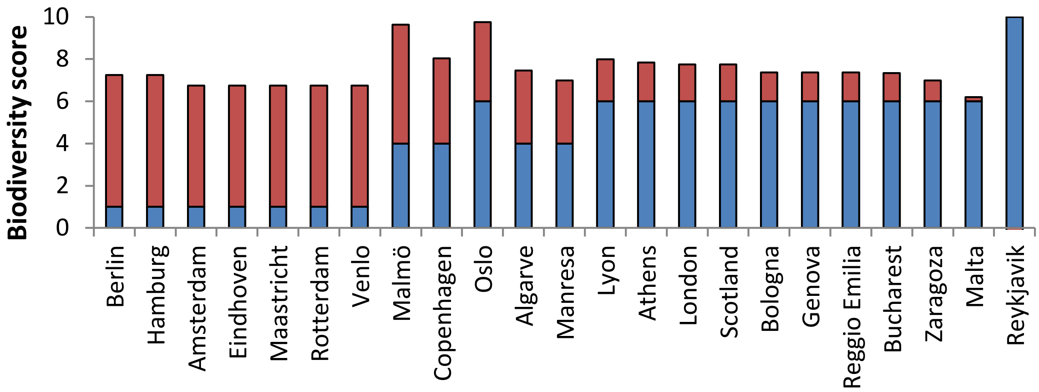

Figure12 A close look at biodiversity. Blue and red together represent the score of the Yale University effects on ecosystems index (EPI, 2010). The EPI score is used in the CB for non-EU cities. Blue represents the CB score according to the WFD (EEA, 2014). There is a large discrepancy in score given that the EPI (water effects on ecosystems) index scores on average 3.3 points higher than the EEA score.

The fact that two different indicator data sources are used to score biodiversity leads to inconsistencies in the overall scoring results because the water (effects on ecosystems) index produces higher scores for all EU cities (3.3 points on average). In fact, there are 7 EU cities that score 6 points higher if the EPI information is used. Besides this scoring issue, cities may have hardly any direct influence on upstream pollution of rivers entering these cities and affecting the urban aquatic biodiversity. In fact, it is unfair if some cities receive a low score while they can hardly decrease upstream pollution and do a lot to decrease their own water polluting activities. Therefore, cities should be judged only on their own activities to prevent or reduce water pollution. For example, the Netherlands is only responsible for about half of the heavy metal pollution, only 25% of the N and P pollution and less than 1% of their PCBs in the river Rhine (Rinaudo and Aulong, 2007).

Secondary and tertiary WWT

Cities are large water polluters. Especially untreated wastewater contains high nutrient loads that cause eutrophication. The high biological oxygen demand (BOD) may also lower oxygen concentrations in surface water. Oxygen depletion may lead to detrimental effects on organisms. A concentration of 5 mg/L dissolved oxygen (DO) is recommended for optimum fish health. Sensitivity to low levels of DO is species-specific, however, most species of fish are distressed when DO falls to 2-4 mg/L. Mortality usually occurs at concentrations less than 2 mg/L. The number of fish that die during an oxygen depletion event is determined by how low the DO gets and how long it stays down (Francis-Floyd, 2011). Because of the high amount of wastewater in urban areas, a stormwater-induced sewage overflow may already have detrimental effects on the quality and biodiversity of surface water (Gessner *et al.,* 2014; Abdellatif *et al.,* 2014; Goulding and Hu, 2009; Grimm *et al.,* 2008), let alone the impact of a constant flux of untreated wastewater. The secondary WWT coverage in Figure 13 suggests that urban surface water is most likely to contain more pollution than the country average water (effects on ecosystems) score that is used in the CB, especially for the red dotted cities. Reykjavik is an exception because Iceland is an island with a low population density. The green dots in Figure 13 shows the cities that receive much pollution from upstream sources. All cities with low biodiversity scores and high secondary WWT coverage are situated next to a river at the lower end of the river basin showing that biodiversity is not a performance indicator. In fact, these cities perform well on prevention or reduction of water polluting activities.

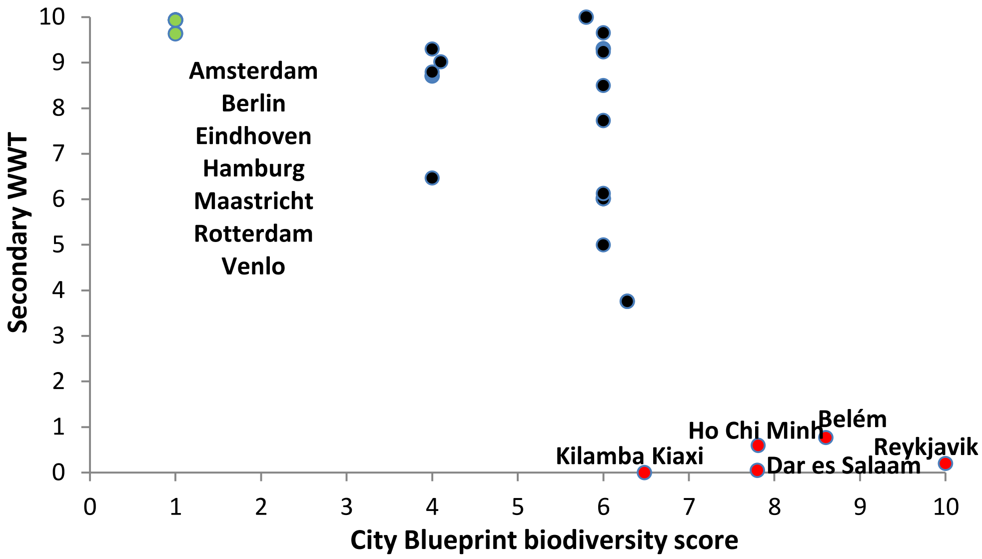

Figure 13 Cities are named when biodiversity (EPI, 2010) and secondary wastewater treatment (OECD, 2013) differ more than 5 points in score. The red dots are cities that most likely have overestimated scores for biodiversity because secondary WWT coverage is low. The green dots are cities situated at the lower end of a river basin and water pollution may be caused by upstream sources.

An important task of this CB review is to make a distinction between city's UWCS performance and *trends and pressures*, in order to improve decision making and sharing of knowledge and experiences. Consequently, cities should be judged only on their own activities to prevent water pollution. Data quality of indicator 21 (*biodiversity*) and 4 *surface water quality*) appears to be poor, increasingly outdated and the information may underestimate actual urban water pollution. In the absence of consistent local data on urban water quality and in order to get more performance-oriented indicators, it is recommended to focus on the main water polluting activities of a city. Wastewater treatment is key to urban water quality and biodiversity, and is clear performance oriented approach. It also better represents the cities own pressure on its local environment. Secondary and tertiary WWT coverage are widely used in other indices including the Yale university EPI which replaces the WQI for secondary WWT from 2010 onwards. Recently, the first international standardized set of city performance indicators, ISO37120, recognized secondary and tertiary WWT as core indicators (ISO, 2014). The UN key set of water indicators also makes use of the wastewater connection rate as part of fulfilling their Millennium Development Goals (UN water, 2014). Also the OECD, the European Green City Index (EGCI) and environmental vulnerability index (EVI) use secondary WWT as indicator (OECD, 2013; Siemens, 2009; SOPAC, 2004).

Assessing all wastewater streams

The CB has a strong focus on urban metabolism, where the main principle is that waste(water) should be seen as a resource for e.g. energy and nutrients. Indicators 12 (*sewage sludge recycling*), 14 (*energy recovery*) and 15 (*nutrient recovery*) clearly measure the reuse of wastewater necessary for a circular city (Figure 8). All three indicators only consider the fraction that is reused from the water treated in the WWT plants. This can be an inaccurate indication of WWT. For example, if a city only treats a fraction of the wastewater but fully recycles the nutrients obtained from this small fraction, it receives a high score while loads of potentially abstracted nutrients simply flush away not being reused. In this case most energy and nutrients from untreated wastewater is not reused or recycled and thus unsustainable waste fluxes are not adequately quantified. It is therefore proposed to fully incorporate the concept of urban metabolism by showing the energy, nutrients and sewage sludge that is recycled as fraction of the total potential that the city's wastewater has to offer. This can be done by simply multiplying the current scores with the urban WWT coverage. On average indicator 15 (*nutrient recovery*) decreases with 0.5 points, indicator 14 (*energy recovery*) decreases with 0.7 points and indicator 12 (*sewage sludge recycling*) decreases with 1 point if all urban wastewater is accounted for rather than only the fraction treated.

Infrastructure lifespan

Sewer systems together with drinking water infrastructures are the largest investments and maintenance costs for UWCS management. For most developed countries these costs are yearly about 1% of the GDP while this is much larger for developing countries (Cashman and Ashley, 2008). Indicator 16 (*average age sewer system*) currently determines the infrastructure refurbishment needs as the average age of the sewer system relative to a maximum age of 100 years. This maximum age is highly dependent on the materials used, subsoil, environmental quality standards and urban pressures. The 100 year maximum age is about the oldest age that a sewer system can potentially be and assumes optimal materials use, environmental circumstances (e.g. no land subsidence or instable soil) and low environmental pollution standards. However, much sewer systems have a lower maximum age e.g. the cast iron pipes often used before 1970's have a lifespan of 25 to 30 years (Pipelining Technology, 2014). Moreover, fast urbanization can expose higher pressure on the sewer system than it was originally designed for, resulting in higher refurbishment rates. In fact, a single maximum age of the sewer system in all circumstances is not plausible. Nevertheless, given the limited time and means of this CB revision, it is not possible to perform a specific and detailed analysis of the maximum age of the sewer system in all cities. The current indicator scores show very low variance (only 3 points) meaning that all cities have approximately equal scores. It is therefore considered reasonable to decrease the maximum age of the sewer system to a value of 60 years. This results in an average decrease in score of 2.3 points and an increase in variance of 2.4 points. For now, this indicator better represents the sewer refurbishment needs for most cities because it is closer to the actual average maximum age of most sewer systems, compensates somewhat for increases in pressure on sewer system by urban growth and compensated better for higher environmental standards i.e. less old sewer systems often have less leakage which alleviates the environment.

Infrastructure leakages

Indicator 7 (*water system leakages*) has similar problems concerning the low variance of 2.06 points resulting in minimal differences in scoring while actual performances differ considerably. This indicator is scored by subtracting the percentage of leakage by 100% and subsequently dividing this by 10. The poorest performing city, Kilamba Kiaxi, scores 5 points (i.e. 50% leakage). The maximum water system leakage here is assumed to be a 100%, implying that a city can only score a zero if all water in the system leaks which is highly unlikely to occur. In order to increase the distinctiveness (or variance) of this indicator, it is chosen to change the scaling by setting the maximum leakage percentage at 50%. Larger leakage rates will score zero points. By doing this the average score is decreased by 2.2 points and the variance is increased by 6.2 points. Furthermore, water system leakage now becomes more or less equal in decisiveness as the other indicators.

Public participation

The Voluntary Participation Index (VPI) is used for indicator 24 (*public participation*) and represents the average number of memberships in voluntary organizations per person. The link between voluntary organizations and public policy involvement is relatively direct because social networks, administrative tasks and commitment to local community and politics is amplified when more people voluntarily join organizations (EFILWC, 2006). For non-EU countries the VPI is estimated using the internet penetration of 2003 (Van Leeuwen and Chandy, 2013). However, given the fast development in internet connections it can be questioned if this correlation will persist in the future. The major disadvantage of the VPI is that it originates from 2003. Recently the 3rd European quality of life survey has been published (EFILWC, 2012). In this survey the percentage of people involved in unpaid work for EU countries is reported, which is considered as a suitable replacement for public participation. Involvement in unpaid work can be in any kind of organization e.g. educational , cultural, sports, community services, social movements or religious *etcetera*. However, for non-EU countries this is not measured and therefore has to be estimated. Fortunately, this indicator shows a high correlation with the World Bank indicator *Rule of law* if both indices are tested for all available EU countries (r= 0.84 n= 27; Figure 14). This linear relation can be used to estimate the percentage of people involved in unpaid work. In order to avoid unrealistic negative values due to extrapolations, the minimum involvement in voluntary work is set at 5% and the maximum involvement in unpaid work is 53% (in Austria). The percentages are standardized according to the min-max method (Annex 7.3) and named *public participation* in order to be consistent with the current CB.

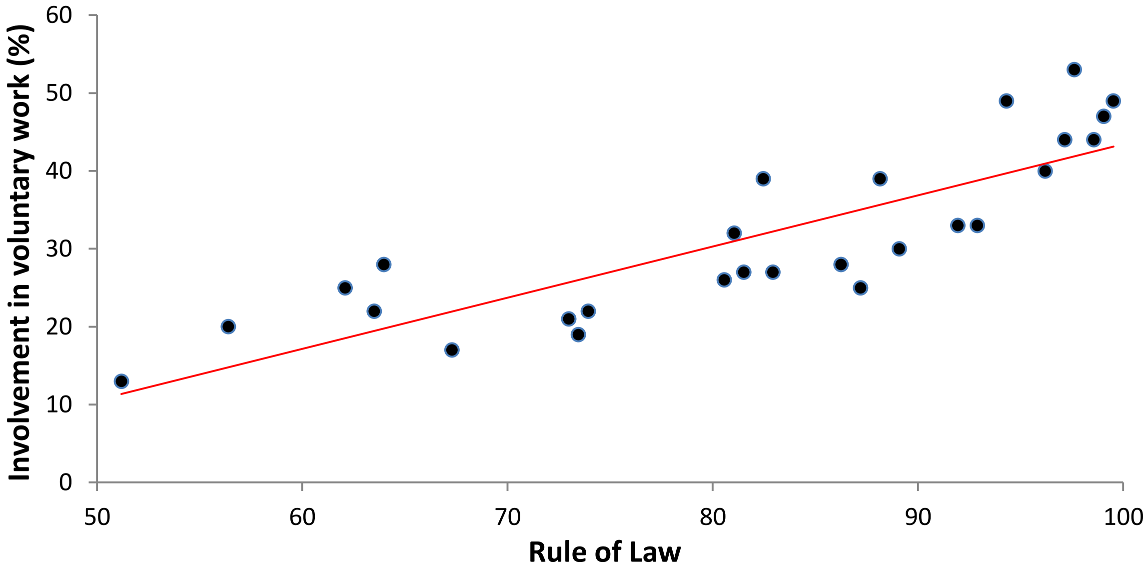

Figure 14 Pearson correlation between *involvement in voluntary work* (*% of population*) and the World Bank indicator *rule of law* (World Bank, 2014). Correlation is high (r= 0.84) and therefore the score for *involvement in voluntary work* (named public participation) for non-EU countries can be estimated using the following relation: public participation = 0.6573 * score for *rule of law* – 22.278.

Excluding climate commitment

Indicator 18 (*climate commitment*) shows a high correlation with indicators 19 (*adaption measures*) r= 0.95, 23 (*management and action plans*) r= 0.86, 20 (*climate-robust buildings*) r= 0.79, 22 (*attractiveness*) r= 0.75 and 8 (*water efficiency*) r= 0.66. Such correlations are only undesirable if they measure the same underlying aspect. The correlation between indicator 18 (*local authority commitment*) and indicator 19 (*adaptation measure*) is exceptionally high. It is most likely that both indicators measure the same underlying aspect because reports addressing climate change issues mostly initiate adaptation measures as well. Previous or ongoing adaptation measures are almost always included in these reports. Therefore if a climate report is available, these two indicators will get similar scores according to this assessment method (Table 5). The highly correlated indicators 8, 18, 19, 20, 22 and 23 are also assessed according to the same assessment method, making it even more presumable that indicator 19 is superfluous because it is also measured in other indicators. Therefore it is advisable to stop using indicator 19 (*climate commitment*) in the CB.

Table 5 Ordinal Indexation of indicators: 8 (*water efficiency*), 13 (*energy efficiency*), 18 (*climate commitment*), 19 (*adaption measures*), 20 (*climate-robust buildings*), 22 (*attractiveness*) and 23 (*management and action plans*).

Indicator score	Assessment
0	No information is available on this subject
1	Limited information is available in a national document
2	Limited information is available in national and local documents
3	The topic is addressed in a chapter in a national document
4	A local policy plan is provided in a publicly available document
5	A local policy plan is provided in a publicly available document
6	As 5 and the topic is also addressed at the local website
7	Plans are implemented and clearly communicated to the public
8	As 7 and budget is allocated to implement the plans
9	As 8 plus annual reports are provided on the progress of the implementation and/or any other activity indicating that this is a very high priority implemented at the level of the local community.
10	As 9 and the activity is in place for 3 years

3.1.4 Category improvements

Categories are important in developing the alternative CB (CB*) because it structures and balances the weighing of the most important components of sustainable IWRM in cities. The three sustainability interfaces as identified in the introduction, i.e. full cost recovery, equitable services, and ecosystem service preservation as well as the triple bottom line should be included in the categories in a balanced way (Figure 7). Furthermore, the aim of this category revision is to allocate indicators logically and to strive for an equal number of indicators per category. In this way all categories (and sustainability interfaces) are of equal importance when determining the alternative BCI (BCI*) score. In this process, new indicators are proposed to strengthen some categories. This chapter will give all relevant recommendations of the CB categories sequentially (Table 2). Annex 7.3 describes the scaling method and data sources of the indicator that will be proposed in this section 3.1.4.

Excluding WF

Category 1 (*Water security*) includes indicator 1 (*total water footprint*), 2 (*water scarcity*) and 3 (*water self-sufficiency*). All three indicators rely on the water footprint (WF) concept which describes the volume of water over the full supply chain of products and services, that is needed to meet the countries demand. It is the sum of blue, green and grey water. Blue is the groundwater and surface water resources used, green water represents the volume of rainwater consumed during the production process and grey water is the quantity of water required to dilute the associated pollution back to natural baseline levels (Hoekstra *et al.,* 2009). The WF is a strong tool to describe the global water usage as a consequence of a certain standard of living and is a telling indicator for sustainable water use. However, the standard of living and the country's import is highly dependent on many social-economic processes and national and global trends on which the local (water) authorities have a negligible influence. Indicator 2 (*water self-sufficiency*) expresses the WF as a fraction of the total renewable water resource. The countries total renewable water resource is abundant or not, regardless of local (water) authorities IWRM. In fact, temperature, rainfall, soil type, river course *et cetera* largely determine the amount of total renewable water resource. Moreover, only country data is available making the contribution that a city can make on the size of the (country's) total renewable water resource even smaller. Indicator 3 (*water self-sufficiency*) is the percentage of water in the WF that is from countries own territory. Again this indicator focusses on country level imports and consumption behavior which are not suitable indicators because the CB aims to measure the performance of IWRM of urban (water) authorities. It is therefore recommended to leave the category *water security* out of the CB.

Including solid waste

Cities are prone to water pollution due to their highly efficient drainage system that quickly collects and discharges polluted water sources. Stormwater runoff is a large source of pollution and is amplified by uncollected solid waste in streets and illegal dumps. Untreated solid waste releases nutrients, heavy metals and other hazardous substances. Cities are the largest source of plastic waste that enters the oceans via rivers and canals. The plastic in the ocean environments affects many marine animals because they cannot differentiate between (micro)plastics and other particulate matter, i.e. food. The amount of plastic in the ocean forms a 'soup' that covers an area twice as large as the United States (McFedries, 2012). Furthermore, solid waste that is dumped in landfills can lead to ground water and surface water pollution, especially when the site management is insufficient (Rosik-Dulewska *et al.,* 2007; Lazarevic *et al.,* 2010). The degradation of plastic waste in landfill is approximately 1 to 5% during a 100 year time period (Bez *et al.,* 1998). Therefore, the sites needs to be monitored for for a long time, in order to avoid emission of leachates and waste in the environment, making landfilling an unsustainable option which on the long term is likely to affect aquatic and marine environment. Urban solid waste treatment is a key parameter of water quality in cities, rivers and oceans. In addition, solid waste treatment is suitable to measure local authority performances and indicators can be selected that are able to communicate improvements in an direct and undisputable manner. Three indicators are proposed for this category. i.e. *solid waste collected*, *solid waste recycled* and *solid waste energy recovery*. *Solid waste collected* is the per capita solid waste that is collected in kg cap^{-1} $year^{-1}$. S*olid waste recycled* is the percentage of collected solid waste that is recycled or composted. Finally, *solid* *waste energy recovery* represents the percentage of collected waste that is incinerated with energy recovery. Unfortunately, no consistent data is available for uncollected waste streams. The concept of urban metabolism is incorporated in these indicators because the indicators measure the waste streams and to what extend solid waste is reused. Similar indicators for solid waste production and treatment are used in the ISO37120 initiative, EGCI and by the OECD (ISO, 2014; OECD, 2013; Siemens, 2009).

Basic water services

Indicator 11 (*safe sanitation*) represents the percentage of the population that has access to improved sanitation facilities. The indicator is currently part of category 4 (s*anitation*). However, it correlates higher with the category 3 (*drinking water*) (r=0.79) than with its own category (r=0.71) (Table 2). This indicator also correlates remarkably high with indicator 6 (*sufficient to drink*) (r=0.82) and 10 (*drinking water quality*) (r=0.78). Access to proper drinking water and improved sanitation are basic UWCS which are recommended to be incorporated in one category called '*basic water services'*. This category adequately represents sustainability interface *equitable services* (Figure 7). The remaining indicators in category 4 (*sanitation*), i.e. indicators 12 (*sewage sludge recycling*), 13 (e*nergy efficiency*), 14 (*energy recovery*) and 15 (*nutrient recovery*) all deal with wastewater treatment. It is therefore recommended to rename category 4 as 'w*astewater treatment'*. The ISO37120 set of indicators for city performances also uses this distinction and here '*water and sanitation'* and '*wastewater'* are different categories (ISO, 2014).

Infrastructure

Because water infrastructure is underground and literally out of sight, it receives little attention (AWWA, 2001). This often results in decreased investments in water infrastructure resulting in a worsening infrastructure state. Of all the global urban infrastructure investments needs up till 2025, it is estimated that 50% is required for water investments, being 22.6 trillion US$ (UNEP, 2013). This shows the importance of category 5 (*infrastructure*) for sustainable IWRM. Currently this category is underweighted in the BCI with only 2 indicators and should therefore be strengthened with more indicators. Indicator 7 (*water system leakages*) is a suitable indicator of the maintenance of the drinking water infrastructure. In this way, indicator 16 (*average age sewer system*) represents the sewer system state and indicator 7 (*water system leakages*) that of drinking water infrastructure. Ideally the total investments in water infrastructure would need to be measured but this is often hindered by the absence of publicly available data. Operation costs and revenues of drinking water and sanitary services, on the other hand, are often available (ib-net.org; OECD, 2010). The ratio of total yearly operating revenues/ operating costs of drinking water and sanitation services is an important indicator of the financial state of the local water management authorities and their ability to make the necessary investments in infrastructure refurbishment. Furthermore, high operating costs recoveries show the opportunity to invest in techniques that can alleviate the pressure on the environment e.g. nutrient recovery, energy recovery, sewer leakages decrease *etcetera*. Hence, this indicator shows the opportunities for full cost recovery in which the price for mitigating or recovering negative environmental impacts of water services as well as adequate infrastructure investment level in water infrastructure are included in the water price (EEA, 2012A; EEA, 2013). Therefore the indicator *Operating cost recovery* is introduced.

Green space

Climate change impacts are complex and ubiquitous in cities and affect the urban water cycle in many ways. However, the EEA (2012A) identifies three climate vulnerabilities with particular reference to urban areas, i.e. heat, water scarcity and flooding. These components should be included in the indicators belonging to category 6 (*climate robustness*). The balance between the solar energy that is absorbed by the surface and transferred into heat is altered because the cooling effect of vegetation is replaced by surfaces sealed with concrete, asphalt and stone (Figure 15) (EEA, 2012A). This urban heat island effect amplifies the effects of heatwaves which will occur more often due to climate change. Green and blue areas store rainwater and evaporate and transpire this water during heat. It therefore reduces urban runoff during rain events and reduces heat during heat events. In order to combat urban heat, it is essential to increase the share of blue and green area in cities. Besides heat alleviation, green and blue area also counteracts air pollution, mitigate for urban drainage flooding and increase the city's recreational and spiritual value (Li *et al.,* 2014; jia *et al.,* 2013; Jonker *et al.,* 2014). The EEA provides an extensive database of the share of blue and green area for 559 EU cities, as well as EU-country averages. The European green city index as well as the ISO37120 set of indicators incorporates green areas implicitly (Siemens, 2009; ISO, 2014). However, to mitigate for urban heating and urban drainage flooding a percentage is considered as a better approximation of climate robustness because it more accurately represents the urban albedo and infiltration capacity per surface area. Many urban regions will experience more storm events and heatwaves (IPCC, 2013). This urges for a better incorporation of green and blue areas in cities to enhance climate robustness. Climate change will increase the vulnerability of cities water scarcity (EEA, 2012A). The domestic and industrial use of drinking water is an adequate indication of how cities combat water scarcity issues. Therefore it is recommended to include indicator 9 (*drinking water consumption*) in this category. The last urban climate vulnerability as defined by the EEA (2012) is flooding which is currently incorporated in indicator 19 (*adaptation measures*) and in the newly proposed indicator *green area*.

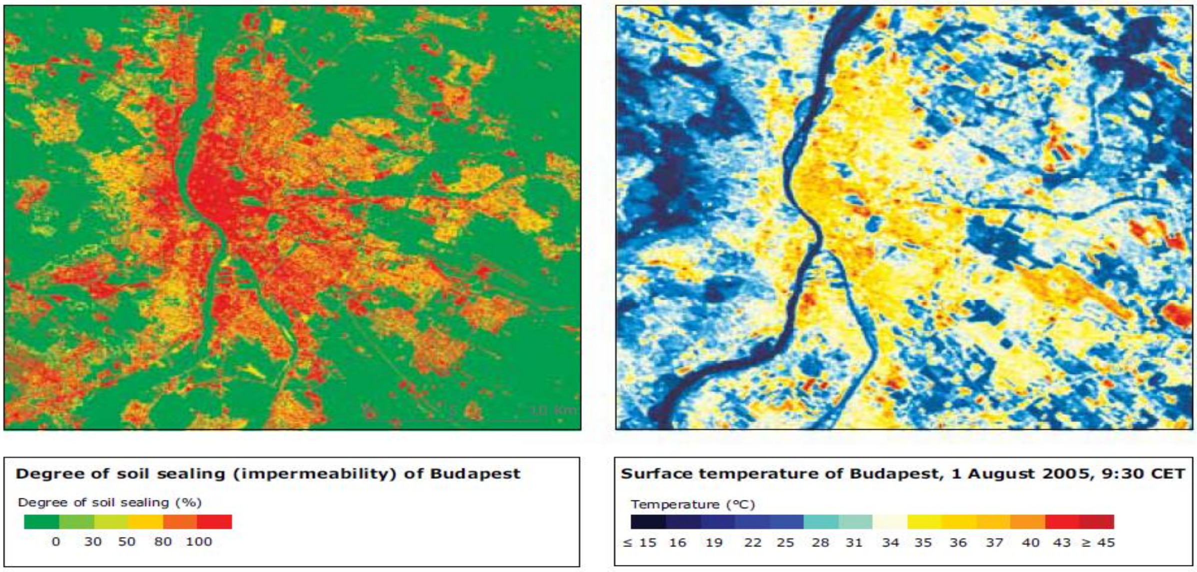

Figure 15 Example of the UHI effect in Budapest. On the left hand, the degree of soil sealing. On the right hand the surface temperature (EEA, 2012A).

Governance

Category 7 (*biodiversity and attractiveness*) currently only consists of indicator 22 (*attractiveness*) because indicator 21 (*biodiversity*) has previously been removed. Attractiveness is basically an assessment of the extent to which surface water supports people's perception of the quality of the urban landscape. This is mainly the result of urban planning by local authorities and the involvement of the local community and private companies (shops, bars *etcetera*) who want to shape an attractive place to live. The relation with governance is also apparent given the high correlations with indicator 23 (*management and action plans*) r=0.74, indicator 24 (*updated public participation*) r=0,76 and indicator 8 (*water efficiency*) r=0.61. Indicator 8 is an assessment of the extent of water efficiency measures in cities. Because indicators 8, 22, 23 and 24 are assessments of how well local authorities manage water issues and because of the high inter-correlations it is advised to group these indicators within category 8 (*governance*).

City blueprint

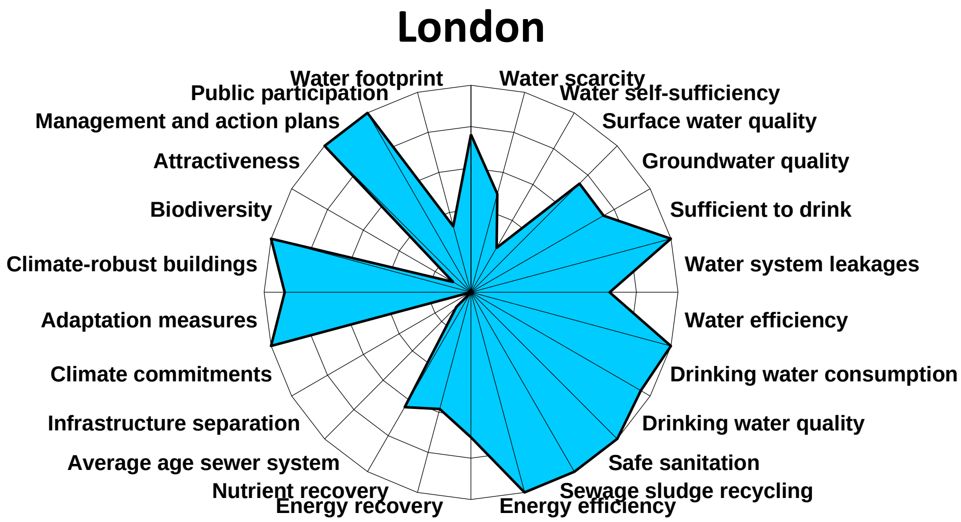

Figure 16 CB London.

Table 6 Overview of the CB indicators. Indicators marked red are removed in the CB*.

I Water security	1.Total water footprint 2.Water scarcity 3.Water self-sufficiency
II Water quality	4.Surface water quality 5.Groundwater quality
III Drinking water	6.Sufficient to drink 7.Water system leakages 8.Water efficiency 9.Consumption 10.Drinking water quality
IV Sanitation	11.Safe sanitation 12.Sewage sludge quality 13.Energy efficiency 14.Energy recovery 15.Nutrient recovery
V Infrastructure	16.Maintenance 17.Infrastructure separation
VI Climate robustness	18.Local authority commitments 19.Adaption measures 20.Climate-robust buildings
VII Biodiversity and attractiveness	21.Biodiversity 22.Attractiveness
VIII Governance	23.Management and action plans 24.Public participation

Alternative City Blueprint

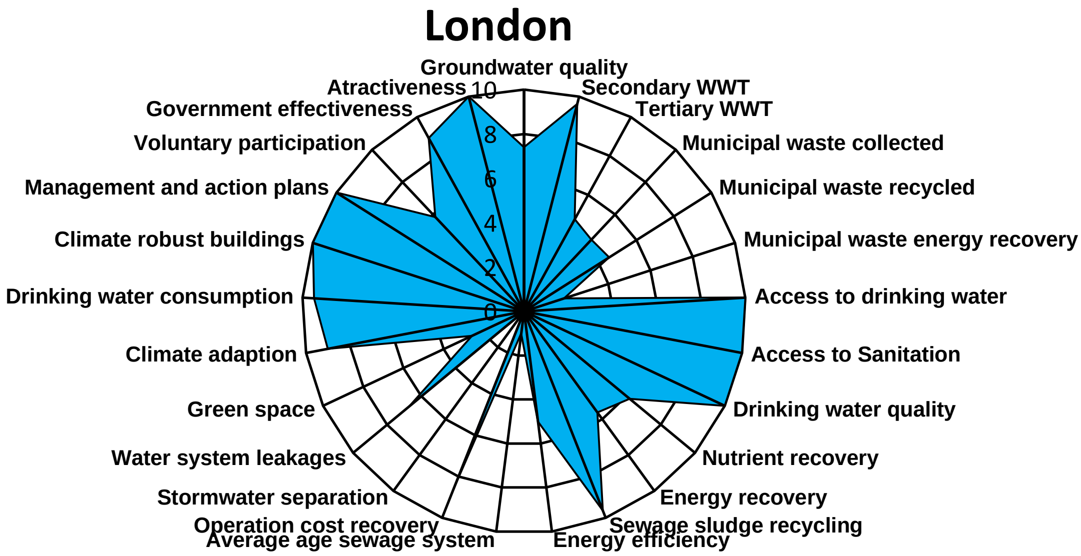

Figure 17 Alternative City Blueprint in London.

Table 7 Overview of the CB* indicators. Indicators marked green are newly added.

I Water quality	1. Secondary WWT 2. Tertiary WWT 3. Groundwater quality
II Solid waste treatment	4. Solid waste collection 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

3.2 Analysis of the alternative City Blueprint approach

3.2.1 Standardization and aggregation method

The CB* indicators are standardized using the min-max method (Equation 1). This is done by using unstandardized values (used for 7 indicators, i.e. 6, 14, 15, 18, 20, and 23) and using percentages (used for 12 indicators, i.e. 1-5, 7-12, 16 and 17). Furthermore, for 6 indicators, i.e. 13, 19, 21, 22, 24 and 25, an ordinal scoring scale is applied. For indicators expressed as percentage, a logical minimum of 0% and maximum of 100% is applied (except for indicator 16. *water system leakages* where the minimum has been set at 50%). The min-max standardization method can be sensitive for extreme values (outliers) that may result in unrealistic scores, especially when unstandardized values are used. In order to detect these outliers, values outside the 1.5 interquartile range (interquartile is the difference between the upper quantile (75% of values) and lower quantile (25% of values)) are checked for errors (Bierkens and Van Geer, 2014).

$$\frac{value - minimum\ value}{maximum\ value - minimum\ value}\ X\ 10 \tag{1}$$

Data for indicator 18 (*green space*) is abundantly available (559 cities). The minimum and maximum value of these 559 cities are therefore quite extreme values. Using these extreme minimum and maximum value in equation (1), results in a low variation in scores of the 32 cities assessed. Hence, the average of the lower and upper 10% is used for the min-max standardization. For the other indicators derived from unstandardized values (indicators 6, 14, 15, 20 and 23), less data is available and the minima and maxima are taken and checked carefully.

For composite indices, issues of weighting and aggregation are particularly sensitive and subjective (EPI, 2012). It should be recognized that assigning explicit weightings, by definition, only represents one viewpoint. Nevertheless, different weighting can be applied to compensate for large differences in variance between categories (EPI, 2012). There is no clear consensus on how to best determine a methodological strategy for combining diverse issues, e.g. solid waste treatment and water infrastructure (EPI, 2012; SDS, 2014). It is explicitly chosen not to use weightings on the indicator or category scale and apply a framework that is understandable for all relevant stakeholders. Therefore, the implicit overweighting due to correlations and/or large differences in variance are addressed before aggregation of the indicators. The differences in indicator variances decreased from 24.7 for the CB indicators to 17.6 for the CB* indicators. Moreover, the number of indicators per category are more equal, resulting in a more or less equal weighting of the categories. Furthermore, the issue concerning correlations between two indicators that measure the same underlying principle are dealt with in Section *3.1.3 Indicator improvements* and *3.1.4 Category improvements.*

The most frequently used aggregation methods are the arithmetic and geometric mean. An important difference is that the arithmetic mean gives no penalty for an unbalanced performance and does not reward balanced achievement in all indicators. In other words, the arithmetic mean does not address that the lower the performance in an indicator, the more urgent it becomes to improve achievements for that indicator (SDS, 2014). 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 would lead to a strong increase in directs inflow of excess nutrients, heavy metals and other health-threatening substances into surface waters. Similarly, regardless of adequate investment in sanitation, WWT infrastructure and water supply, human health and quality of life can still be threatened if flood risk is not taken into account (Ligtvoet *et al.,* 2014). Hence, the lower a performance is, the more urgent it becomes to improve the achievements on this indicator. In other words, balanced indicator scores should be rewarded. Therefore, a geometric mean is considered to be suitable to index sustainable IWRM (See Box 1). However, if only one indicator value is close to 0, it will bring the aggregated overall score also close to zero. This would lead to low BCI* scores for almost all cities which in turn would result in little distinctiveness. Moreover, these scores would prevent city-to-city learning. i.e. sharing knowledge and experience amongst the cities and could even discourage further implementation of best practices.

Since a geometric mean can be defined as the n^{th} 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. In practice different workarounds are applied. The SSI standardizes the indicators from 1-10 points. However, the lowest possible score is in this case 1 point, while the highest possible score remains 10 points which decreases the range of scoring. It is therefore chosen to re-standardize the indicators to a score of 1-11, aggregate the indicators scores with the geometric mean and finally subtract 1 point from this score to obtain the BCI* (see Box 1). In this way, the 10 point range remains intact while balanced performances amongst the indicators is rewarded without getting low distinctiveness between city scores. Hence sustainable IWRM is optimally measured over a convenient and more distinctive 0-10 point standardized indicator, category and BCI* range.

Box 1 Example of the difference between arithmetic an geometric aggregation

BCI-value water security in Melbourne

Solid waste collected	3
Solid waste recycled	10
Solid waste energy recovered	10

Arithmetic mean: $\frac{n1 + n2 + \dots + nx}{n}$ $\qquad \frac{3 + 10 + 10}{3}$ = 7.67

Geometric mean: $[(n1+1) * (n2+1) * \dots * (nx+1)]^{1/n} - 1 \qquad [(3+1) * (10+1) * (10+1)]^{1/3} - 1$ = 6.85

Figure 18 shows that in all cases the geometric scores (in blue) are lower than the arithmetic scores (blue + red). The ranking of the cities calculated with the geometric and the arithmetic mean are more or less similar although some cities score relatively poor under the geometric mean because some indicators score particularly low. Moreover, the distinctiveness in score for the geometric mean is slightly higher (geometric variance 3.39 points; arithmetic variance 2.87 points).

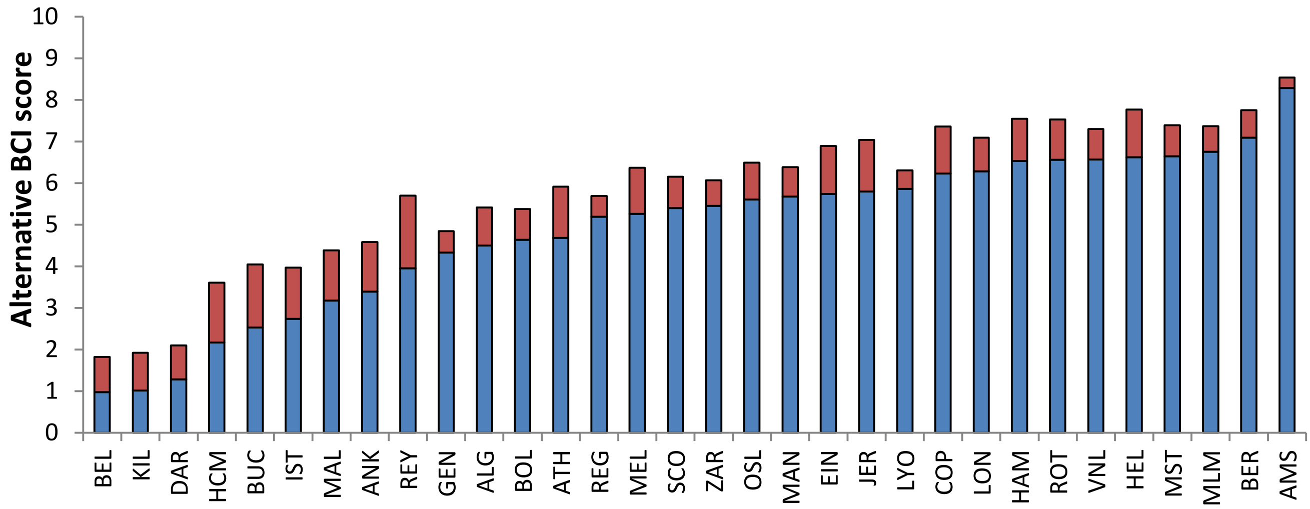

Figure 18 Red + blue: BCI* according to arithmetic aggregation method and only blue represents the BCI* score according to the geometric aggregation method.

3.2.2 Comparison between current and alternative City Blueprint

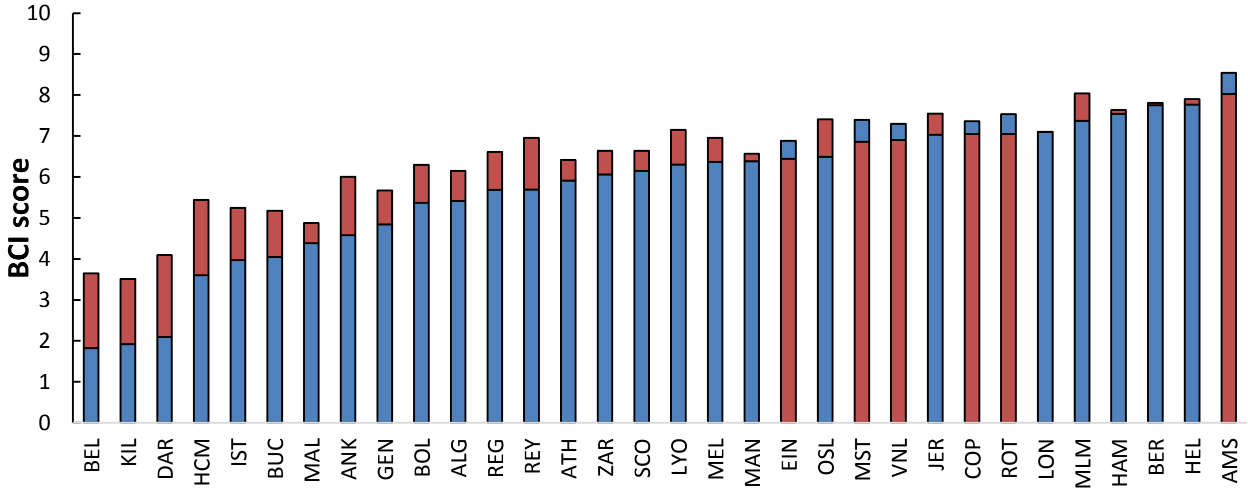

Figure 19 Arithmetic BCI* (in blue) compared to BCI (in red). Variance of the arithmetic BCI* (2.87 points) is two times larger than the BCI variance. For most cities the BCI scores are higher. However, Eindhoven, Maastricht, Venlo, Copenhagen, Rotterdam and Amsterdam have higher BCI* scores. The correlation between both arithmetic BCIs is high (r= 0.96).

Figure 19 shows that the scoring range of the arithmetic BCI* is larger (variance is 2.87 points which is two times the variance of the BCI scores). Especially the cities with lower BCI scores have considerably lower arithmetic BCI* scores. The score distributions of the BCI and the arithmetic BCI* are approximately similar (r=0.96). The effect of the geometric aggregation method slightly decreases this similarity in score distribution (correlation between the BCI and the BCI* is r= 0.94). The differences between the BCI and the BCI* are shown in Figure 20. The variance in scores is 2.35 times larger for the BCI* than for the BCI (variance BCI* is 3.39 points; variance BCI is 1.44 points). Only the score for Amsterdam has slightly increased. The cities with lower BCI scores now have even lower (geometric) BCI* scores. The BCI* is negatively correlated with the BC* trends and pressure index (r=-0.77; Figure 9) implying that cities that experience many social, environmental and financial pressures, have a low performance on IWRM.

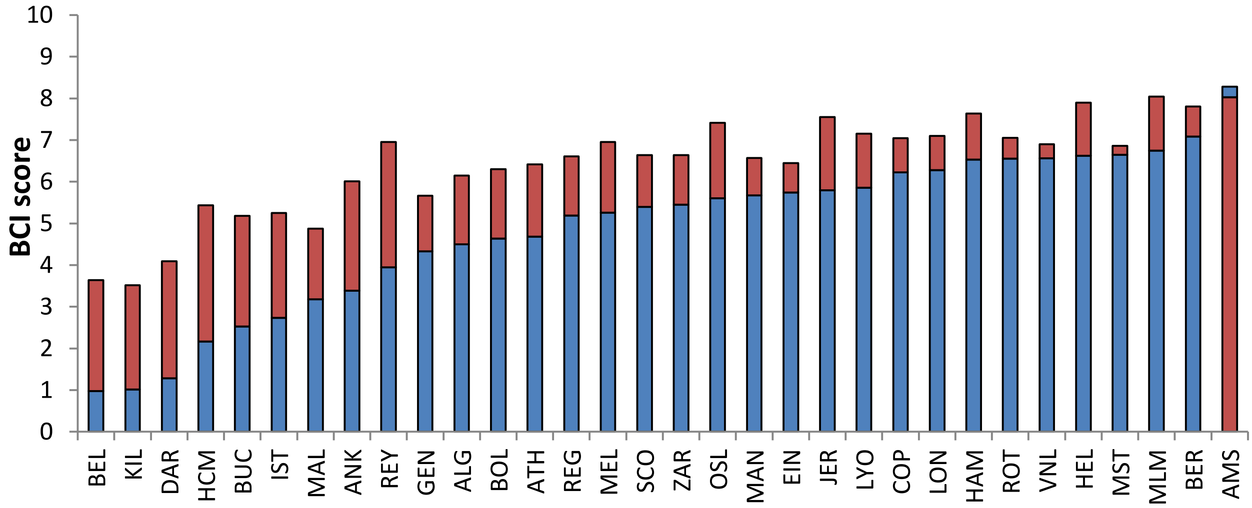

Figure 20 BCI (in red) compared to BCI* (in blue). Variance of the BCI* (3.39 points) is 2.35 times larger than the BCI variance. In general the BCI* scores are lower because of the more performance-oriented indicators and geometric aggregation method. Only the city of Amsterdam has a higher score under the proposed assessment.

3.2.3 Comparison of alternative City Blueprint with other city descriptors

The BCI* and *trends and pressures* score (Figure 9) have been compared in order to place the CB* in the context of other indices and parameters that describe the state of cities, regions and countries. It should be emphasized that only correlations are examined here and not cause-effect relations. The BCI* correlated remarkably well with the ND-GAIN climate readiness index (r=0.89; Figure 21). This indicator measures the country's ability to absorb financial resources and mobilize them efficiently to adapt to climate change by taking into account economic (50% of score), governance (25%) and social factors (25%) (ND-GAIN, 2013). *Trends and pressures* and NG-GAIN climate readiness are even better correlated but negatively (r=-0.91; Figure 21). Correlation with the GDP is also high (r=0.86; r=-0.88; IMF, 2013; Figure 22). The BCI* is positively and *trends and pressures* is negatively correlated with all governance indicators of the World Bank (Table 8; World Bank, 2014). Interestingly, the BCI* is strongly correlated (r=0.82) with the Environmental Awareness Index (EAI) (for *trends and pressures* this is r=-0.69) (Harju-Autti and Kokkinen, 2014). Furthermore, correlations with public participation, i.e. involvement in voluntary work are high (r=0.85; r=-0.84; EFILWC, 2006).

Table 8 Correlations BCI* and *trends and pressures* with the World Bank indicators (World bank, 2014).

	BCI*	*Trends and pressures*
Government Effectiveness	0,87	-0,86
Regulatory Quality	0,86	-0,86
Rule of Law	0,85	-0,86
Control of Corruption	0,83	-0,86
Voice & Accountability	0,82	-0,86
Political Stability	0,59	-0,70

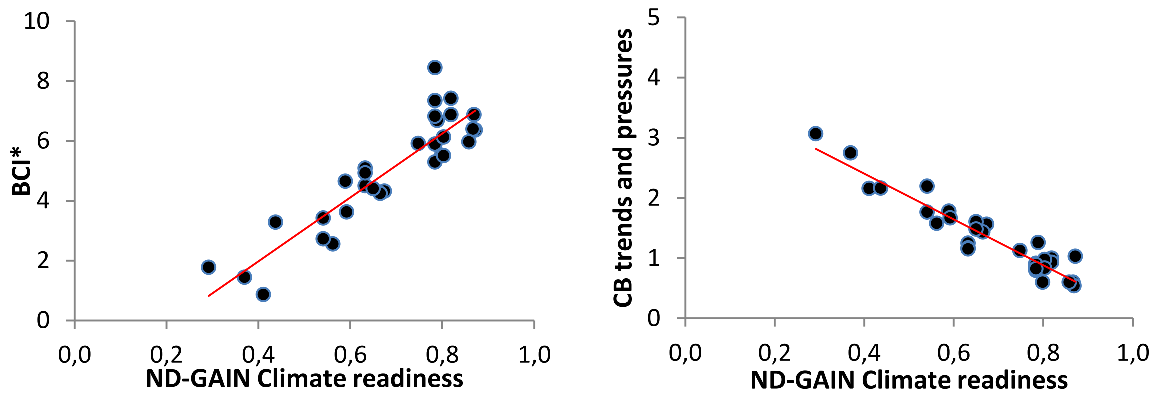

Figure 21 Correlation of the BCI* and *trends and pressure* index with the ND-Gain Climate readiness index (ND-GAIN, 2014). The BCI* is positively correlated to the ND-GAIN index (r=0.89) and negatively correlated with *trends and pressures* (r=-0.91).

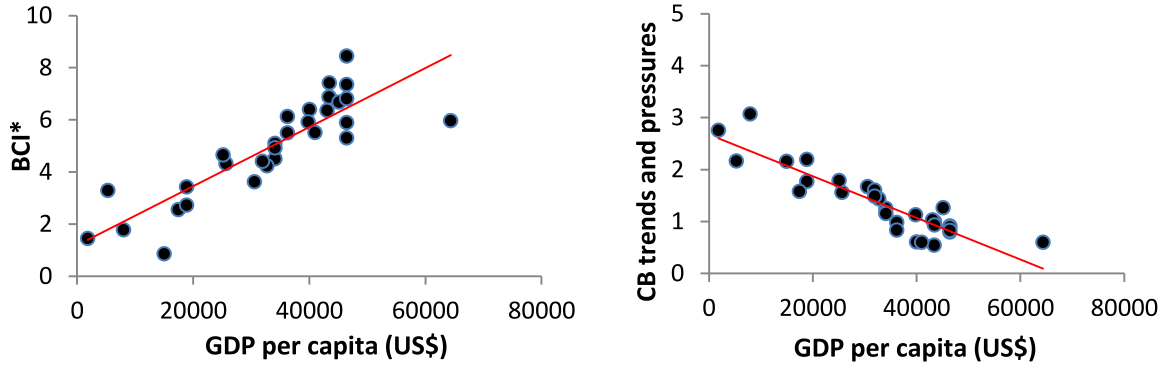

Figure 22 Correlation of the BCI* and CB trends and pressure index with GDP (IMF, 2013). The BCI* is positively correlated to the GDP (r= 0.86) and negatively correlated with *trends and pressures* (r=-0.88).

4. **Discussion**

Trends and pressure **framework**

The CB* is composed of two separated indicator frameworks that embody the distinction between city's *trends and pressures* and the IWRM performance of a city. A performance-oriented set of indicators is essential to show the potential gain possible by sharing knowledge and experiences amongst cities. The *trends and pressure* framework provides a wider context, which is key to obtain insight in the limitations and windows of opportunities for urban IWRM. The *trends and pressures* framework consists of a social, environmental and financial category. Each category consists of four indicators which in turn can be an average of sub-indicators. Local data is often not available. Therefore, mostly national data has been used to calculate the *trends and pressure* indicators. This limits the accuracy of city assessments, especially in large countries with much regional variety. Moreover, insufficient spatial and temporal coverage of measurements, poor reporting and inconsistent sampling design pose serious issues concerning data reliability of the indicators that assess water pollution (Srebotnjak *et al.,* 2012). Additional local data might be needed to improve the city's water pollution trends and pressures indicators. The overall arithmetic average of the *trends and pressure* indicators has a negative correlation with the BCI* (r=-0.77) meaning that cities with many pressures, have a lower performance on IWRM (Figure 23). A city rarely scores an overall concern (3 points) or great concern (4 points) because the framework is only aims to provide the CB* performance framework with context and create awareness of the most stressing topics. Moreover, a high overall score of *trends and pressures* can be misinterpret as an indication that little improvements in performances is attainable while this is often untrue. Instead, only the indicators that show a concern or great concern (3 or 4 points) are communicated to stakeholders. Next, CB* performance is shown, followed by the category scoring and raking (Annex 7.1). This simple graphical representation allows for a quick overview of cities on their path to become water wise cities (Figure 4), which is in the interest of all stakeholders involved in IWRM.

Dividing indicators into *trends and pressures* and *performances*

The WF concept used in CB category 1 (*water security*), describes the yearly country averaged water consumption over the full supply chain (Hoekstra *et al.,* 2009). This is strongly dependent on many social-economic processes as well as on national and global trends. Because local (water) authorities have little influence on these factors, the WF concept is removed from CB*. Furthermore, CB indicators 4 (s*urface water quality)* and 21 (*biodiversity*) are transferred to the *trends and pressures* framework. Both indicators are country averages, while cities have little influence on most of these pollution practices. Instead, the cities own point-source and diffuse water pollution management is assessed. Hence, secondary and tertiary WWT, as well as a solid waste category are added. Indicator 3 (*groundwater quality*) represents the percentage of groundwater bodies that has a good chemical status (EEA, 2012B) and remains in the CB* performance framework. However, because the indicator is a country average, it mainly represents nitrogen emission from agriculture (Kronvang *et al.,* 2008; Brion *et al.,* 2001) instead of performance-oriented urban groundwater pollution prevention practices. Groundwater pollution is often related to urban development e.g. industrial pollution, unprotected landfills, pit latrines *etcetera* (Mtoni *et al.,* 2013; Nguyen *et al.,* 2010). Groundwater quality should be quantified using local data which is often not publicly available. Therefore, additional data needs to be collected (i.e. asked for in a questionnaire for all CB cities) in order to provide a comprehensive assessment of the city's groundwater quality. For now, the existing assessment method is continued but this remains an issue for further discussion. However, it should be mentioned that groundwater pollution is indirectly incorporated in the CB* because solid waste and WWT indicators are added. Indicator 20 (*drinking water consumption),* includes metered and non-metered commercial, industrial or public purposes (TRUST, 2012). On the contrary, the ISO37120 and UN set of key indicators considers only domestic water consumption (ISO, 2014; UN Water, 2014). Because the domestic drinking water consumption is a small portion of the total consumption, e.g. only 10% in the EU (ISO, 2014), the total drinking water consumption is used. However, it should be communicated that some cities with a large share of industry or tourism consume more water while this cannot be considered as a low performance of local water authorities.

Data limitations

Only publicly available data is used in this CB revision in order to promote transparency, and reduce time and costs. City scale data concerning urban IWRM appeared to be particularly scarce. Moreover, the level of detail is relatively moderate because accurate and reliable data is needed from all cities. Public data concerning flood risk and economic indicators are particularly sparse. Information on urban flood vulnerability is available. i.e. vulnerability to river peaks and sea level rise (Jongman *et al.,* 2014; EEA, 2012A). These data represent flood vulnerability but disregard flood protection. Hence, these indicators are included in the *trends and pressures*. Ideally, a flood return interval is used to quantify the performance of flood defense. However, flood return intervals are not consistently reported, let alone, calculated in comparable manner.

Drinking water affordability

The affordability of drinking water, defined as the percentage of the disposable income that is spent on drinking water by the poorest 10% of the population, is relevant to guarantee equitable UWCS (OECD, 2010; Figure 7). However, the drinking water price may include many different costs per city (IWA, 2014), making it difficult to compare. A high affordability, associated with a low price, often implies that not all costs. i.e. WWT or water infrastructure maintenance, are recovered. Moreover, the price is dependent on the local water treatment necessities. e.g. the need to desalinize. Furthermore, a low affordability is mostly caused by a low disposable income, for which local water authority are not responsible. Likewise, water prices are a negligible expenditure in most cities with a medium to high disposable income (OECD, 2013). Hence, the water price is often not performance-oriented. On the contrary, investments in water infrastructure are performance-oriented, urgent and essential to provide affordable water of sufficient quality (WHO, 2013).

Water infrastructure investments

Of all urban infrastructure investments needs up till 2025, it is estimated that 50% is required for water investments being 22.6 trillion US$ (UNEP, 2013). This is roughly 60% more than is spent on infrastructure in the same period until now (McKinsey and McKinsey, 2013). The sewer system is the most expensive asset of the city's water infrastructure and, as such, a good indicator for the financial state of water infrastructure. 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 14 *average age sewer*) is decisive for the city's financial IWRM performance. However, the current indicator is an inaccurate approximation of the financial performances because only an average age is roughly estimated and divided by an assumed standard average sewer lifespan which does not take into account local circumstances. 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 (2); Bosseler, 2014). The infrastructure lifespan and system asset value should be calculated separately for each local situation. By using equation (2), a yearly investment which should be reserved for infrastructure maintenance, can be calculated. The actual investment in infrastructure can be scored as a fraction of this yearly investment requirement. Furthermore, based on knowledge of the age and lifespan distribution of the infrastructure, a projected yearly investment requirement can be calculated, called a Nessie curve (Figure 24; AWWA, 2001). This provides insight into the long term infrastructure costs which is essential for sustainable urban IWRM and stimulates a sufficient yearly investment necessary to maintain the water infrastructure on the long term.

$$\textit{Lifespan (years)} \quad \frac{\boldsymbol{Yearly\ investments}\ (\text{€}\ \boldsymbol{per\ year})}{\boldsymbol{System\ asset\ value}\ (\text{€})}\ x\ \ 10 \qquad (2)$$

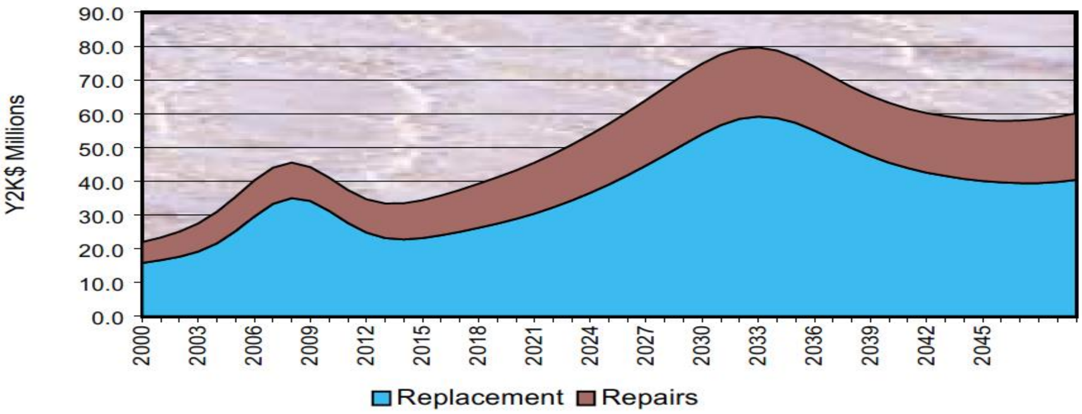

Figure 24 Nessie curve of Denver, Colorado. Projected total yearly expenditures on water infrastructure (y-axis), can vary considerable depending on the average age of the infrastructure (AWWA, 2001).

Statistical limitations
In this CB revision, data of 32 cities has been used and all the necessary data for the proposed CB* indicators is collected. However, these 32 cities do not represent the global urban population distribution since EU-cities are strongly overrepresented, and only a few cities represent the urban population in developing countries. In order to equalize the contribution of each category to the BCI*, the variances of each category should be relatively equal. However, the actual variance of indicators and categories can be different from the output of the 32 analyzed cities, e.g. the variance of category 3 (*basic water services*) and 7 (*governance*) is expected to be larger if the number of cities in developing countries would not have been underrepresented. Nevertheless, the variance of the indicator variances is 7.1 points lower for the CB* (CB is 24.7 points; CB* is 17.6 points). Furthermore, the average indicator variance is 1.4 points higher for the CB*. Hence, the distinctiveness of the CB* is higher while the indicators and categories have a more equal contribution (variance) to the BCI* (Figures in annex 7.4.1, 7.4.2 and 7.4.3). The indicator and the category framework appear to be more coherent because the correlation between indicators belonging to the same category (intra-category correlation) is much higher than the inter-category correlation, i.e. the correlations of indicators belonging to different categories (Tables in annex 7.4.1 and 7.4.2).

Balancing sustainability components in the CB framework
The sustainability components of full cost recovery, ES preservation and equitable costs (Figure 7) are all included in the CB*. Category 2 (*solid waste treatment*) is included in the CB* because solid waste often leads to water pollution that strongly affects ES (e.g. the ocean ecosystems). It is also linked to urban metabolism, performance-oriented, and the cost of solid waste are internalized. Category 3 (*basic water services*) mainly addresses the equitability of sustainable urban IWRM. The preservation of ES sustainability component is included in many CB* indicators, most prominently in category 1 (*water quality preservation*), 2 (*solid waste treatment*) and 4 (*wastewater treatment*). Especially category 5 (*infrastructure*) embodies the financial security of urban IWRM, while category 2 (*solid waste treatment*) and 4 (*wastewater treatment*) represent full cost recovery component of sustainability. Category 6 (*climate robustness*) emphasizes the long term character of sustainable urban IWRM. Category 7 (*governance*) measures the capacity of urban IWRM to apply all aspects of sustainability (Figure 7).

Standardization and aggregation method
Using the min-max scaling method can be risky because extreme values or reporting errors have a large disturbing influence on the scoring (SDS, 2014). Therefore, most proposed indicators have a percentage unit because the natural boundaries largely prevent scaling issues. The minimum and maximum values are carefully checked and selected from as many cities as possible in order to avoid large changes in the scoring range of future updates. The contribution of each category is equalized by leveling the variances, therefore no corrections are made by assigning lower weighting to high variance categories or indicators. An integrative approach is essential for providing effective management solutions. For example, sanitation facilities that are built without WWT connections will lead to a strong surface water deterioration (Ligtvoet *et al.,* 2014). Hence, the progress in sanitation facilities is offset by surface water deterioration. Therefore, the geometric aggregation method is used because it gives a penalty for unbalanced indicator scoring. The geometric BCI* score increases most if the lowest scoring indicators is increased (SDS, 2014). This method therefore communicates that the lower an indicator performs, the more urgent it is to improve its achievements. Hence, this method is selected because it addresses the integrative nature of IWRM.

Relevance and interpretation of the CB*
Compared to the BCI, the BCI* correlates similar or better with the various city descriptors (*Table 8*). The high correlations of the BCI* and *trends and pressures* with ND-GAIN climate readiness index, GDP, EAI and World Bank governance indicators suggests that the CB* framework addresses the importance of adequate financial resources, awareness and good governance for urban IWRM. However, correlation coefficients do not represent cause-effect relations and therefore not prove causality. Climate change and IWRM are strongly interrelated (SWITCH, 2011; EEA, 2012; Paton *et al.,* 2014) and the countries that emit the most GHGs, are often not the countries with the largest climate vulnerabilities (UN, 1987; IPCC, 2013). Cities are no exception and accordingly cities with high BCI* scores, have higher GHG emissions (Figure 25). Therefore, it should be emphasized that the CB* addresses water-related climate adaptation but does not point at cities responsibility to reduce GHG-emissions. This is because the CB* is primarily oriented on the urban IWRM and GHG emissions in the UWC are often only a small fraction of the total urban GHG-emissions (Dhakal, 2010;

Moore *et al.,* 2013). Although climate mitigating IWRM can reduce GHG, e.g. rainwater harvesting reduces and desalination increases GHG-emissions (Paton *et al.,* 2014), the development of a consistent framework for scoring UWC GHG-emission is a complex task and requires detailed local information. Unfortunately, public data of UWC related GHG-emissions appeared to be insufficient and more research is needed to develop a transparent urban IWRM tool for UWC GHG-emissions. It is promising that the ISO37120 set of city performances indicators includes a core indicator that assesses the GHG-emissions for all the city's activity (ISO, 2014).

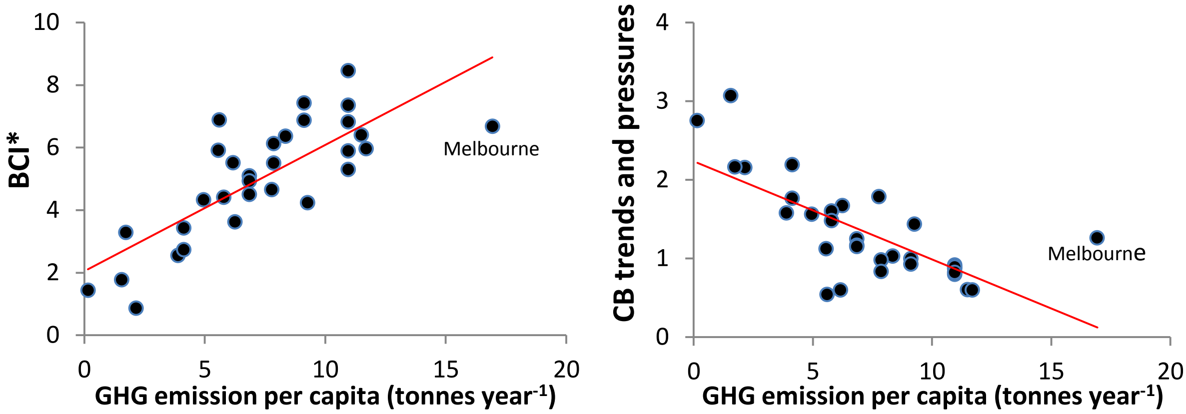

Figure 25 Correlation of BCI*: r= 0.85; *Trends and pressures*; r= -0.81 to the per capita yearly GHG emission (World Bank, 2015), when Melbourne is excluded. Including Melbourne r is respectively -0.76 and -0.72.

Most existing indicators are not standardized, consistent, or comparable over time or between cities (ISO, 2014). Recent initiatives such as ISO-37120 and smart cities program (Vienna University, 2014; ISO, 2014) are promising and may provide a future data base of indicators that meets these requirements. However, there is little attention for IWRM which strongly hampers the transition of cities towards a sustainable, long term IWRM approach. Imminent threats such as climate change, rapid urbanization, water pollution and deterioration of outdated infrastructure amongst others, lead to flooding, water scarcity, adverse health effects, and rehabilitation costs on a scale that will overwhelm the capacity of cities (SWITCH, 2011). Therefore action is needed to prevent even higher costs in the near future. There is a need for more awareness and insight in the local costs and benefits of IWRM and climate adaptation measures by monitoring and evaluation tools (EEA, 2014B; Brears, 2014). Furthermore, there is a need for an approach that addresses the essential role that ecosystems have in attaining sustainable IWRM by emphasizing management practices that preserve the ecosystem services on which cities strongly depend (UNEP, 2007; EEA, 2014B). Hence, the CB* is important in providing a comprehensive scientific indicator framework that addresses these vital issues. The CB* framework improvements resulted in 2.35 point increase in BCI* variance (variance BCI is 1.44; BCI* 3.39) which better emphasizes the potential gain that is attainable by sharing best practices amongst cities.

5. Conclusion

- A distinction has been made between *trends and pressures* and IWRM *performance* by developing two separate frameworks, i.e., a trends and pressures framework and a City Blueprint (CB) performance framework. The trends and pressure framework has been developed to provide a context to the IWRM performance of cities and is centered around the social, environmental and financial trends and pressures. In order to create awareness of the most important trends and pressures, only indicators that score a concern or great concern are communicated without giving an overall score.
- The CB performance framework (CB*) has been optimized and the following changes have been made: Category 1 (w*ater security*) has been removed because the water footprint approach focusses primarily at the national level and is not sufficiently performance-oriented as cities can hardly influence the outcomes. Two new categories. i.e. *basic water services* and s*olid waste treatment* are added. Because of data inaccuracy and overlap, CB indicator 4 (s*urface water quality*), 18 *(local authority commitment*) and 21 (*biodiversity*) have been removed. Furthermore, new performance-oriented indicators are proposed, i.e., secondary and tertiary WWT, three indicators for solid waste treatment, operation cost recovery, and green space. Moreover, the CB* incorporates the relevant sustainability components (Figure 7).
- Most new indicators have percentage units in order to prevent scaling issues. Indicators scored according to the min-max method are carefully checked for outliers and reporting errors. Furthermore, the geometric aggregation is applied because it emphasizes the integrative nature of IWRM by penalizing unbalanced indicator scores.
- The BCI* and *trends and pressures* index correlate with ND-GAIN climate readiness index (r=0.89 and r=-0.91, respectively), GDP (r =0.86; r=-0.88), public participation (r=0.85; r=-0.84), the Environmental Awareness Index (r=0.82; r=-0.69) and all World Bank governance indicators. Hence, the CB* framework seems to address the importance of adequate financial resources, awareness and good governance for urban IWRM. However, correlation coefficients do not represent cause-effect relations.
- The development of a *trends and pressure* framework together with an optimized CB* framework, result in an up-to-data coherent analysis that comprehends both the local context as well as incentives to increase the IWRM performances in order to become a water wise city. Moreover, the BCI* scores show a 2.35 times higher variance than the BCI scores which leads to more emphasizes on the potential gain that is attainable by sharing best practices as a result of city to city learning.
- In Annex 7.1 the proposed graphical presentation is shown for seven cities. The trends and pressures framework is shown followed by the CB* spider-web and category ranking. This simple graphical representation of the results allows for a quick overview of cities on their path to become water wise cities (Figure 4), which is in the interest of all stakeholders involved in IWRM.

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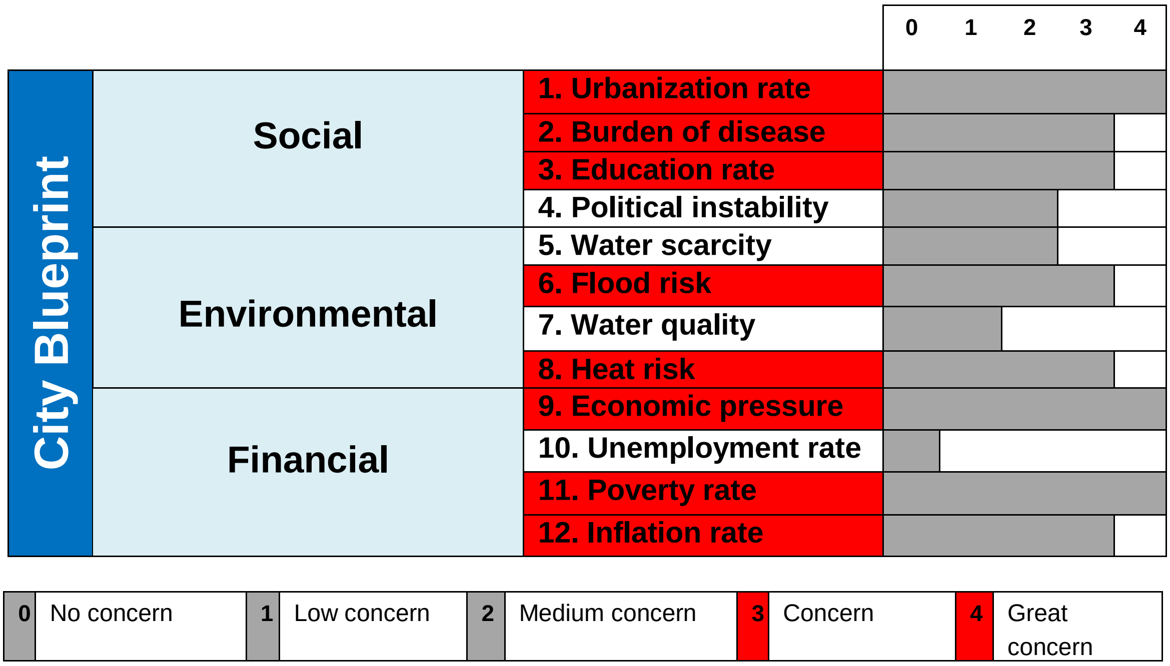
7. Annexes

Annex 7.1 Alternative City Blueprint: 7 examples

Examples of the alternative City Blueprint graphical representations for cities with increasing BCIs: Dar es Salaam (BCI: 1.3), Kilamba Kiaxi (BCI: 1.8), Ho Chi Minh City (BCI: 2.2), Istanbul (BCI: 2.7), Bologna (BCI: 5.1), Melbourne (BCI: 5.4) and Amsterdam (BCI: 8.4).

Annex 7.1.1 Dar es Salaam (Tanzania)

Table 7.1.1 Trends and pressures in Dar es Salaam. In this table a short summary is provided of the key (sub-) indicators of concern or great concern and how these affect UWCS.



Explanation of the concerns Dar es Salaam

Dar es Salaam experiences vast urbanization with a population growth of 4.8% per year (CIA, 2014). The city experiences a high burden of disease of 63.043 years per 100.000 people (WHO, 2014), meaning the overall services such as healthcare are sparse or are not affordable. Only 81% of the children in Dar es Salaam complete primary education (World Bank, 2014C). The financial pressure in Dar es Salaam is extremely high with one of world's lowest GDP per capita of 695 US$ per year, meaning that an average civilian can only spend 1.90 US$ per day. Hence, over 70% of the population has less than 2 US$ to spend a day (World Bank, 2014D). Hence, financial opportunities for sustainable development are small. Furthermore the inflation rates are 7% annually (WHO, 2013). This is relatively high and impedes long term investments in water infrastructure. Population growth, urbanization and rapid economic growth result in a high increase in people living in flood prone areas which also increases due to sea level rise. 143.000 people (5.3% of the current population) and an estimated 168 million US$. Also due to illegal groundwater abstraction, Dar es Salaam experiences seawater intrusion (Kebede and Nicholls, 2011). Moreover, green space is rapidly decreasing leading to urban drainage flooding as well as low alleviation of the heat island effect (Mng'ong'o, 2004; Kebede and Nicholls, 2011).

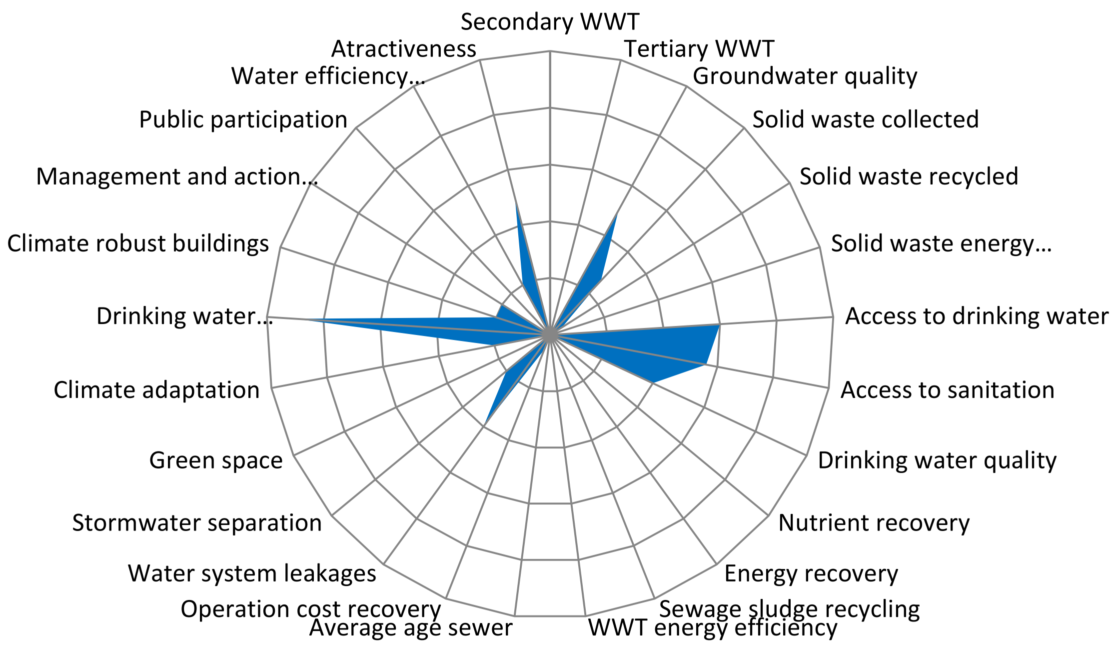
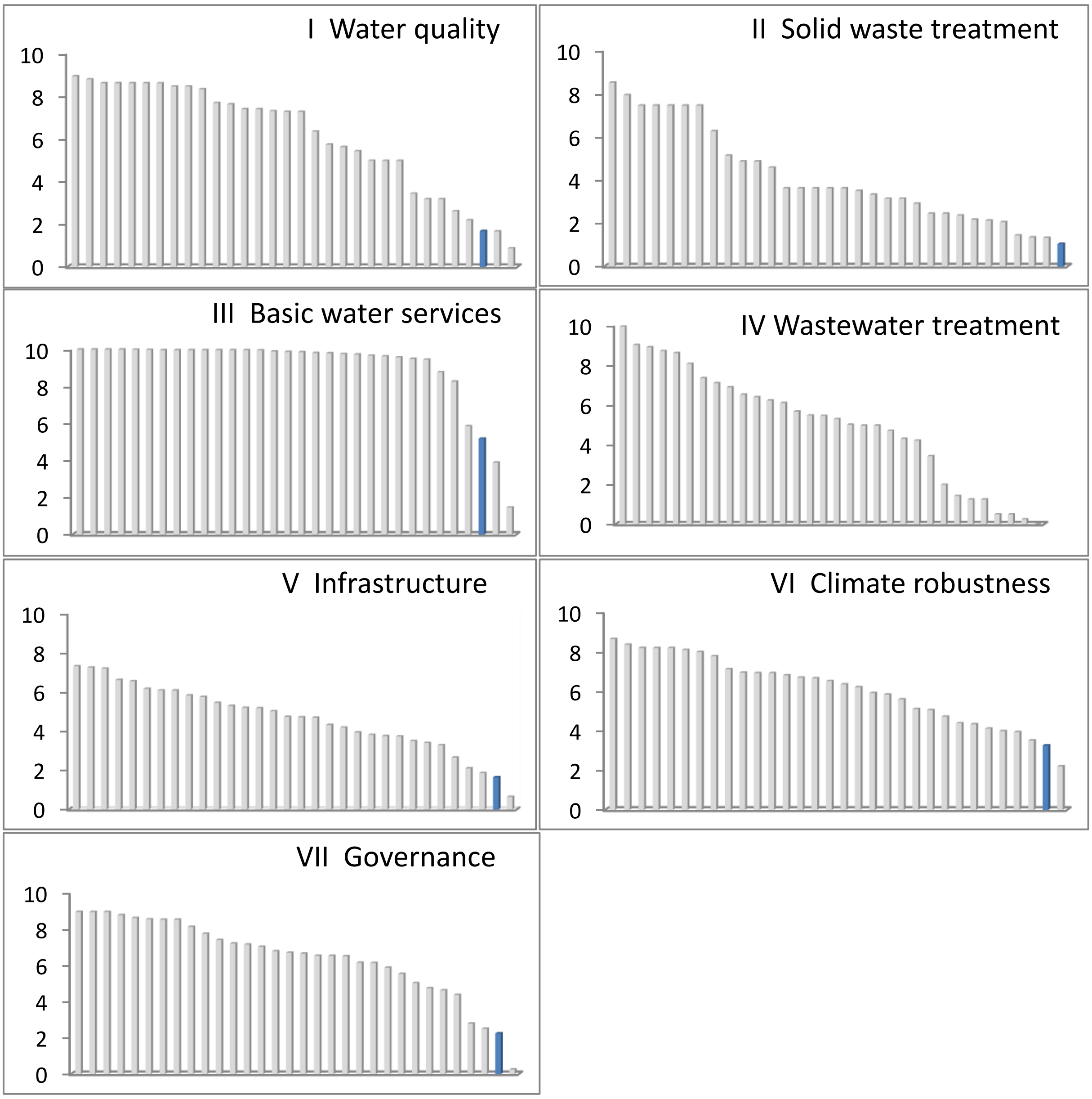


Figure 7.1.1 City Blueprint of Dar es Salaam. A score of 0 (inner circle) means that further attention is needed and a score of 10 is an excellent score (outer circle). The Blue City Index has a score of 1.3 points.

Category	No.	Indicator	Score
I	1	Secondary WWT	0.1
	2	Tertiary WWT	0.0
	3	Groundwater quality	5.0
II	4	Solid waste collected	2.6
	5	Solid waste recycled	0.5
	6	Solid waste energy recovered	0.0
III	7	Access to drinking water	6.0
	8	Access to sanitation	5.6
	9	Drinking water quality	4.0
IV	10	Nutrient recovery	0.0
	11	Energy recovery	0.0
	12	Sewage sludge recycling	0.0
	13	WWT Energy efficiency	0.0
V	14	Average age sewer	0.0
	15	Operation cost recovery	0.6
	16	Water system leakages	4.0
	17	Stormwater separation	2.0
VI	18	Green space	0.0
	19	Climate adaptation	2.0
	20	Drinking water consumption	9.0
	21	Climate robust buildings	2.0
VII	22	Management and action plans	2.0
	23	Public participation	0.0
	24	Water efficiency measures	2.0
	25	Attractiveness	5.0

The category rankings of Dar es Salaam compared to the performances of the other cities.



Annex 7.1.2 Kilamba Kiaxi (Angola)

Table 7.1.2 Trends and pressures in Kilamba Kiaxi. In this table a short summary is provided of the key (sub-) indicators of concern or great concern and how these affect UWCS.

			0 1 2 3 4
City Blueprint	Social	1. Urbanization rate	
		2. Burden of disease	
		3. Education rate	
		4. Political instability	
	Environmental	5. Water scarcity	
		6. Flood risk	
		7. Water quality	
		8. Heat risk	
	Financial	9. Economic pressure	
		10. Unemployment rate	
		11. Poverty rate	
		12. Inflation rate	

0	No concern	1	Low concern	2	Medium concern	3	Concern	4	Great concern

Explanation of the concerns of Kilamba Kiaxi

Kilamba Kiaxi is one of the fastest growing cities in the world with an annual growth rate of 4.3% (CIA, 2014). The city experiences a high burden of disease (WHO, 2012) meaning the overall services such as healthcare are sparse or are not affordable. Only 54% of the children in Kilamba Kiaxi complete primary education (World Bank, 2014B). Flood risk is high because many slums are situated in flood prone areas and flood protection is mostly insufficient or absent. The city is vulnerable to both coastal and riverine floods which is amplified by land subsidence due to groundwater overexploitation (Mendelsohn *et al.,* 2010). Rainfall is high with an average of 1010 mm per year (Climatedata.EU). The city center is densely populated with a strong increase in paved areas leading to a high vulnerability to urban drainage flooding as well. Heat risk is imminent because the green space is mostly lacking and temperatures are high. The GDP per capita is 5668 US$ per person per year (World bank, 2013A), meaning that an average civilian can only spend 15.5 US$ per day. This is also apparent as 67.4% of the people are below the poverty line of 2 US$ a day (World bank, 2014C). Hence, financial opportunities for sustainable development are small. Furthermore the inflation rates are 6.7% annually (World Bank, 2013A). This is relatively high and impedes long term investments in water infrastructure.

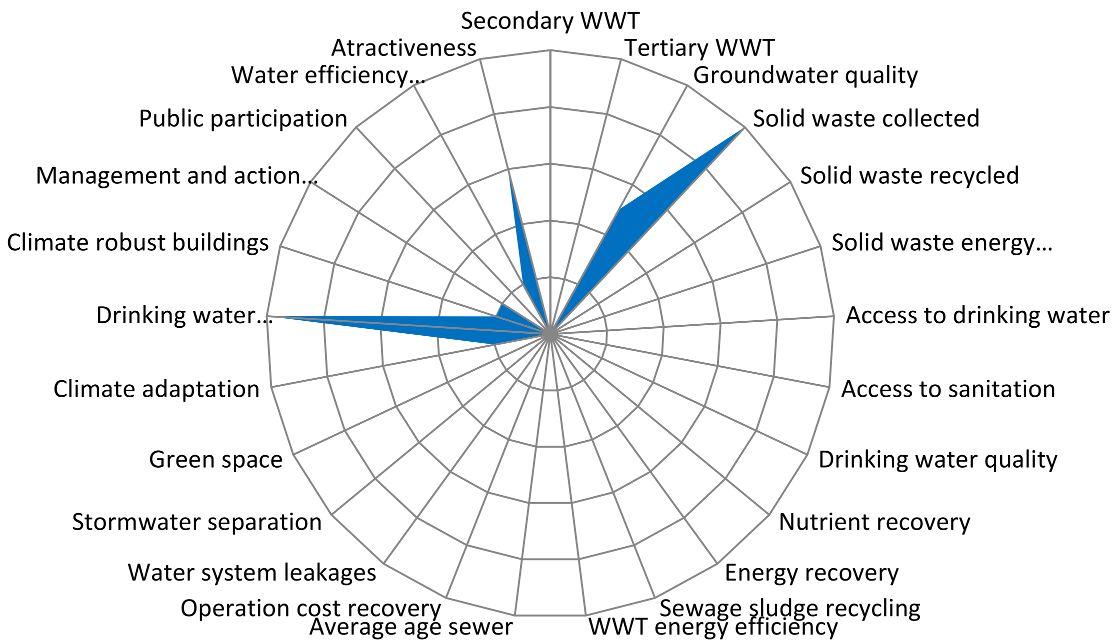
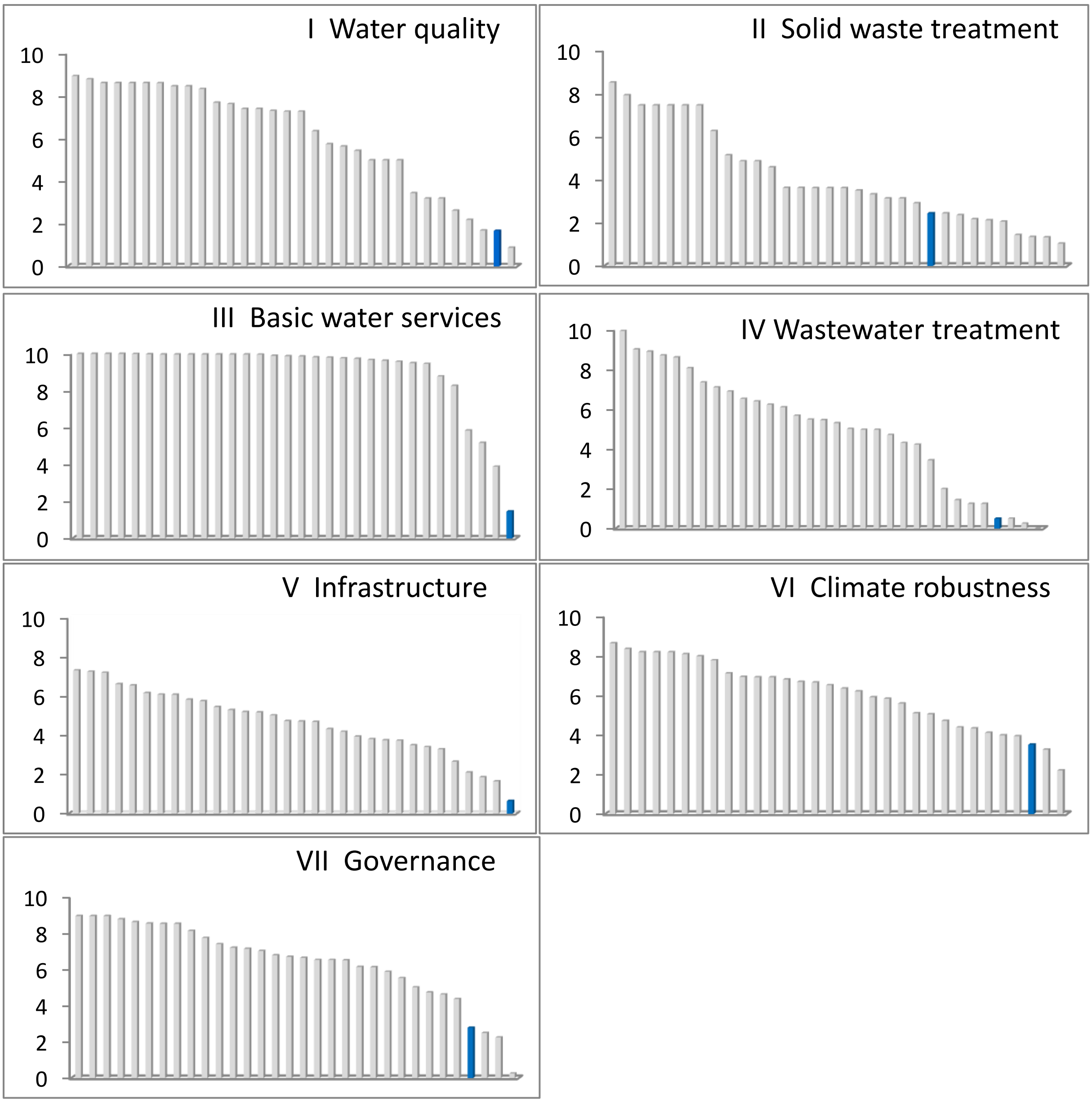


Figure 7.1.2 City Blueprint of Kilamba Kiaxi. A score of 0 (inner circle) means that further attention is needed and a score of 10 is an excellent score (outer circle). The Blue City Index has a score of 1.8.

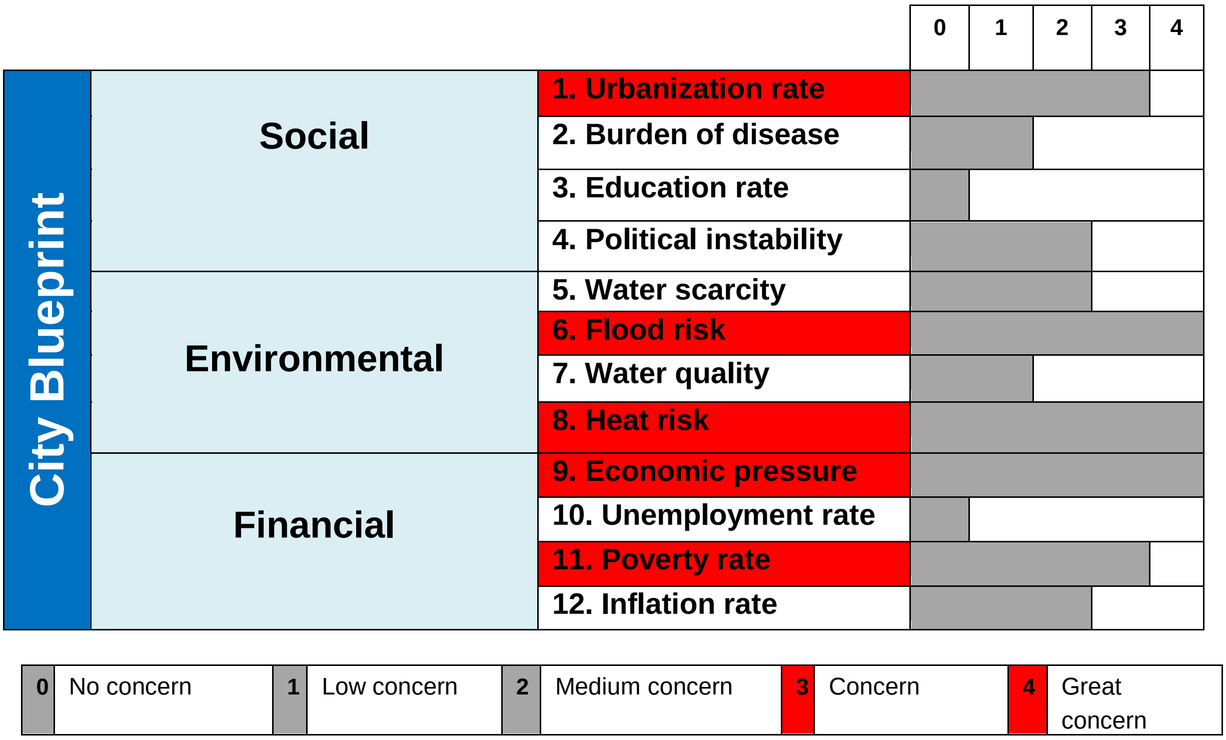
Category	No.	Indicator	Score
I	1	Secondary WWT	0.0
	2	Tertiary WWT	0.0
	3	Groundwater quality	5.0
II	4	Solid waste collected	10.0
	5	Solid waste recycled	0.0
	6	Solid waste energy recovered	0.0
III	7	Access to drinking water	0.4
	8	Access to sanitation	0.0
	9	Drinking water quality	4.0
IV	10	Nutrient recovery	0.0
	11	Energy recovery	0.0
	12	Sewage sludge recycling	0.0
	13	WWT Energy efficiency	0.0
V	14	Average age sewer	0.0
	15	Operation cost recovery	0.6
	16	Water system leakages	0.0
	17	Stormwater separation	2.0
VI	18	Green space	0.0
	19	Climate adaptation	2.0
	20	Drinking water consumption	10.0
	21	Climate robust buildings	2.0
VII	22	Management and action plans	2.0
	23	Public participation	0.0
	24	Water efficiency measures	2.0
	25	Attractiveness	6.0

The ranking of Kilamba Kiaxi compared to the performances of the other cities.



Annex 7.1.3 Ho Chi Minh City (Vietnam)

Table 7.1.3 Trends and pressures in Ho Chi Minh City. In this table a short summary is provided of the key (sub-) indicators of concern or great concern and how these affect UWCS.



Explanation of the concerns Ho Chi Minh City

Ho Chi Minh City has an urbanization rate of 3% a year (CIA, 2014) leading to exploitation of groundwater. This induces amongst land subsidence and associated flood risk (Tong Minh Dinh *et al.,* 2008). Nearly half of the city is less than one meter above sea level and the city recently experienced a flood event in October 2013 (Lempert *et al.,* 2013). River peaks, sea level rise and urban drainage flooding are all great concerns. Moreover, due to the high population densities and lack of green space, the urban heat island effect is widely observed (Phi, 2008). The GDP per capita is only 1191 US$ per person per year (World Bank, 2014B). Moreover, 12.5% of the people are below the poverty line of 2 US$ a day (World bank, 2014). Hence, financial opportunities for sustainable development are small.

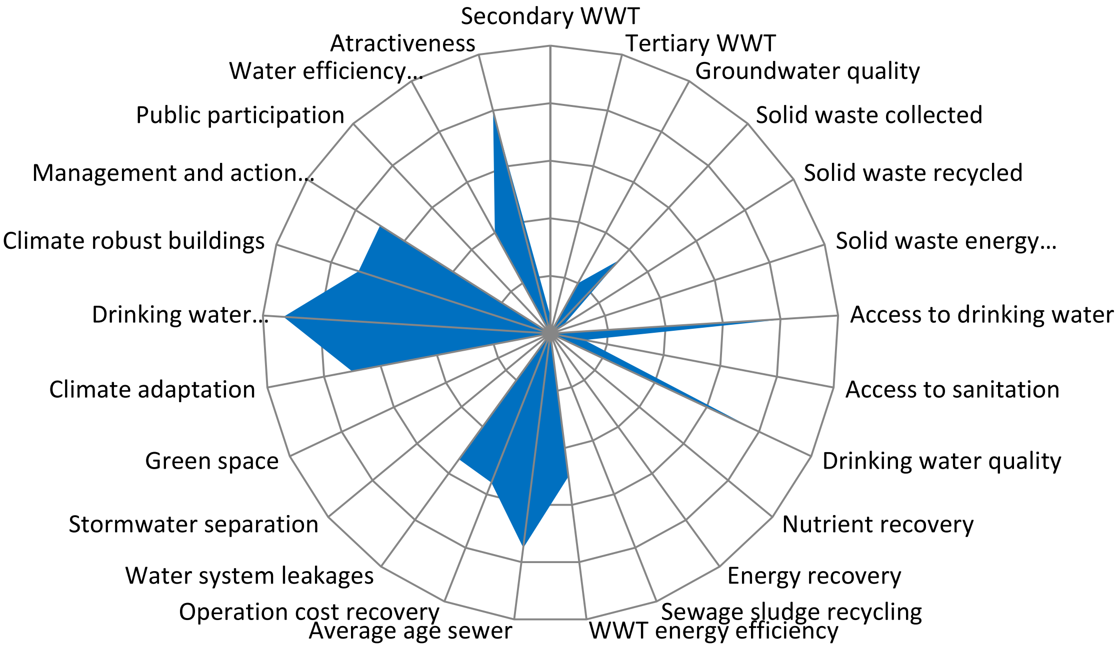
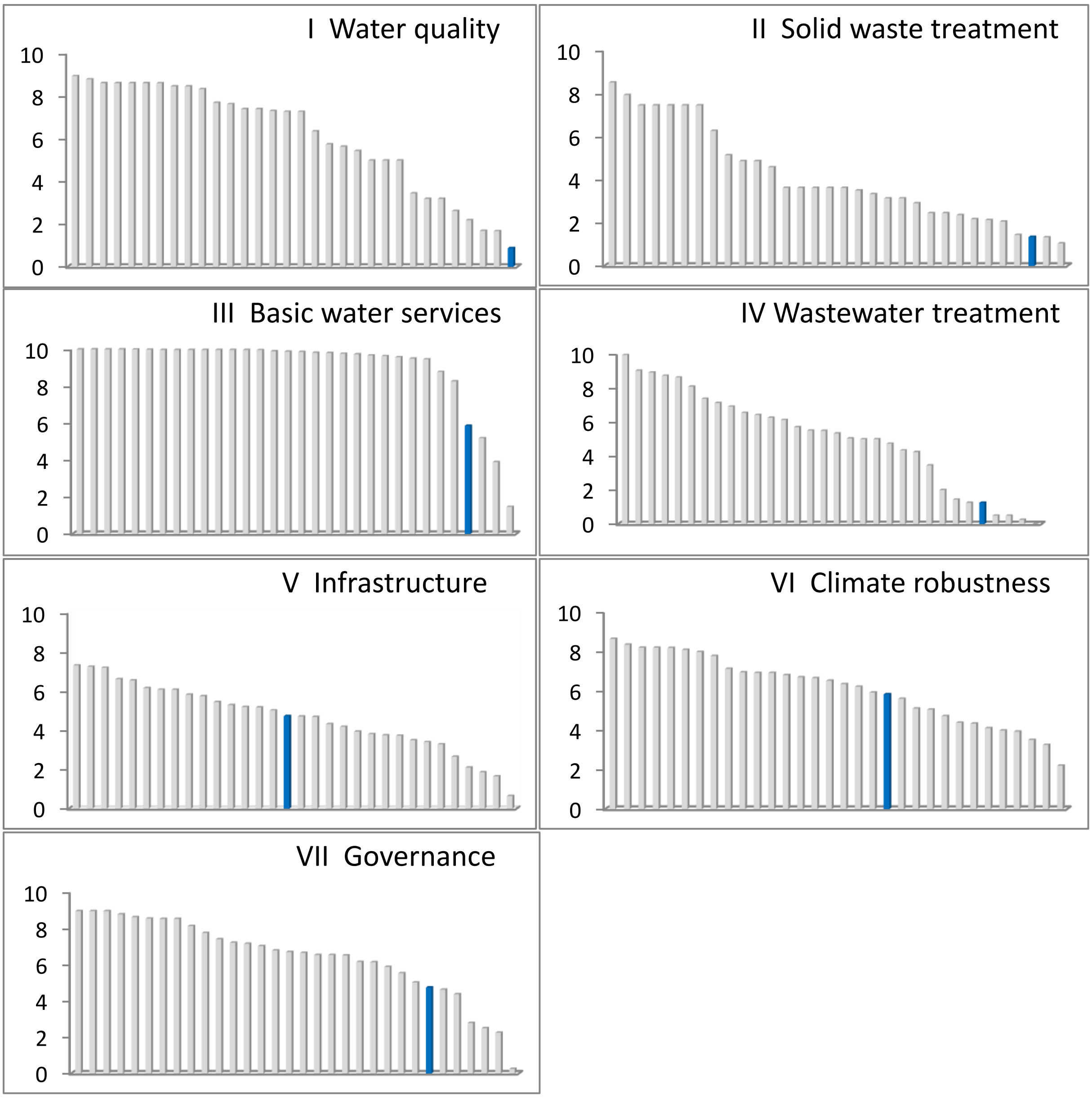


Figure 7.1.3 City Blueprint of Ho Chi Minh City. A score of 0 (inner circle) means that further attention is needed and a score of 10 is an excellent score (outer circle). The Blue City Index has a score of 2.2.

Category	No.	Indicator	Score
I	1 2 3	Secondary WWT Tertiary WWT Groundwater quality	0.6 0.0 2.0
II	4 5 6	Solid waste collected Solid waste recycled Solid waste energy recovered	3.5 0.5 0.0
III	7 8 9	Access to drinking water Access to sanitation Drinking water quality	8.4 1.2 8.0
IV	10 11 12 13	Nutrient recovery Energy recovery Sewage sludge recycling WWT Energy efficiency	0.0 0.0 0.0 5.0
V	14 15 16 17	Average age sewer Operation cost recovery Water system leakages Stormwater separation	7.5 5.6 5.4 0.1
VI	18 19 20 21	Green space Climate adaptation Drinking water consumption Climate robust buildings	0.0 7.0 9.3 7.0
VII	22 23 24 25	Management and action plans Public participation Water efficiency measures Attractiveness	7.0 0.0 4.0 8.0

The category rankings of Ho Chi Minh City compared to the performances of the other cities.



Annex 7.1.4 Istanbul (Turkey)

Table 7.1.4 Trends and pressures in Istanbul. In this table a short summary is provided of the key (sub-) indicators of concern or great concern and how these affect UWCS.

City Blueprint		
	Social	1. Urbanization rate
		2. Burden of disease
		3. Education rate
		4. Political instability
	Environmental	5. Water scarcity
		6. Flood risk
		7. Water quality
		8. Heat risk
	Financial	9. Economic pressure
		10. Unemployment rate
		11. Poverty rate
		12. Inflation rate

0	No concern	1	Low concern	2	Medium concern	3	Concern	4	Great concern

Explanation of the concerns Istanbul

According to the World Bank (2014) the political stability of Turkey is a concern. This may hinder effective urban IWRM. Due to reductions in runoff, increased withdrawals in response to higher demand, and as a result of sea level rise, saltwater intrusion is one of the key threats for Istanbul. Two big lagoons (Büyücekmece and Kücükcekmece) and the Halic estuary that separates old town from the business district in Istanbul are vulnerable to salinization (Karaca and Nicholls, 2008). Furthermore, flood vulnerability is a great concern of Istanbul. Moreover, the capacity of flood protection works is insufficient to ensure long term flood safety (Duman *et al.,* 2005). The sea level rise together with the reporting's of land subsidence pose imminent threats (Karaca and Nicholls, 2008). Furthermore, the percentages of the soil that is sealed with impermeable concrete and asphalt is high making the city vulnerable to urban drainage flooding. Because of this lack of green space and due to the a moderate increase in the number of hot days and tropical night, Istanbul is vulnerable to the urban heat island effect (Siemens, 2009; EEA, 2012A). The GDP per capita of Istanbul is 18.636 US$ per person per year (IMF, 2013) which is relatively low. Finally the inflation rate of Turkey is high (World Bank, 2014B), which may impede long term investments in water infrastructure, flood protection measures and heat adaptation measures.

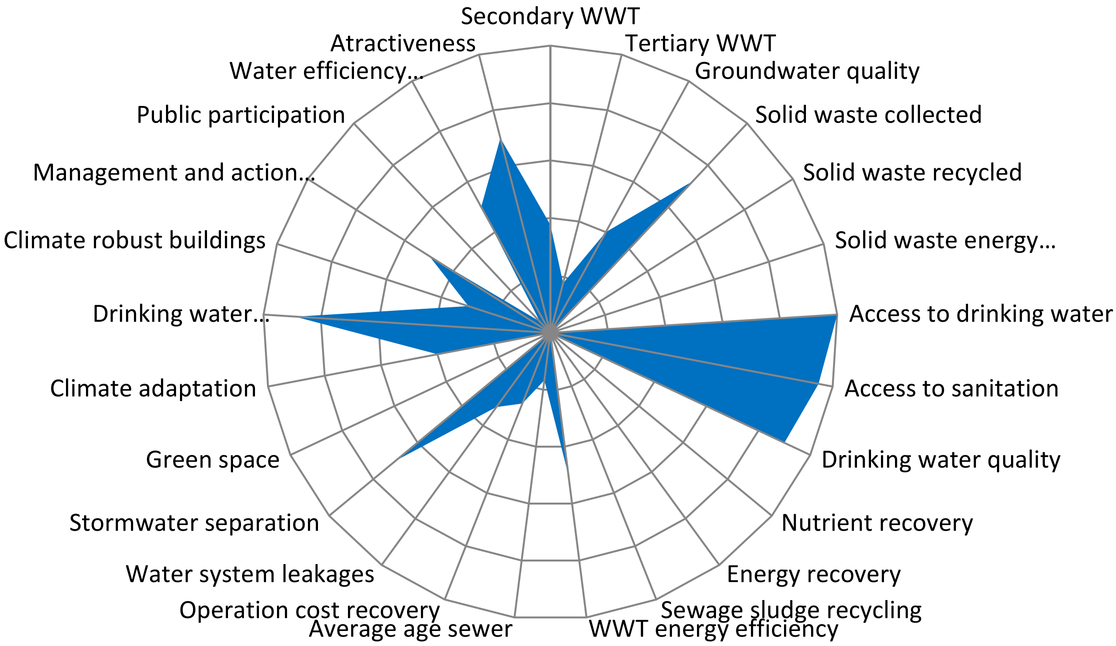
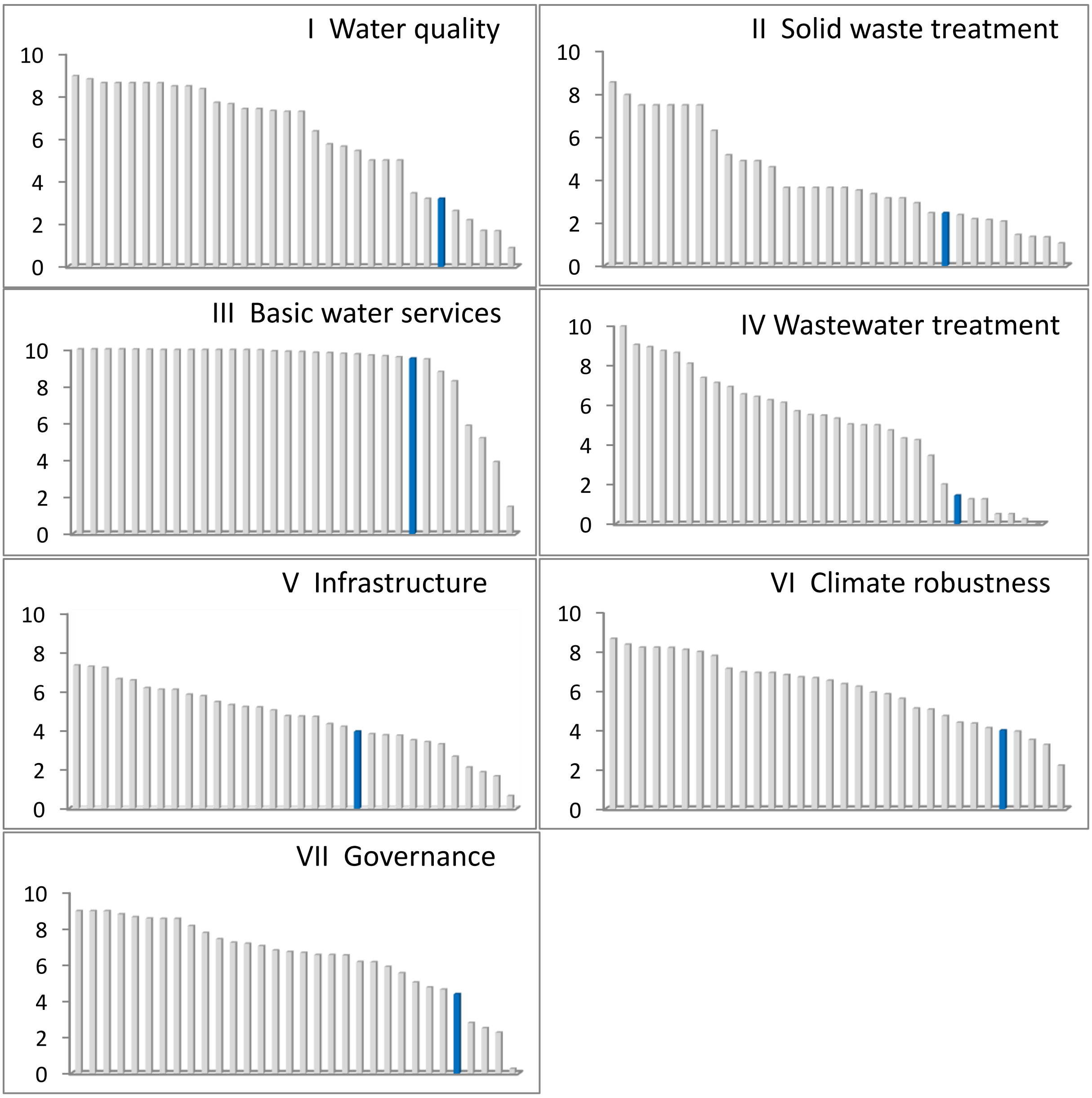


Figure 7.1.4 City Blueprint of Istanbul. A score of 0 (inner circle) means that further attention is needed and a score of 10 is an excellent score (outer circle). The Blue City Index has a score of 2.7.

Category	No.	Indicator	Score
I	1	Secondary WWT	3.8
	2	Tertiary WWT	1.8
	3	Groundwater quality	4.0
II	4	Solid waste collected	7.1
	5	Solid waste recycled	0.1
	6	Solid waste energy recovered	0.0
III	7	Access to drinking water	10.0
	8	Access to sanitation	9.5
	9	Drinking water quality	9.0
IV	10	Nutrient recovery	0.0
	11	Energy recovery	0.4
	12	Sewage sludge recycling	0.0
	13	WWT Energy efficiency	5.0
V	14	Average age sewer	1.7
	15	Operation cost recovery	2.7
	16	Water system leakages	3.2
	17	Stormwater separation	7.0
VI	18	Green space	0.0
	19	Climate adaptation	4.0
	20	Drinking water consumption	8.9
	21	Climate robust buildings	3.0
VII	22	Management and action plans	5.0
	23	Public participation	0.5
	24	Water efficiency measures	5.0
	25	Attractiveness	7.0

The category rankings of Istanbul compared to the performances of the other cities.



Annex 7.1.5 Bologna (Italy)

Table 8 Trends and pressures in Bologna. In this table a short summary is provided of the key (sub-) indicators of concern or great concern and how these affect UWCS.

			0 1 2 3 4
City Blueprint	Social	1. Urbanization rate	
		2. Burden of disease	
		3. Education rate	
		4. Political instability	
	Environmental	5. Water scarcity	
		6. Flood risk	
		7. Water quality	
		8. Heat risk	
	Financial	9. Economic pressure	
		10. Unemployment rate	
		11. Poverty rate	
		12. Inflation rate	

0	No concern	1	Low concern	2	Medium concern	3	Concern	4	Great concern

Explanation of the concerns of Bologna

Bologna has a relative small green area of 24.2% coverage while the increase in the number of hot days >35 °C and nights >20°C due to climate change is estimated to be considerable. This increases the vulnerable of the city to urban heat risks (EEA, 2012A). In the financial category some ''low concerns'' are scored for which it is estimated that these not largely hinder urban IWRM. Furthermore, water scarcity is of low concern although, more specifically 23.5% of the freshwater resource is abstracted (Aquastat, 2015) and therefore may be a concern for urban IWRM. Flood risk is of low concern although urban drainage flooding may be an issue of concern because soil sealing is relatively high (52.5%) in the city (EEA, 2012A). Furthermore, the city sensitivity to river peak discharges is a great concern because more than 40% of the city will be flooded if the water level increases with 1 meter and flood defenses fail (EEA, 2012A). Finally, land subsidence is of medium concern because the city experiences damage to infrastructure and contributes to future sensitivity of flooding.

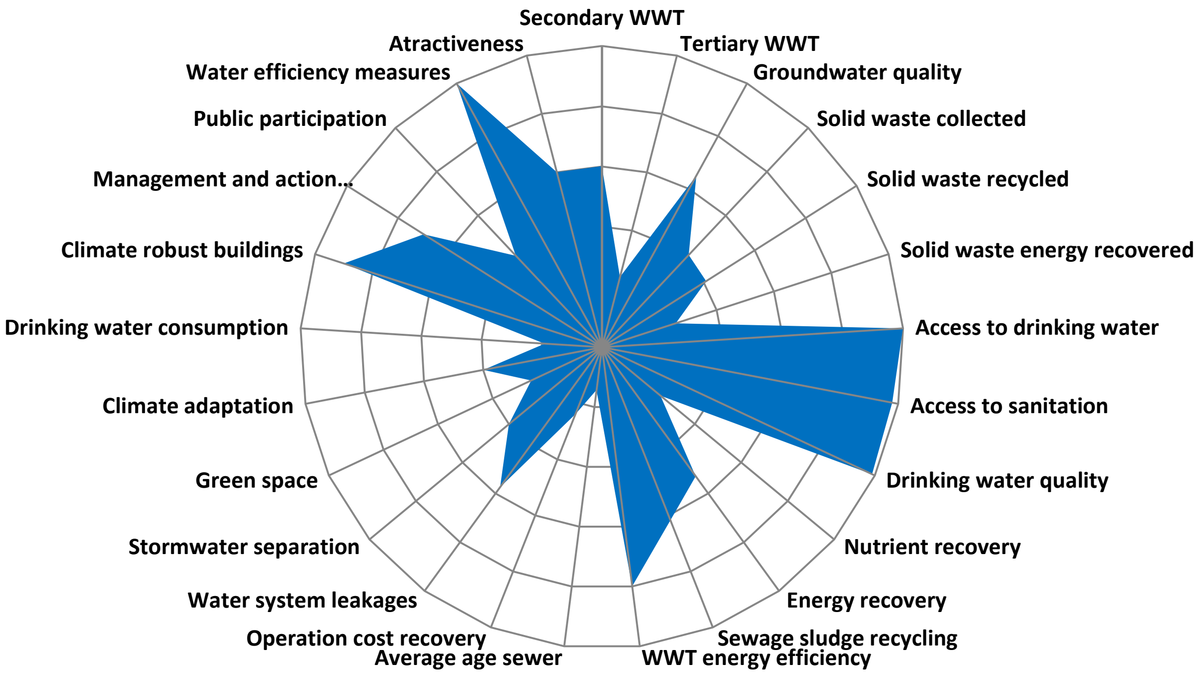
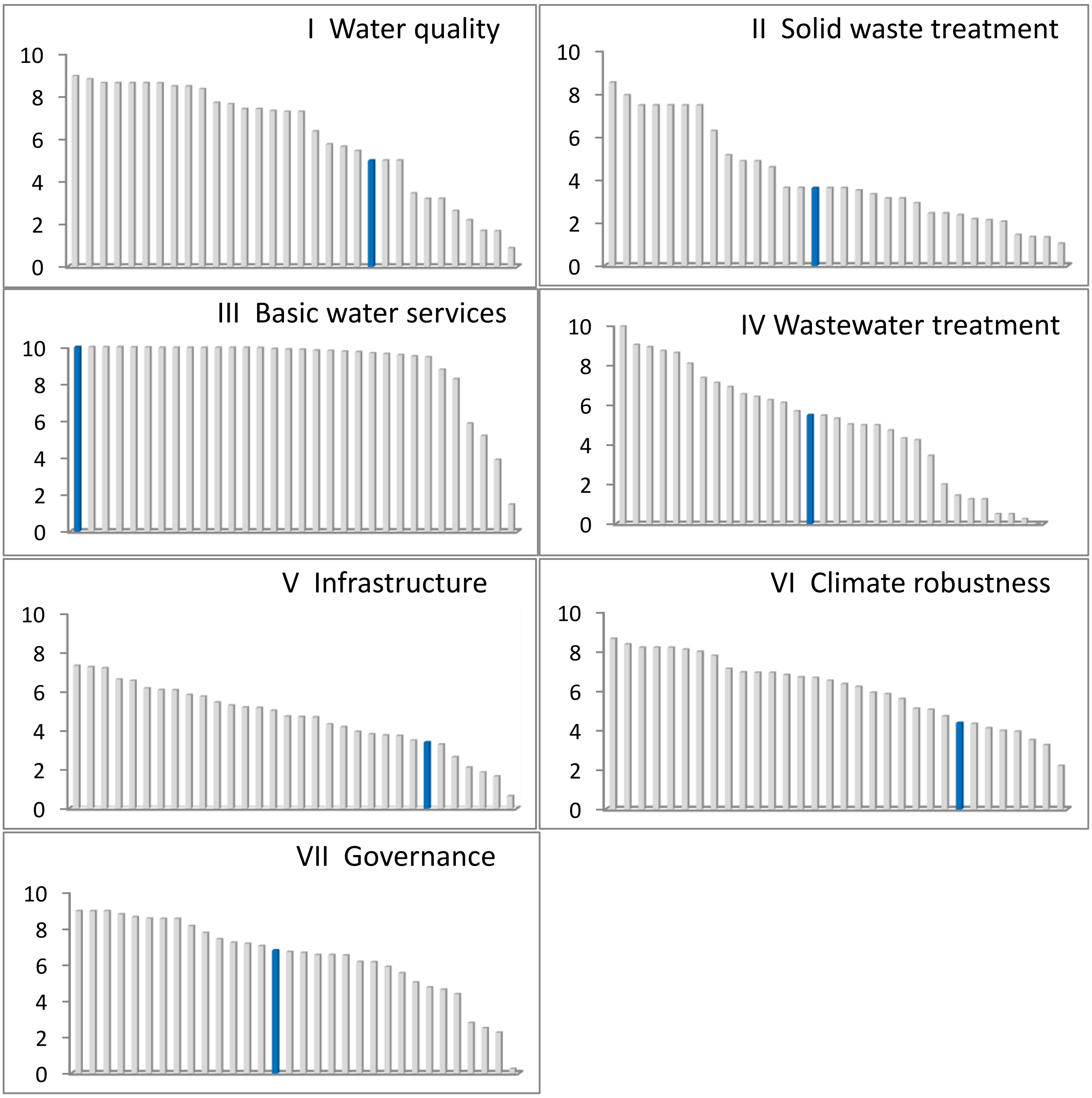


Figure 7.1.5 City Blueprint of Bologna. A score of 0 (inner circle) means that further attention is needed and a score of 10 is an excellent score (outer circle). The Blue City Index has a score of 5.1.

Category	No.	Indicator	Score
I	1 2 3	Secondary WWT Tertiary WWT Groundwater quality	6.0 2.4 6.5
II	4 5 6	Solid waste collected Solid waste recycled Solid waste energy recovered	4.2 4.1 2.6
III	7 8 9	Access to drinking water Access to sanitation Drinking water quality	10.0 9.8 9.9
IV	10 11 12 13	Nutrient recovery Energy recovery Sewage sludge recycling WWT Energy efficiency	2.5 5.3 6.2 8.0
V	14 15 16 17	Average age sewer Operation cost recovery Water system leakages Stormwater separation	1.4 2.4 5.7 4.0
VI	18 19 20 21	Green space Climate adaptation Drinking water consumption Climate robust buildings	2.6 4.0 1.9 9.0
VII	22 23 24 25	Management and action plans Public participation Water efficiency measures Attractiveness	7.0 4.2 10.0 6.0

The ranking of Bologna compared to the performances of the other cities.



Annex 7.1.6 Melbourne (Australia)

Table 7.1.4 Trends and pressures in Melbourne. In this table a short summary is provided of the key (sub-) indicators of concern or great concern and how these affect UWCS.

City Blueprint	Category	Indicator	0 1 2 3 4
	Social	1. Urbanization rate	
		2. Burden of disease	
		3. Education rate	
		4. Political instability	
	Environmental	5. Water scarcity	
		6. Flood risk	
		7. Water quality	
		8. Heat risk	
	Financial	9. Economic pressure	
		10. Unemployment rate	
		11. Poverty rate	
		12. Inflation rate	

0	No concern	1	Low concern	2	Medium concern	3	Concern	4	Great concern

Explanation of the concerns Melbourne

Melbourne is a city with a moderate rainfall pattern, affected by climate change. The city receives on average approximately 600 mm of rain per year. Currently no concerns or great concerns were found in Melbourne. Although heat risk and inflation rates are of medium concerns. On the other hand, the challenges of Melbourne under a changing and uncertain climate became starkly apparent during the 'Millennium drought', a decade long period of extreme dry conditions across southern Australia throughout the 2000s (Chong, 2014).

The scores for trends and pressures are based on a quick scan and more in depth research might reveal concerning trends and pressures. For example, the city may experience another new period of drought and water scarcity. Furthermore, also urban drainage flooding can be a serious issue due to extreme weather events (although the city has a large cover of permeable surfaces). Furthermore, higher sea levels in from 2070 onwards, coupled with more intense storms, will greatly expand the coastal and riverine areas that are likely to be inundated by storm events. In the immediate future these effects are negligible (National Tidal Centre, 2011). It can be concluded that Melbourne has beneficial circumstances to improve their urban IWRM.

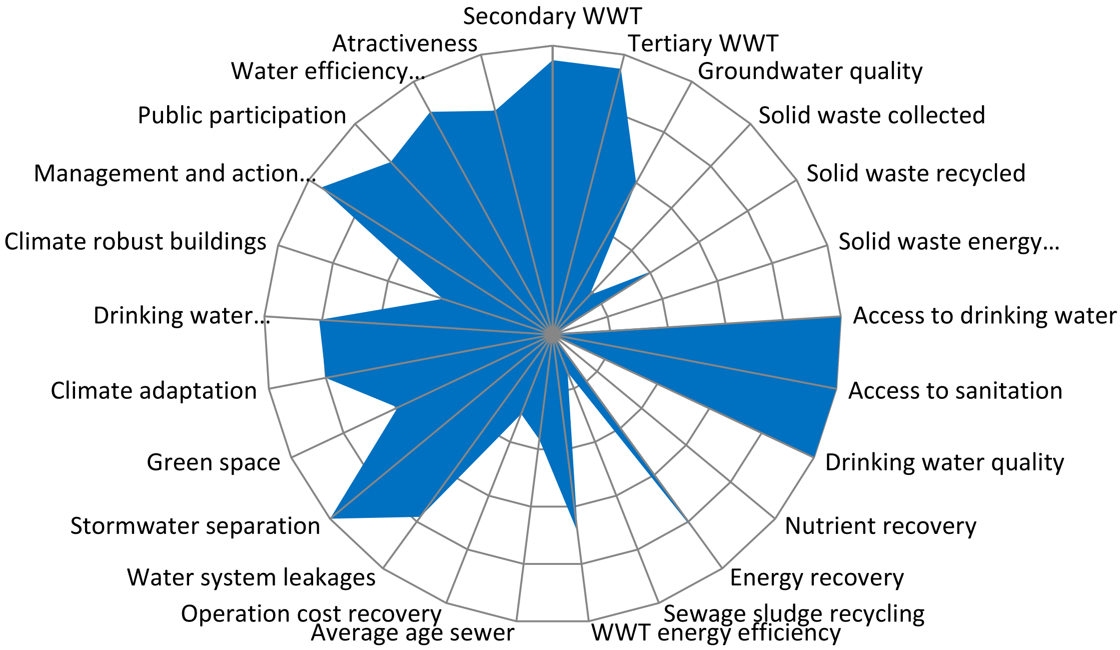
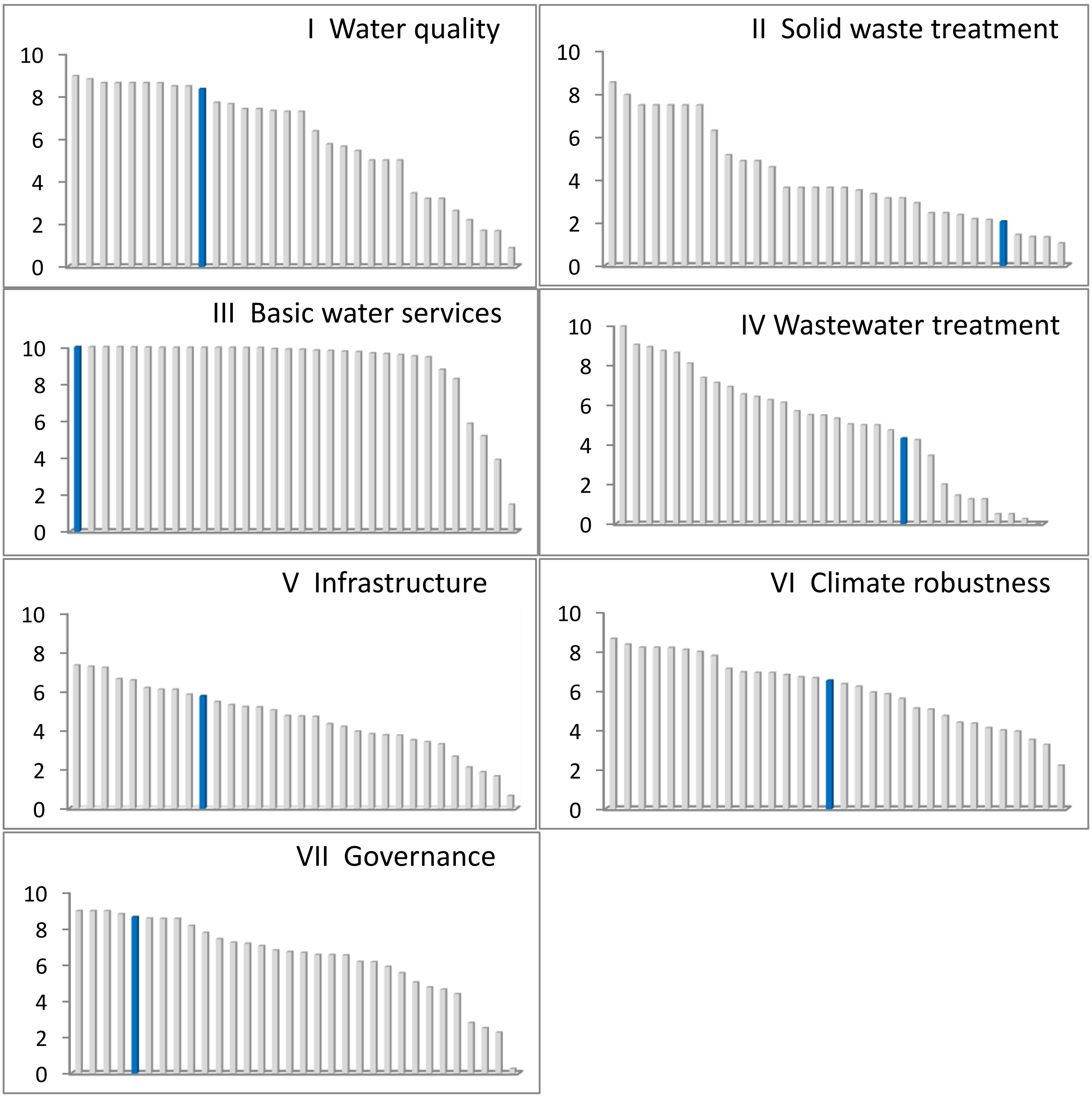


Figure 7.1.6 City Blueprint of Melbourne. A score of 0 (inner circle) means that further attention is needed and a score of 10 is an excellent score (outer circle). The Blue City Index has a score of 5.4.

Category	No.	Indicator	Score
I	1	Secondary WWT	9.5
	2	Tertiary WWT	9.5
	3	Groundwater quality	6.0
II	4	Solid waste collected	1.9
	5	Solid waste recycled	4.1
	6	Solid waste energy recovered	0.2
III	7	Access to drinking water	10.0
	8	Access to sanitation	10.0
	9	Drinking water quality	10.0
IV	10	Nutrient recovery	0.0
	11	Energy recovery	9.0
	12	Sewage sludge recycling	1.4
	13	WWT Energy efficiency	6.9
V	14	Average age sewer	3.7
	15	Operation cost recovery	3.0
	16	Water system leakages	7.8
	17	Stormwater separation	10.0
VI	18	Green space	5.9
	19	Climate adaptation	8.0
	20	Drinking water consumption	8.1
	21	Climate robust buildings	4.0
VII	22	Management and action plans	9.5
	23	Public participation	8.2
	24	Water efficiency measures	8.8
	25	Attractiveness	8.0

The category rankings of Melbourne compared to the performances of the other cities.



Annex 7.1.7 Amsterdam (The Netherlands)

Table 7.1.7 Trends and pressures in Amsterdam. In this table a short summary is provided of the key (sub-) indicators of concern or great concern and how these affect UWCS.

			0 1 2 3 4
City Blueprint	Social	1. Urbanization rate	
		2. Burden of disease	
		3. Education rate	
		4. Political instability	
	Environmental	5. Water scarcity	
		6. Flood risk	
		7. Water quality	
		8. Heat risk	
	Financial	9. Economic pressure	
		10. Unemployment rate	
		11. Poverty rate	
		12. Inflation rate	

0	No concern	1	Low concern	2	Medium concern	3	Concern	4	Great concern

Explanation of the concerns of Amsterdam

Amsterdam is a wealthy city and has relatively small social and financial concerns that would hinder IWRM. The concern score for water quality is relatively high because it is largely determined by the river Rhine and therefore receives much pollution from upstream sources. Flood risk is a concern in Amsterdam because more than 40% of the city will flood if the water defenses fail (EEA, 2012A). Hence flooding is a concern for the IWRM in the city of Amsterdam. Furthermore, the aquatic biodiversity (sub-indicator) is a great concern in Amsterdam. This is partly due to pollution sources upstream of the river Rhine but also local waterfront adaptations may improve the local aquatic biodiversity (EEA, 2012B; Dyson and Yocom, 2014).

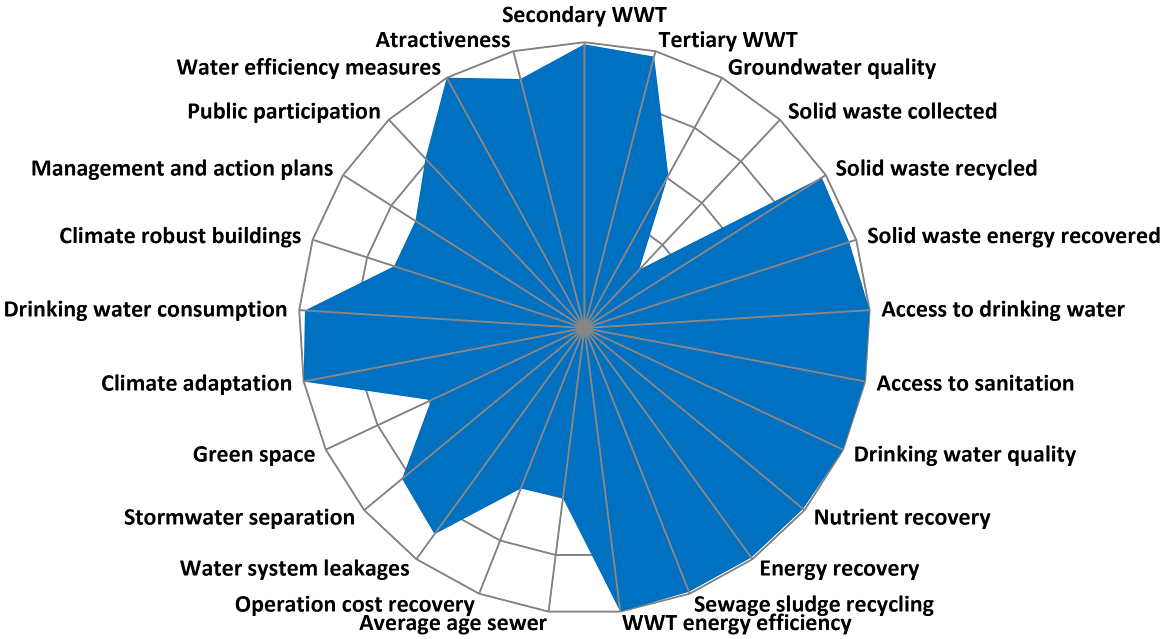
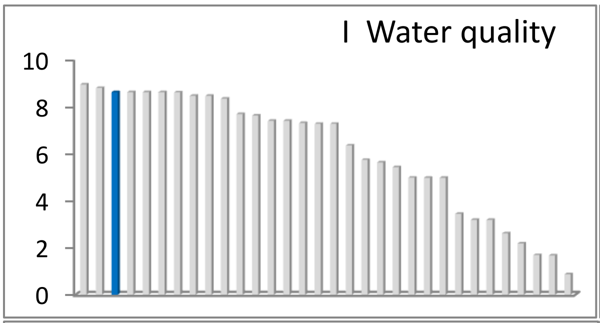
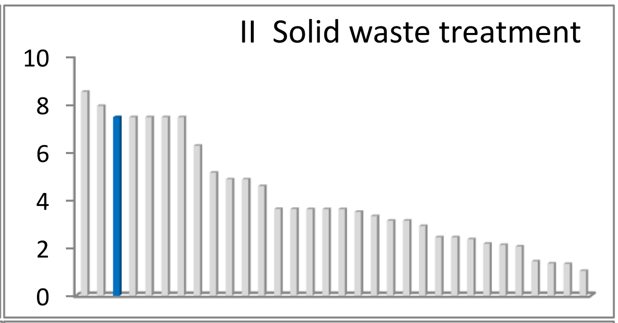


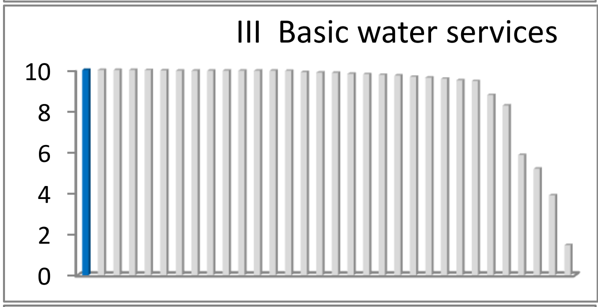
Figure 7.1.7 City Blueprint of Amsterdam. A score of 0 (inner circle) means that further attention is needed and a score of 10 is an excellent score (outer circle). The Blue City Index has a score of 8.4.

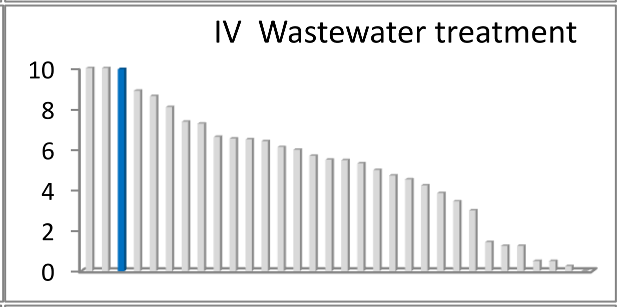
Category	No.	Indicator	Score
I	1 2 3	Secondary WWT Tertiary WWT Groundwater quality	6.1 9.9 9.8
II	4 5 6	Solid waste collected Solid waste recycled Solid waste energy recovered	2.8 9.8 9.7
III	7 8 9	Access to drinking water Access to sanitation Drinking water quality	10.0 10.0 10.0
IV	10 11 12 13	Nutrient recovery Energy recovery Sewage sludge recycling WWT Energy efficiency	9.9 9.9 9.9 10.0
V	14 15 16 17	Average age sewer Operation cost recovery Water system leakages Stormwater separation	6.0 6.0 8.3 8.9
VI	18 19 20 21	Green space Climate adaptation Drinking water consumption Climate robust buildings	5.9 10.0 9.8 7.0
VII	22 23 24 25	Management and action plans Public participation Water efficiency measures Attractiveness	7.0 8.1 10.0 9.0

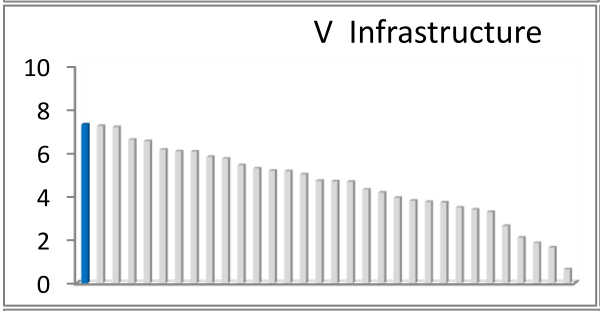
The category rankings of Amsterdam compared to the performances of the other cities.

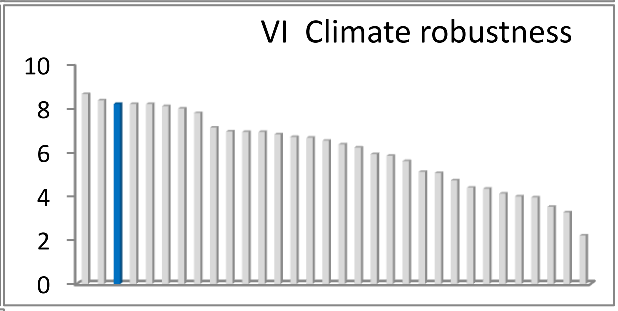


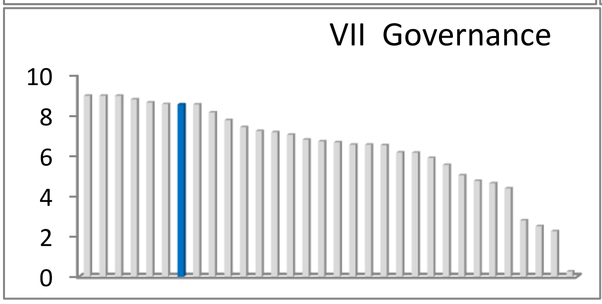












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Annex 7.2 Methodology City Blueprint trends and pressures

Table 7.2.1 Trends and pressure framework. Left are the three categories, in the middle are the indicators and right are the sub-indicators that are averaged to calculate the indicator that they belong to.

Trends and pressures	**Social Pressure**	**1. Urbanization rate**	
		2. Burden of disease	
		3. Education rate	
		4. Political instability	
	Environmental Pressure	**5. Water scarcity**	Freshwater scarcity Groundwater scarcity Salinization and seawater intrusion
		6. Flood risk	Urban drainage flood River peak discharges Sea level rise Land subsidence
		7. Water quality	Surface water quality Groundwater quality Biodiversity
		8. Heat risk	Heat island effect
	Financial Pressure	**9. Economic pressure**	
		10. Unemployment rate	
		11. Poverty rate	
		12. Inflation rate	

Table 7.2.2 Each indicator is scored from 0 to 4 points. The score and their label are shown here.

Score	Label
0.0 – 0.5	No concern
0.5 – 1.5	Little concern
1.5 – 2.5	Medium concern
2.5 – 3.5	Concern
3.5 - 4.0	Great concern

Indicator 1: Urbanization rate

Principal: Percentage of population growth either by birth or migration. The percentages are annually averages per country. Urbanization increases the pressure on IWRM in cities.

Calculation method
There is no urbanization rate reported that exceeds 5%. Therefore the following scoring method is applied:

Urbanization rate (%)	Score
<0	0
0 - 1	1
1 – 2	2
3 – 4	3
>4	4

Data sources
CIA (Central Intelligence Agency), 2014. The World Factbook. Urbanization. Available on world wide web <https://www.cia.gov/library/publications/the-world-factbook/fields/2212.html> [Accessed on November 5, 2014].

Data available in

Netherlands	**EU**	**Worldwide**
Yes	Yes	Yes

Scale: National scale.

Example Kilamba Kiaxi: Kilamba Kiaxi has a urbanization rate of 4.3% growth per year. It therefore scores a 4 implying a great concern.

Indicator 2: Burden of disease

Principal: The gap between current health status and an ideal situation where everyone lives into old age, free of disease and disability (WHO, 2004).

Calculation method
The indicator measures the age-standardized disability-adjusted life years (DALY) per 100.000 people. DALY is the quantification of premature death, burdens of disease and disability in life years. It is a time-based measure that combines years of life lost due to premature mortality and years of life lost due to time lived in states of less than full health, e.g. disease, injuries and risk factors (WHO, 2004).

WHO calculation of DALY
Years of premature death: Sum of, the number of deaths at each age * [global standard life expectancy for each age - the actual age].
Years lost due to disability: Number of incident cases in that period * average duration of the disease * weight factor.
Years of premature death + Years lost due to disability = DALY

The average DALY per 100.000 people is a strong tool to quantify and indicate the burden of disease. The WHO subdivided these DALY's per 100.000 people into 5 classes. These classes are used to standardize this indicator to a score of 0 to 4 in the City Blueprint pressure analysis as shown below.

DALY per 100.000 people	Score
0 - 20.000	0
20.000 - 40.000	1
40.000 - 60.000	2
60.000 - 80.000	3
80.000 <	4

Data sources
WHO (World Health Organization), 2014. Burden of disease. Age-standardized disability-adjusted life year –DALY- rates per 100 000 (population): 2012. Available on world wide web <http://gamapserver.who.int/gho/interactive_charts/mbd/as_daly_rates/atlas.html> [Accessed on January 9, 2015].

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: National scale

Example Bélem: Bélem is a city in Brazil which has on average 31.632 Disabled Adjusted Life Years (DALY's) per 100.000 people. This is between the 20.000 – 40.000 DALY's per 100.000 people and therefore receives a score of 1. This score implies a low concern for disease burden in Bélem.

Literature
WHO (World Health Organization), 2004. The Global Burden of Disease 2004 Update. Available on world wide web <http://www.who.int/healthinfo/global_burden_disease/GBD_report_2004 update_full.pdf?ua=1> [Accessed on October 10, 2014].

Indicator 3: Education rate

Principal: Education rate expressed as percentage of children completing their primary education.

Calculation method

From the data of all countries in the world the most recent percentage is taken if it was within the last 10 years. These percentages are ranked from high to low and divided into 5 classes of equal number of countries. Please note that this method is not normative and is only used to select the concerns and great concerns regarding education rate in order to give a general context of the city (also the context relative to other cities/countries). The following classification is made using the described method:

% completing primary education	score
>100	0
98-100	1
92-98	2
74-92	3
<74	4

Data sources

World Bank, 2014C. Primary completion rate, total (% of relevant age group). Available on world wide web <http://data.worldbank.org/indicator/SE.PRM.CMPT.ZS/countries/1W-AO?display=default> [Accessed on November 13, 2014].

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Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: National scale.

Example Belém: Belém is a city in Brazil. In Brazil 87.6% of the children have completed their primary education in 2013. According to the classification Belém receives a score of 3 implying that it is of concern for the city.

Indicator 4: Political instability (and absence of violence)

Principal: The estimated likelihood that the government will be destabilized or overthrown by violent means such as terrorism and politically-motivated violence.

Calculation method

Political stability (and absence of violence) is part of the set of governance indicators developed by the World Bank. The estimates of the indicator are aggregates of sub-indicators normalized by a standard normal distribution ranging from -2.5 to 2.5. The sub-indicators used by the World Bank to develop this indicator are:

Orderly transfer; Armed conflict; Violent demonstrations; Social Unrest; International tensions/terrorist threat; Cost of Terrorism; Frequency of political killings; Frequency of disappearances; Frequency of tortures; Political terror scale; Security Risk Rating; Intensity of internal conflicts: ethnic, religious or regional; Intensity of violent activities of underground political organizations; Intensity of social conflicts (excluding conflicts relating to land); Government stability; Internal conflict; External conflict; Ethnic tensions;
Civil unrest: How widespread political unrest is, and how great a threat it poses to investors. Demonstrations in themselves may not be cause for concern, but they will cause major disruption if they escalate into severe violence. At the extreme, this factor would amount to civil war;
Terrorism: Whether the country suffers from a sustained terrorist threat, and form who many sources. The degree of localization of the threat is assessed, and whether the active groups are likely to target or affect businesses (World Bank, 2014).

The indicator political stability and absence of violence in this City Blueprint pressure analysis is normalized using the reversed min-max method:

$$\mathbf{4} - \left[\frac{\text{Estimated political stability score} - -2.5}{\mathbf{2.5} - \ -\mathbf{2.5}}\ \boldsymbol{x}\ \mathbf{4}\right] = \boldsymbol{Score}$$

Data sources

World Bank, 2014A. Worldwide Governance Indicators. Available on world wide web <http://info.worldbank.org/governance/wgi/index.aspx#faq> [Accessed on October 21, 2014].

Data available in

Netherlands	**EU**	**Worldwide**
Yes	Yes	Yes

Scale: National scale.

Example Amsterdam: The estimated political stability for the Netherlands is 1.17. Lowest and highest score possible for this indicator is -2.5 and 2.5, respectively. If we apply the min-max method together with these methodological boundaries we obtain:

$$4 - \left[\frac{1.17 - -2.5}{2.5 - -2.5}\ x\ 4\right] = 1.06$$

A is approximatelA score of 1.06 is approximately 1 which implies low concern.

Literature

World Bank, 2014. Political Stability and Absence of Violence/Terrorism. Available on world wide web <http://info.worldbank.org/governance/wgi/pdf/pv.pdf> [Accessed on October 10, 2014].

Indicator 5: Water scarcity

Indicator 5 consists of three sub-indicators:
5.1 Freshwater scarcity
5.2 Groundwater scarcity
5.3 Salinization & seawater intrusion

Indicator: 5.1 Freshwater scarcity

Principal: The abstracted freshwater as percentage of total renewable resource. This includes surface water and groundwater sources.

Calculation method
The scoring method is in accordance with the European Environmental Agencies classification (OECD, 2004; WRI, 2013).

% of renewable resource abstracted	Score
0 - 2	0
2 - 10	1
10 – 20	2
20 – 40	3
>40	4

Data sources
Aquastat: Water use → Pressure on water resources → Freshwater withdrawal as % of total actual renewable water resources.
Aquastat, 2015. Select variables. Available on world wide web <http://www.fao.org/nr/water/aquastat/data/query/index.html;jsessionid=B022D1C2732DF571D2A384B57E0128D6> [Accessed on January 19, 2015].

WRI (World resources institute), 2013. Aquaduct global maps 2.0. *Working paper.* Available on world wide web <http://pdf.wri.org/aqueduct_metadata_global.pdf#page=11> p.8 [Accessed on January 19, 2015].

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: National scale.

Example Manresa: Manresa is a city in Spain where 29.02% of the total renewable water resource is used. It therefore receives a score of 3 meaning that freshwater scarcity is a concern in Manresa.

Literature
OECD (Organization for economic communication and development), 2004. OECD key environmental indicators. Paris, France. Available on world wide web <http://www.oecd.org/environment/indicators-modelling-outlooks/31558547.pdf> [Accessed on January 19, 2015].

WRI (World resources institute), 2013. Aquaduct global maps 2.0. *Working paper.* Available on world wide web <http://pdf.wri.org/aqueduct_metadata_global.pdf#page=11> [Accessed on January 19, 2015].

Indicator: 5.2 Groundwater scarcity

Principal: The abstracted groundwater as a percentage of the annual groundwater recharge. This is a measure of the pressure on groundwater resources.

Calculation method
The indicator scoring is in accordance with the classification used by UNESCO.

% abstracted of annual recharge	Score
0 - 2	0
2 - 20	1
20- 50	2
50 - 100	3
>100	4

Data sources
Igrac, 2010. Groundwater Development stress. Available on world wide web <http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/temp/wwap_pdf/Groundwater_development_stress_GDS.pdf> p. 15 [Accessed on January 19, 2015].

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: National scale.

Example Ankara: Ankara is the capital of Turkey. Turkey abstracts 20 to 50% of the annual recharged groundwater and therefore receives a score of 2 implying that groundwater scarcity is of medium concern for Ankara.

5.3 Salinization & seawater intrusion

Principal: Measure of the vulnerability of seawater intrusion and salinization of the soil.

Calculation method
This indicator score is based on a quick literature check in which seawater and groundwater intrusion are scored as suggested below.

Seawater intrusion

Description	Score
No seawater intrusion reported and city not prone to (future) intrusion	0
No seawater intrusion reported and city can experience intrusion in coming century	1
No seawater intrusion reported but city is prone to intrusion in the near future	2
Seawater intrusion reported	3
Seawater intrusion reported and city is particularly prone to intrusion	4

Groundwater salinization
Based on literature studies, here the following scheme is applied to determine a score:

Description	Score
No concern	0
Low concern	1
Medium concern	2
Concern	3
Great concern	4

The highest score of both indicators is used as the final score for salinization and seawater intrusion.

Data sources
Seawater intrusion map Europe:
EEA (European environmental agency), 2003. Indicator fact sheet. Saltwater intrusion. Available on world wide web <http://www.eea.europa.eu/data-and-maps/indicators/saltwater-intrusion/saltwater-intrusion> [Accessed on January 19, 2015].

Indication of groundwater salinization in Europe:
JRC (Joint Research Centre), 2015. European soil portal – Soil data and information system. Available on world wide web <http://eusoils.jrc.ec.europa.eu/library/themes/salinization/> [Accessed on January 19, 2015].

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: City scale.

Example Melbourne: Seawater intrusion: the city is prone to seawater intrusion and therefore already receives a score of 2. Moreover, the city has reported seawater intrusion and thus receives even a higher score of 3. Groundwater salinization: There are some problems of groundwater salinization given the fact that the climate is unfavorable. Based on a concise literature research this score is set on 2. The overall score for salinization and seawater intrusion is equal to the maximum score which is given to seawater intrusion, i.e., a score of 3 stating that seawater intrusion and salinization is a concern for the city.

Indicator 6: Flood risk

The indicator flood risk consists of 4 sub-indicators:
6.1 Urban drainage flood
6.2 Sea level rise
6.3 River peak discharges
6.4 Land subsidence

6.1 Urban drainage flood

Principal: Risk of flooding due to intensive rainfall expressed as the share of urban soil that is sealed.

Calculation method
Sealed soil cover in the city standardized according to the min-max method. The minimum and maximum value are determined by taking the bottom and the top 10% of the 572 European cities assessed. Green and blue areas refer to sports and leisure facilities, agricultural areas, semi-natural areas and wetlands, forests, discontinuous low density urban fabric as a proxy for private gardens and water bodies (EEA, 2012A).

Data sources
Soil sealing for EU countries:
EEA (European environmental agency), 2015. Urban adaptation to climate change. Annex II. City data sensitivity. Available on world wide web <http://www.eea.europa.eu/data-and-maps/figures/mean-soil-sealing-in-european> [Accessed on January 19, 2015].

An estimated score for non-EU countries is based on descriptions of soil sealing of the cities (mostly without exact coverage's) found in literature.

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: City scale.

Example Amsterdam: Soil sealing for Amsterdam is 45.4%. Lower 10% of all European cities assessed is 31.7%, top 10% has a share of green area of 69.6%. Min-max transformation leads to:

$$\frac{45.4 - 31.7}{69.6 - 31.7}\, x\, 5 = 1.8$$

A score of 1.8 implies that urban drainage flooding is of medium concern for the city of Amsterdam (Table 7.2.2).

6.2 Sea level rise

Principal: Measure of the vulnerability of flooding due to sea level rise. Percentage of the city that would flood with 1 meter sea level rise. Only environmental circumstances are considered. Protection measures such as dikes, dams *etcetera* are not considered (that would be a performance).

Calculation method
In accordance with the European Environmental Agency (2012) the following classification is used to standardize the area being affected by a 1 meter sea level increase without flood protection on a scale from 1 to 5.

Urban area affected (%)	Score
0-5	0
6-10	1
11-20	2
21-40	3
41-100	4

For non-European cities, the assessment is based on literature available. Classes are in principle the same as for European cities.

Data sources
EEA (European environmental agency), 2015. Urban adaptation to climate change. Annex II. Coastal flooding. Available on world wide web <http://www.eea.europa.eu/data-and-maps/figures/mean-soil-sealing-in-european> [Accessed on January 19, 2015].

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: City scale.

Example Rotterdam: Rotterdam has more than 40% of its city area flooded as a consequence of 1 meter sea level rise if no flood protection measures would be taken. Therefore the city is highly vulnerable to sea level rise and receives a score of 4.

Literature
EEA (European Environment Agency), 2012. Urban adaptation to climate change in Europe Challenges and opportunities for cities together with supportive national and European policies. ISBN 978-92-9213-308-5. Available on world wide web <http://www.eea.europa.eu/publications/urban-adaptation-to-climate-change> [Accessed on September 8, 2014].

6.3 River peak discharges

Principal: Measure for the vulnerability of flooding due to river level rise. Also flash floods from outside the city are included in this indicator. Percentage of the city that would flood with 1 meter river level rise. Only environmental circumstances are considered. Protection measures such as dikes, dams etcetera are not considered (that would be a performance).

Calculation method

In accordance with the European Environmental Agency (2012) the following classification is used to standardize the area being affected by a 1 meter river level increase without flood protection on a scale from 1 to 5.

Urban area affected (%)	Score
0-5	0
6-10	1
11-20	2
21-40	3
40-100	4

For non-European cities, the assessment is based on literature available. Classes are in principle the same as for European cities.

Data sources

EEA (European environmental agency), 2015. Urban adaptation to climate change. Annex II. River flooding. Available on world wide web <http://www.eea.europa.eu/data-and-maps/figures/mean-soil-sealing-in-european> [Accessed on January 19, 2015].

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: City scale.

Example Athens: More than 40% of Athens will flood if the river level would increase with 1 meter. The city therefore receives a score of 4.

Literature

EEA (European Environment Agency), 2012. Urban adaptation to climate change in Europe Challenges and opportunities for cities together with supportive national and European policies. ISBN 978-92-9213-308-5. Available on world wide web <http://www.eea.europa.eu/publications/urban-adaptation-to-climate-change> [Accessed on September 8, 2014].

6.4 Flood risk due to subsidence

Principal: Land subsidence increases the risks of river and coastal floods and salt water intrusion. The cause of land subsidence is irrelevant for its impact on flooding.

Calculation method
This score is based on a qualitative assessment according to the following classification:

Score	Description
0	No infrastructure damage, no flood risk
1	Low/medium infrastructure damage expected, no major increase in flood risk expected
2	Experienced infrastructure damage and medium infrastructure damage expected or <0.50m subsidence by 2100 in a substantial area of the city.
3	Serious experienced infrastructural damage or < 1m subsidence by 2100 in a substantial area of the city
4	Serious experienced infrastructure damage, Imminent flooding/ < 2m subsidence by 2100 in a substantial area of the city

Data sources
Local websites, government reports, strategic plans *etcetera*.

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: City scale

Example Rotterdam: Substantial parts of Rotterdam are expected to subside by 40-60 cm by 2050. Since Rotterdam is already prone to flood risk, this subsidence imposes an extra flood risk in the future. It therefore receives a score of 3 implying that flood risk due to subsidence is a concern.

Indicator 7: Water quality

Water quality consists of two sub-indicators:
7.1 Surface water quality
7.2 Biodiversity

7.1 Surface water quality

Principal: Measure of relative surface water quality. A lower Indicator score is given for better quality.

Calculation method
A national surface water quality index (WQI) is available as a measure out of 100. Then, the indicator is calculated as follows:

$$\frac{100 - WQI}{25} = score$$

Data sources
The WQI data are obtained from the Country Profiles:
EPI (Environmental performance index), 2010. Available on world wide web <http://www.ciesin.columbia.edu/repository/epi/data/2010EPI_country_profiles.pdf> [Accessed on January 19, 2015].

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: Country scale

Example Venlo: Venlo is situated in the Netherlands. The WQI for the Netherlands is 73.2.

$$\frac{100-73.2}{25} = 1.07$$

A score of 1.07 implies that the surface water quality that a city receives is of low concern for the city of Venlo.

7.2 Biodiversity

Principal: Measure of the biodiversity of aquatic ecosystems in the city. A low indicator score is given where biodiversity is good.

Calculation method
The calculation is based on national or regional data when city-level data are not available. There are many ways of assessing biodiversity, so there is no globally uniform approach.
For EU countries, it is recommended to use data from the European Environment Agency (EEA) on 'percent of classified waters in less than good ecological status' as shown in this map – for which a high resolution version is available via the link.

EEA (European environmental agency). Percent of classified water bodies in less than good ecological status of potential. Available on world wide web <http://www.eea.europa.eu/data-and-maps/figures/proportion-of-classified-surface-water/proportion-of-classified-surface-water/image_original> [Accessed on January 19, 2015].

Then apply the following criteria to determine an Indicator score

% of waters with less than good ecological status or potential	Indicator 21 value (for EU countries)
<10%	0
10 to 30%	1
30 to 50%	2
50 to 70%	3
≥ 70%	4

For non-EU countries, it is recommended to use data from a programme called the Environmental Performance Index (EPI), led by Yale University (epi.yale.edu).
The latest 2012 update does not include the relevant parameter called 'Water – impact on ecosystem'. This is available from the 2010 version (see also Indicator 4).
The value is obtained from the Country Profiles:

EPI (Environmental performance index), 2010. Available on world wide web <http://www.ciesin.columbia.edu/repository/epi/data/2010EPI_country_profiles.pdf> [Accessed on January 19, 2015].

This is a 327 page document, with 2 pages per country in alphabetical order.
On the first page of the country, take the 'Country' value for 'Water (impact on ecosystems)', which is a factor out of 100.

$$\frac{100-Water\ (impact\ on\ ecosystems)}{25} = score$$

Example Istanbul (no data are provided by the EEA): Water (impact on ecosystem) = 62.8. This leads to the following score: [100 – 62.8] / 25 = 1.49. This score implies that (aquatic) biodiversity is an issue of medium concern in Istanbul.

Example London (EU country): City-specific information is available for London. Only one of the 47 water bodies in London is of good ecological potential. London therefore receives a score of 4. This score implies that aquatic biodiversity is of great concern for London.

Indicator 8: Heat risk

Principal: Prediction of heat island effects severity on human health.

Calculation method
1. Number of combined tropical nights (>20 ^{o}C) and hot days(>35 ^{o}C) in the period 2071-2100, where the maximum is set on 50 days. The number is standardized using the following formula:
[Number of combined tropical nights and hot days / 50] x 4 = score

2. Percentage of green and blue urban area. Share of green and blue areas is available for all European cities. The EEA city database presents data for of 367 European cities. From these data the average of the lowest 10% is taken as minimum (16%) and the average of the highest 10% is taken as maximum (48%). The percentages for the EU cities are standardized according to the min-max method. For non-European cities percentages for green and blue area are mostly not available. A best estimate is given by comparing this city to a similar European city. It is important for these cities to provide better information on the share of green area.
4 - [(% green and blue area – 16) / (48 -16) x 4] = score

3. The overall score is the arithmetic average of both standardized scores.

Data sources for EU cities
1. Number of combined tropical nights and hot days for Europe
Arcgis, 2015. Available on world wide web
<http://www.arcgis.com/home/webmap/viewer.html?webmap=d4124af689f14cbd82b88b815ae81d76>
[Accessed on January 19, 2015].
Otherwise best estimate based on the local climate**.**

2. City specific:
EEA (European environmental agency), 2015. Urban adaptation to climate change. Annex II. City data sensitivity. Available on world wide web <http://www.eea.europa.eu/data-and-maps/figures/mean-soil-sealing-in-european> [Accessed on January 19, 2015].

Country average:
EEA (European environmental agency), 2015. Available on world wide web
<http://www.eea.europa.eu/data-and-maps/figures/percentage-of-green-and-blue/percentage-of-green-and-blue/image_original> [Accessed on January 19, 2015].

For cities where exact numbers are not available the country average is used**.** If the country is outside Europe, a best estimate is given by comparing the city with a comparable city in Europe.

Data available in

Netherlands	**EU**	**Worldwide**
Yes	Yes	Yes

Scale: City scale

Example Athens: Athens has a green coverage of 14.1% and the number of combined nights higher than 20 ^{o}C and days above 35 ^{o}C is higher than 50 days. The green coverage is only 14.1%, which is the lowest score which results in a maximum score of 4.Combined tropical nights and hot days: for Athens this is the maximum of 50 hence a score of 4 overall score is the mean: (4 + 4) / 2 = 4.

Indicator 9: Economic pressure

Principal: Gross Domestic Product (GDP) per head of the population is a measure of the economic power of a country. A low GDP per capita implies a large economic pressure.

Calculation method
The average of the 10% highest (59,231 US$) and the 10% lowest (515 US$) GDP per capita of all countries (IMF, 2013) are respectively selected as minimum and maximum value that standardize this indicator.

Data sources
EEA (European Environmental Agency), 2015. Urban adaptation to climate change. Annex II. City data sensitivity. Available on world wide web <http://www.eea.europa.eu/data-and-maps/figures/mean-soil-sealing-in-european> [Accessed on January 19, 2015].

If city data is lack than per country:
World Bank. GDP per capita (current US$). Available on world wide web < http://data.worldbank.org/indicator/NY.GDP.PCAP.CD> [Accessed on January 19, 2015].

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: National scale.

Example Ho Chi Minh City: GDP per capita per year for Viet Nam is US$ 1.191. The minimum GDP per capita which is the average of the 10% poorest countries is 515 US$ and maximum GDP per capita which is the average of the 10% riched countries is 59,231 US$. A high GDP can be considered as a low concern and *vice versa*. Therefore the reversed min-max method is applied here.
4 - [[(1191 – 515) / (59231 – 515)] X 4] = 3.95   This score implies that GDP per capita is a great concern in Ho Chi Minh City.

Indicator 10: Unemployment rate

Principal: Percentage of population of the total labor force without a job.

Calculation method
Scores are provided in the table below:

Percentage unemployed of labor force	Score
0 - 5	0
5 - 10	1
10 - 15	2
15 - 20	3
>20	4

Data sources
World Bank, 2015. Unemployment total (% of total labor force) (modelled ILO estimate). Available on world wide web <http://data.worldbank.org/indicator/SL.UEM.TOTL.ZS> [Accessed on January 19, 2015].

Data available in

Netherlands	**EU**	**Worldwide**
Yes	Yes	Yes

Scale: National scale.

Example London: London is the capital of the United Kingdom which has an unemployment rate of 7.9% of its labor force. This is in the category 5 – 10 and therefore receives a score of 1. This score implies that unemployment in London is of (relative) low concern.

Indicator 11: Poverty rate

Principal: Percentage of people that is below the poverty line of 2 *US$* a day.

Calculation method
Here a normative classification is made. All countries that have more than 10% of their population living from less than 2 US$ a day (which is the world's average in 2010) should be reported as a concern.

% below poverty line of 2US$	Score
0-2	0
2-5	1
5-10	2
10-30	3
>30	4

Data sources
World Bank, 2014D. Poverty gap at $2 a day (PPP) (%). Available on world wide web <http://data.worldbank.org/indicator/SI.POV.GAP2/countries/1W?display=default> [Accessed on November 13, 2014].

Data available in

Netherlands	**EU**	**Worldwide**
Yes	Yes	Yes

Scale: National scale.

Example Dar es Salaam: Dar es Salaam is the capital of Tanzania where 73% of the people live below the poverty line of 2 US$ a day. It therefore receives a score of 4 implying that poverty is a great concern for the city of Dar es Salaam.

Indicator 12: Inflation

Principal: Percentage inflation per year. High inflation rates may hamper investments.

Calculation method
Inflation rate (%)is scored as follows:

Inflation (%)	Score
<2,5	0
2,5. – 5	1
5 - 7,5	2
7,5 – 10	3
>10	4

Data sources
World Bank, 2015. Inflation, costumers price (annual %). Available on world wide web <http://data.worldbank.org/indicator/FP.CPI.TOTL.ZG> [Accessed on January 19, 2015].

Data available in

Netherlands	**EU**	**Worldwide**
Yes	Yes	Yes

Scale: National scale.

Example Berlin: Berlin is the capital of Germany and Germany has an inflation rate of 0.8% per year. This is in the category <2.5 and therefore Berlin receives a score of 0 which implies that inflation is not a concern for Berlin.

Annex 7.3 Methodology alternative City Blueprint

- Bold are newly added indicators for which the method is explained in this document.
- Underlined are indicators of which the methodology is adjusted.
- The other indicators remain unchanged and can be found in the CB indicator description http://www.eip-water.eu/sites/default/files/EIP-Water-City-Blueprint_Action_%20ANNEX%202-CityBlueprintQuestionnaire_December_2014.pdf

1. Water quality

1. **Secondary WWT**
2. **Tertiary WWT**
3. Groundwater quality

2. Solid waste treatment

4. **Solid waste collected**
5. **Solid waste recycled**
6. **Solid waste energy recovered**

3. Basic water services

7. Access to drinking water
8. Access to sanitation
9. Drinking water quality

4. Wastewater treatment

10. <u>Nutrient recovery</u>
11. <u>Energy recovery</u>
12. <u>Sewage sludge recycling</u>
13. Energy efficiency WWT

5. Infrastructure

14. <u>Average age sewer</u>
15. **Operation cost recovery**
16. Stormwater separation
17. <u>Water system leakages</u>

6. Climate robustness

18. **Green space**
19. Climate adaptation
20. Drinking water consumption
21. Climate robust buildings

7. Governance

22. Management and action plans
23. <u>Public participation</u>
24. Water efficiency measures
25. Attractiveness

1. Water quality

Indicator 2: Secondary WWT

Principal: Measure of the urban population connected to secondary waste water treatment plants. The focus on secondary treatment is chosen because primary treatment is considered rather insufficient for BOD and nutrient removal.

Calculation method
Percentage of population connected to secondary sewage treatment. Assumed that there is only tertiary treatment after secondary treatment has been done.

<u>Definition secondary WWT</u>: Secondary treatment: process generally involving biological treatment with a secondary settlement or other process, with a BOD removal of at least 70% and a COD removal of at least 75% (OECD, 2013).

Data sources
OECD (Organization for Economic Co-operation and Development), 2013. Environment at a glance 2013. OECD indicators. OECD Publishing. DOI: 10.1787/9789264185715-en. Available on world wide web <http://www.oecd-ilibrary.org/environment/environment-at-a-glance-2013_9789264185715-en> p. 96 [Accessed on November 7, 2014].

Search for ''Sanitation status (name city)''
IWA Water Wiki. Information resource & hub for the global water community. Available on world wide web<http://www.iwawaterwiki.org/xwiki/bin/view/Main/Search?text=Ho+Chi+Minh+City+sanitation+status&space> [Accessed on January 19, 2015].

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: Both city scale and national scale.

Example Amsterdam: Amsterdam has 1% of only secondary treatment and 98% of tertiary treatment. The score for the coverage of secondary WWT becomes: [1% + 98%] / 10 = 9.9

Literature
OECD (Organization for Economic Co-operation and Development), 2013. Environment at a glance 2013. OECD indicators. OECD Publishing. DOI: 10.1787/9789264185715-en. Available on world wide web <http://www.oecd-ilibrary.org/environment/environment-at-a-glance-2013_9789264185715-en> p. 96 [Accessed on November 7, 2014].

Indicator 3: Tertiary WWT

Principal: Measure for the urban population connected to tertiary waste water treatment plants. This treatment step is important for water quality because much nutrients and chemical compounds are removed from the water before it inters the surface water.

Calculation method
Percentage of population connected to tertiary sewage treatment.

Definitions
Tertiary treatment: Tertiary treatment: treatment of nitrogen or phosphorous or any other pollutants affecting the quality or a specific use of water (microbiological pollution, colour, etc.) (OECD,2013).

Data sources
OECD (Organization for Economic Co-operation and Development), 2013. Environment at a glance 2013. OECD indicators. OECD Publishing. DOI: 10.1787/9789264185715-en. Available on world wide web <http://www.oecd-ilibrary.org/environment/environment-at-a-glance-2013_9789264185715-en> p. 96 [Accessed on November 7, 2014].

Search for ''Sanitation status (name city)''
IWA Water Wiki. Information resource & hub for the global water community. Available on world wide web<http://www.iwawaterwiki.org/xwiki/bin/view/Main/Search?text=Ho+Chi+Minh+City+sanitation+status&space> [Accessed on January 19, 2015].

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: Both city scale and national scale.

Example Amsterdam: Amsterdam has 98% of their waste water treated with tertiary treatment. The score for the coverage of secondary and tertiary treatment becomes: 98 / 10 = 9.8

Literature
OECD (Organization for Economic Co-operation and Development), 2013. Environment at a glance 2013. OECD indicators. OECD Publishing. DOI: 10.1787/9789264185715-en. Available on world wide web <http://www.oecd-ilibrary.org/environment/environment-at-a-glance-2013_9789264185715-en> p. 96 [Accessed on November 7, 2014].

2. Solid waste treatment

Indicator 4: Solid waste collected

Principal: Represents waste collected from households, small commercial activities, office buildings, institutions such as schools and government buildings, and small businesses that threat or dispose of waste at the same used for municipally collected waste (OECD, 2013).

Calculation method
Data is in kg/cap/year. The min-max method is applied here as explained in the example.

Data sources
OECD (Organization for Economic Co-operation and Development), 2013. Environment at a glance 2013. OECD indicators. OECD Publishing. DOI: 10.1787/9789264185715-en. Available on world wide web <http://www.oecd-ilibrary.org/environment/environment-at-a-glance-2013_9789264185715-en> p. 98 [Accessed on November 7, 2014].

In non-EU cities local data of solid waste treatment are mostly available on local sites, municipal or company reports *etcetera.*

Data available in

Netherlands	**EU**	**Worldwide**
Yes	Yes	Yes

Scale: Mostly National scale and sometimes the city scale.

Example Malmö: Malmö's average municipal waste production is 460 kg/cap/year. The minimum amount of municipal waste production is in Dar es Salaam (292 kg/cap/year) (World Bank, 2012). The maximum amount of municipal waste is in the United States municipalities (730 kg/cap/year) (OECD, 2013). Applying the min-max method gives:
[(460 – 292) / (730 – 292)] * 10 = 6.2

World Bank, 2012. Municipal solid waste management in Dar es Salaam. Washington, DC. Available on world wide web < http://siteresources.worldbank.org/INTUSWM/Resources/463617-1202332338898/MSWM_Dar-es-Salaam.pdf> [Accessed on January 13, 2015].

Indicator 5: Solid waste recycled

Principal: Percentage of solid waste that is recycled or composted.

Calculation method
This indicator represents the percentage of the total collected municipal waste that is recycled or composted. However, when solid waste is used for incineration with energy recovery, it is not possible to also use it for recycling while both practices are sustainable. Therefore the % solid waste that is incinerated is subtracted from the total (100%) of collected municipal waste to obtain the potential percentage of solid waste that can be recycled (in numerator). Thus this indicator is calculated as shown below.

$$\frac{\%\, recycled\ or\ composted}{100 - \%\, used\ for\ incineration\ with\ energy\ recovery}\ x\ 10$$

Data sources
OECD (Organization for Economic Co-operation and Development), 2013. Environment at a glance 2013. OECD indicators. OECD Publishing. DOI: 10.1787/9789264185715-en. Available on world wide web <http://www.oecd-ilibrary.org/environment/environment-at-a-glance-2013_9789264185715-en> p. 98 [Accessed on November 7, 2014].

In non-EU cities local data of solid waste treatment are mostly available on local sites, municipal or company reports *etcetera.*

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: Mostly national scale and sometimes the city scale.

Example Venlo: Venlo belongs to the Netherlands. In the Netherlands 61% of the solid waste is composted or recycled. Furthermore, 38% of the municipal solid waste is incinerated with energy recovery.

$$\frac{61\%}{100\% - 38\%}\ x\ 10 = 9.8$$

Indicator 6: Solid waste energy recovery

Principal: Percentage of solid waste that is incinerated with energy recovery.

Calculation method
This indicator represents the percentage of the total collected municipal waste that incinerated with energy recovery (techniques). However, when solid waste is recycled or composted , it is not possible to also use it for incineration with energy recovery, while both practices are sustainable. Therefore the % solid waste that is recycled or composted is subtracted from the total (100%) of collected municipal waste to obtain the potential percentage of solid waste that can be incinerated with energy recovery (in numerator). Thus this indicator is calculated as shown below.

$$\frac{\%\, incinerated\ with\ energy\ recovery}{100 - \%\, recycled\ or\ composted}\ x\ 10$$

Data sources
OECD (Organization for Economic Co-operation and Development), 2013. Environment at a glance 2013. OECD indicators. OECD Publishing. DOI: 10.1787/9789264185715-en. Available on world wide web <http://www.oecd-ilibrary.org/environment/environment-at-a-glance-2013_9789264185715-en> p. 98 [Accessed on November 7, 2014].

In non-EU cities local data of solid waste treatment are mostly available on local sites, municipal or company reports *etcetera.*

Data available in

Netherlands	**EU**	**Worldwide**
Yes	Yes	Yes

Scale: Mostly National scale and sometimes the city scale.

Example Venlo: Venlo is a city in the Netherlands. In the Netherlands 38% of the solid waste is incinerated with energy recovery. Furthermore, 61% of the municipal solid waste is recycled or composted.

$$\frac{38\%}{100\% - 61\%}\ x\ 10 = 9.7$$

4. Wastewater treatment

Indicator 10: Nutrient recovery

Principal: Measure of the level of nutrient recovery from the wastewater system.

Calculation method
A. Wastewater treated with nutrient recovering techniques at the wastewater treatment plants (Mm^3 $year^{-1}$)
B. Total amount of wastewater passing the wastewater treatment plants (Mm^3 $year^{-1}$)

[A / B] x % secondary WWT coverage x 10 = score

Data sources
OECD (Organization for Economic Co-operation and Development), 2013. Environment at a glance 2013. OECD indicators. OECD Publishing. DOI: 10.1787/9789264185715-en. Available on world wide web <http://www.oecd-ilibrary.org/environment/environment-at-a-glance-2013_9789264185715-en> p. 96 [Accessed on November 7, 2014].

Improvement in calculation method: In the city blueprint only water that enters the WWT facilities is considered as total volume of water. Hereby disregarding the city's wastewater that is not treated at all. To measure the full potential of nutrient abstraction from all wastewater the above equation is applied.

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: City scale.

Indicator 11: Energy recovery

Principal: Measure of energy recovery from the wastewater system.

Calculation method
A) Total volume of wastewater treated with techniques to recover energy (Mm^3/year).
B) Total volume of water produced by the city (Mm^3/year).

[A / B] * 10 = score

Often only the total volume of wastewater that enters the treatment facilities is known together with wastewater treatment coverage's (% of water going to the treatment facilities). In this case:
C) Total volume of wastewater treated with techniques to recover energy (Mm^3/year).
D) Total volume of wastewater treated in wastewater treatment plants (Mm^3/year).

[C / D] * % secondary WWT coverage * 10 = score

Data sources
Data needs to be provided locally. For WWT coverage's:
OECD (Organization for Economic Co-operation and Development), 2013. Environment at a glance 2013. OECD indicators. OECD Publishing. DOI: 10.1787/9789264185715-en. Available on world wide web <http://www.oecd-ilibrary.org/environment/environment-at-a-glance-2013_9789264185715-en> p. 96 [Accessed on November 7, 2014].

Improvement in calculation method: In the city blueprint only water that enters the WWT facilities are considered as total volume of water. Hereby disregarding the city's wastewater that is not treated at all. Therefore the City Blueprint scores are multiplied by the share of WWT coverage. In this way the concept of urban metabolism is better represented.

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: City scale.

Indicator 12: Sewage sludge recycling

Principal: A measure of the proportion of sewage sludge recycled or re-used. For example, it may be thermally processed and/or applied in agriculture.

The decision whether or not to apply sewage sludge in agriculture depends on the levels of organic and inorganic micro-contaminants. Often, sewage sludge is contaminated and in many countries it is not allowed to apply sewage sludge in agriculture. Instead, the sludge is burned in waste destruction installations or as biomass in power plants for the generation of electricity.

Calculation method

A. Dry weight of sludge produced in wastewater treatment plants serving the city
B. Dry weight of sludge going to landfill
C. Dry weight of sludge thermally processed
D. Dry weight of sludge disposed in agriculture
E. Dry weight of sludge disposed by other means
(As a check, A should = B + C + D +E)

[(C + D) / A] x % secondary WWT coverage x 10 = score

To measure the full potential of nutrient and energy recovery, It is specifically chosen to multiply the first term in the equation above with the percentage of secondary WWT coverage as secondary WWT produces much more sewage sludge than primary WWT.

Data sources

Data needs to be provided locally. For WWT coverage's:
OECD (Organization for Economic Co-operation and Development), 2013. Environment at a glance 2013. OECD indicators. OECD Publishing. DOI: 10.1787/9789264185715-en. Available on world wide web <http://www.oecd-ilibrary.org/environment/environment-at-a-glance-2013_9789264185715-en> p. 96 [Accessed on November 7, 2014].

Improvement in calculation method: In the city blueprint only water that enters the WWT facilities are considered as total volume of water. Hereby disregarding the city's wastewater that is not treated at all. To measure the full potential of nutrient and energy recovery from wastewater by using wastewater abstracted sewage sludge, secondary WWT is incorporated in the calculation and not primary WWT. In this way the concept of urban metabolism is better represented.

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: City scale.

Example Scotland: A total sludge produced is 20030 tonnes dry DS/year (dry substance per year); **B** Not given; **C** Zero tonnes DS/year is thermally processed; **D** 19520 tonnes DS/year is processed in agriculture; % secondary WWT coverage in Scotland is 97%.
[(0 + 19520) / 20030] x 0.97 x 10 = 9.45.

5. Infrastructure

Indicator 14: Average age sewer

Principal: The age of the infrastructure for wastewater collection and distribution system is an important measure for the financial state of the UWCS.

Calculation method
The average age of the infrastructure is an indication of the commitment to regular system maintenance and replacement. The method compares the average age of the system to an arbitrarily maximum age of 70 years.

[(70 – average age) / (70 – 0)] *10 = score

Data sources
Local data sources can provide an adequate estimate.

Improvement in calculation method: In the City Blueprint the average age was set on 100 years. Infrastructure refurbishment requirements obviously depend on age but this depends highly on subsoil, material used *etcetera*. The differences in scores for this indicator appeared to be minimal because most average ages are much younger that the maximum age. Together with literature based estimates the average maximum age has now been set at 70 years.

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: City scale.

Example Amsterdam: The average age of the sewer system in Amsterdam is 28 years.
[(70 – 28) / (70 – 0)] x 10 = 6.0

Indicator 15: Operating costs recovery

Principal: Measure of revenue and cost balance of operating costs of water services. A higher ratio means that there is more money available to invest in water services.

Calculation method
Total annual operational revenues / Total annual operating costs
Only the operational cost and revenues for Domestic water supply and sanitation services are included.

Data sources
IB-net.org. The international benchmarking network for water and sanitation utilities. Available on worl d wide web <http://www.ib-net.org/> [Accessed on January 19, 2015].
City Level: Explore detailed country maps with indicators information for each utility.
Where city data is not available: The IBnet Water Supply and Sanitation Blue Book 2014 provides means for each country.

OECD (Organization for economic co-operation and development), 2010. Pricing water resources and water and sanitation services. ISBN 2224-5081. Available on world wide web <http://browse.oecdbookshop.org/oecd/pdfs/product/9710041e.pdf> p. 71 [Accessed on January 19, 2015].

When data is not available in the mentioned sources, local websites can provide the necessary information.

Data available in

Netherlands	**EU**	**Worldwide**
Yes	Yes	Yes

Scale: National and local data, but city level data are preferred.

Example Venlo: The operating cost recovery ratio for Venlo was not found but for the Netherlands this value is: 2.03. Malta has the lowest operating cost recovery ratio: 0.64
Copenhagen has the highest operating cost recovery: 2.78.

The score for Venlo using the min max normalization is:
[(2.03 – 0.64) / (2.78 – 0.64)]* 10 = 6.5

Indicator 15: Water system leakages

Principal: A measure of the percentage of water lost in the distribution system due to leaks (typically arising from poor maintenance and/or system age).

Calculation method
Leakage rates of 50% or more are taken as maximum value and thus scored zero. A best score of 10 is given when the water system leakage is zero.
[(50 - % water system leakages) / (50 – 0)] = score

Improvement in calculation method: In the City Blueprint the maximum rate of water system leakages was set to 100% which means that all the water is flowing away. The variance for these indicator scores are very low. The maximum leakage was found for Kilamba Kiaxi with 50%. Hence this is set as the new maximum leakage loss and thus scored with a zero.

Data sources
The European Green City Index report (Siemens, 2009) provides data for 31 cities.
Siemens, A. G., 2009. European Green City Index. Assessing the environmental impact of Europe's major cities. Munich, Germany. Available on world wide web <http://www.thecrystal.org/assets/download/European-Green-City-Index.pdf> [Accessed on October 30, 2014].

Data available in

Netherlands	**EU**	**Worldwide**
Yes	Yes	Yes

Scale: City scale.

Example Amsterdam: Amsterdam has a water system leakages rate of 3.5%.
[(50 – 3.5) / (50 – 0)] x 10 = 9.3

6. Climate robustness

Indicator 18: Green space

Principal: Represents the share of green and blue area which is essential to combat the heat island effect in urban areas.

Calculation method
City specific: Numbers are provided in %
Country average: Share of green and blue areas is available for all European cities. The EEA city database presents data for of 367 European cities. From these data the average of the lowest 10% is taken as minimum (16%) and the average of the highest 10% is taken as maximum (48%). The percentages for the EU cities are standardized according to the min-max method. For non-European cities percentages for green and blue area are mostly not available. A best estimate is given by comparing this city to a similar European city. It is important for these cities to provide better information on the share of green area.

Definition of green area (EEA, 2012A): These are green urban areas, sports and leisure facilities, agricultural areas, semi-natural areas and wetlands, forests, discontinuous low density urban fabric as a proxy for private gardens and water bodies.

Data sources
City specific: EEA (European environmental agency), 2015. Urban adaptation to climate change. Annex II. City data sensitivity. Available on world wide web <http://www.eea.europa.eu/data-and-maps/figures/mean-soil-sealing-in-european> [Accessed on January 19, 2015].

Country average: EEA (European environmental agency), 2015. Available on world wide web <http://www.eea.europa.eu/data-and-maps/figures/percentage-of-green-and-blue/percentage-of-green-and-blue/image_original> [Accessed on January 19, 2015].

For cities where exact numbers are not available use country average.

Data available in

Netherlands	EU	Worldwide
Yes	Yes	Yes

Scale: City scale.

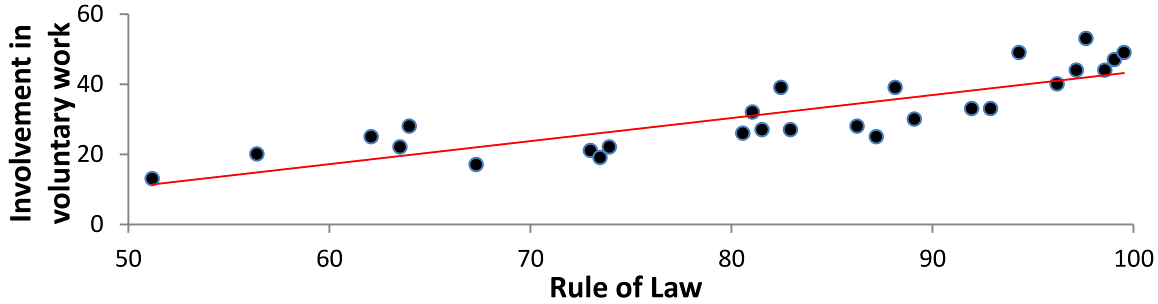
Example Venlo: For Venlo the share of green and blue area is 24,3%. The mean highest 10% of green and blue area measured by the EEA is 48%. The mean lowest 10% of green space measured by the EEA is 16%. With min-max transformation the score for Venlo becomes: [(24.4 - 16) / (48 – 16)] * 10 = 2.6. The green space score for Venlo is 2.6.

7. Governance

Indicator 23: Public participation

Principal: A measure of share of people involved or doing unpaid work.

The obtained estimates for the indicator involvement in voluntary work (*public participation)* are standardized using the min-max method. To avoid unrealistic values due to extrapolations (e.g. negative number of people being involved or doing voluntary work), the minimum for *public participation* is set on 5%. Extrapolations from the indicator *rule and law* that give pertentages for *public participation* that are below 5% are set to 5% and consequently scored zero in the City Blueprint.



Improvement in calculation method: In the City Blueprint, public participation is based on data for a comparable indicator from a 2003 report of the Eurofound Quality of Life Survey. For non-European countries this indicator is estimated given the 2003 internet connection rates. It was therefore necessary to update this indicator with more recent information based on a more recent report (EFILWC, 2012).

Data sources
EU countries: EFILWC (European Foundation for the Improvement of Living and Working Conditions), 2006. First European Quality of life survey: Participation in civil society. Dublin. ISBN 92-897-0961-8. Available on world wide web <http://eurofound.europa.eu/sites/default/files/ef_files/pubdocs/2006/76/en/1/ef0676en.pdf> p. 87.[Access on November 6, 2014].
Non-EU countries: World Bank, 2014A. Worldwide Governance Indicators. Available on world wide web <http://info.worldbank.org/governance/wgi/index.aspx#faq> [Accessed on October 21, 2014].

Netherlands	**EU**	**Worldwide**
Yes	Yes	Yes

Data available in

Scale: Country scale.

Example Reykjavik: Reykjavik is situated in Iceland for which data on involvement or execution of unpaid work is not available. Therefore the world bank indicator *rule of law* is used. For Iceland this score is 92. Using the above formula: 0.6573 * 92 – 22.278 = 38.2. The score for Reykjavik then becomes: $\frac{38.2-5}{53-5}$ x 10 = 7.06.

Literature

EFILWC (European Foundation for the Improvement of Living and Working Conditions), 2012. Quality of life in Europe: Impact of the crisis. Luxembourg. ISBN 978-92-897-1099-2. Available on world wide web <http://eurofound.europa.eu/sites/default/files/ef_files/pubdocs/2012/64/en/1/EF1264EN.pdf> [Accessed on January 15, 2015].

Annex 7.4: Statistical analysis alternative City Blueprint

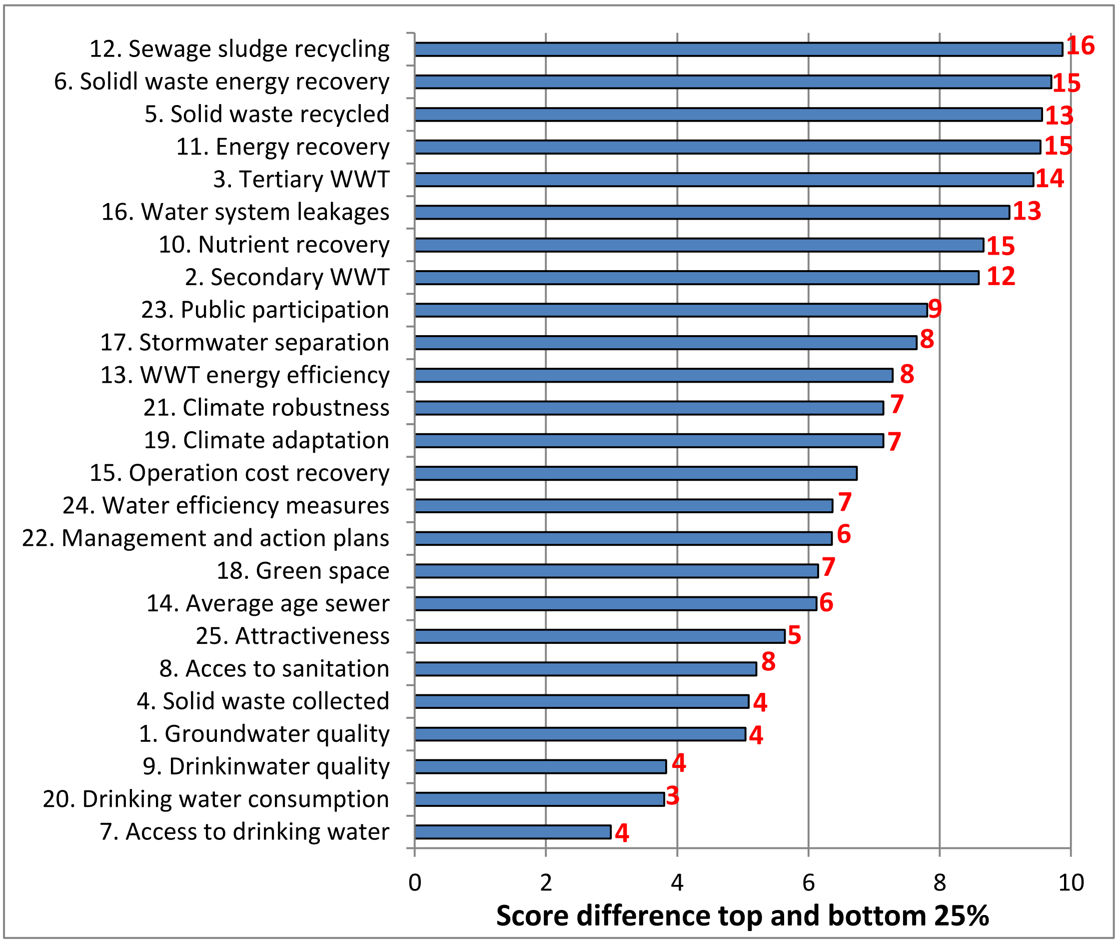


Figure 7.4.1 Space for improvement and sharing of knowledge and experience. Difference between average score of top 25% and bottom 25% per indicator of the BCI*. Red number is the indicator variance for 32 cities.

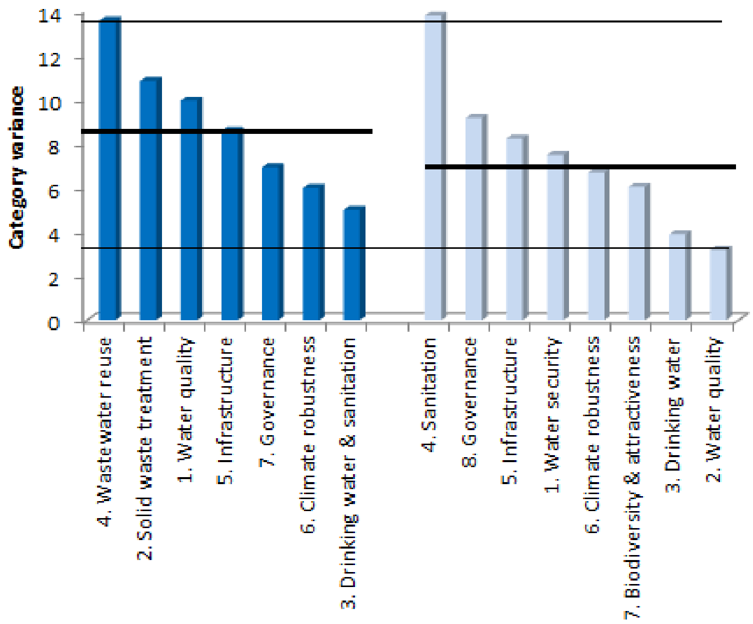


Figure 7.4.2 The category variance of the CB* categories (left) and CB categories (right). On average the BC* categories are 1.4 points higher in variance. Moreover, the differences in variance amongst the categories is lower for the CB*.

Table 7.4.1 The 25 CB* indicators (x-axis) and their Pearson correlation r with each category (y-axis). The white boxes highlight the R of the indicators with their own category. Because the indicators constitute the category, it is desirable to have a high r with their own category. In orange are the indicators that correlated higher to another category.

Categories	Indicator	I	II	III	IV	V	VI	VII
I Water quality	Groundwater quality	0,47	0,48	0,30	0,22	0,21	0,27	0,38
	Secondary WWT	0,93	0,51	0,70	0,80	0,46	0,58	0,72
	Tertiary WWT	0,91	0,63	0,52	0,68	0,64	0,64	0,73
II Solid waste treatement	Municipal waste collected	-0,42	-0,13	-0,45	-0,40	-0,48	-0,57	-0,58
	Municipal waste recycled	0,80	0,88	0,49	0,58	0,54	0,69	0,71
	Municipal waste energy recovery	0,56	0,91	0,36	0,50	0,45	0,52	0,53
III Basic water services	Access to drinking water	0,55	0,23	0,92	0,55	0,58	0,52	0,67
	Access to sanitation	0,68	0,35	0,95	0,62	0,50	0,56	0,75
	Drinking water quality	0,55	0,34	0,89	0,51	0,55	0,54	0,69
IV Wastewater treatment	Nutrient recovery	0,26	0,21	0,28	0,64	0,10	0,22	0,20
	Energy recovery	0,65	0,33	0,47	0,80	0,39	0,51	0,58
	Sewage sludge recycling	0,83	0,61	0,59	0,88	0,45	0,59	0,69
	Energy efficiency WWT	0,55	0,29	0,56	0,73	0,39	0,53	0,59
V Infrastructure	Average age sewage system	0,20	0,05	0,27	0,20	0,53	0,23	0,27
	Operation cost recovery	0,28	0,30	0,31	0,05	0,51	0,45	0,50
	Stormwater separation	0,34	0,16	0,33	0,34	0,67	0,08	0,20
	Water system leakages	0,75	0,56	0,62	0,58	0,78	0,71	0,75
VI Climate robustness	Green space	0,49	0,51	0,46	0,40	0,31	0,69	0,56
	Climate adaption	0,64	0,42	0,60	0,68	0,51	0,90	0,88
	Drinking water consumption	0,03	0,10	-0,14	-0,10	0,17	0,34	0,09
	Climate robustness	0,56	0,33	0,58	0,56	0,39	0,81	0,80
VII Governance	Management and action plans	0,64	0,26	0,65	0,58	0,53	0,79	0,89
	Voluntary participation	0,84	0,71	0,68	0,60	0,58	0,79	0,88
	Government effectiveness	0,78	0,57	0,81	0,66	0,64	0,81	0,91
	Attractiveness	0,39	0,15	0,45	0,43	0,36	0,61	0,74

Table 7.4.2 All indicator Pearson correlations of r>0.75 of the CB* set of indicators. On top are the correlations between indicators of different categories. Below are the correlations between indicators belonging to the same category. The amount of indicators correlations of indicators of the same category is larger than in the CB set of indicators (8 for CB* and 3 for CB).

Between categories		R
19. Climate adaptation	22. Management and action plans	0.84
21. Climate-robust buildings	22. Management and action plans	0.84
2. Tertiary WWT	12. Sewage sludge recycling	0.83
3. Groundwater quality	5. Solid waste recycled	0.81
5. Solid waste recycled	23. Public participation	0.81
3. Groundwater quality	12. Sewage sludge recycling	0.77
18. Green space	23. Public participation	0.75

Within categories		
5. Solid waste recycled	6. Solid waste energy recovered	0.95
7. Access to drinking water	8. Access to sanitation	0.82
2. Tertiary WWT	3. Groundwater quality	0.81
22. Management and action plans	24. Water efficiency measures	0.77
22. Management and action plans	25. Attractiveness	0.76
9. Drinking water quality	8. Access to sanitation	0.76
19. Climate adaptation	21. Climate-robust buildings	0.75
9. Drinking water quality	7. Access to drinking water	0.75

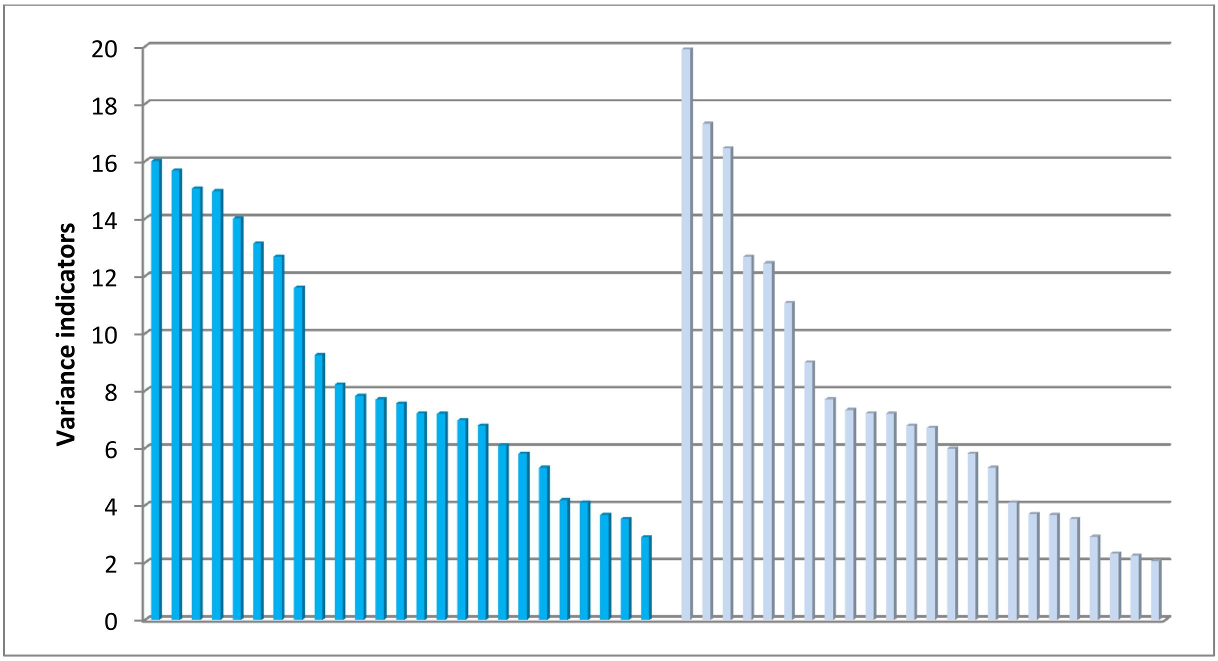


Figure 7.4.3 Variances of the CB* indicators (left) and CB indicators (right). Not that the variances of the CB* have lower differences between the lowest and highest indicator variances than the CB indicators.