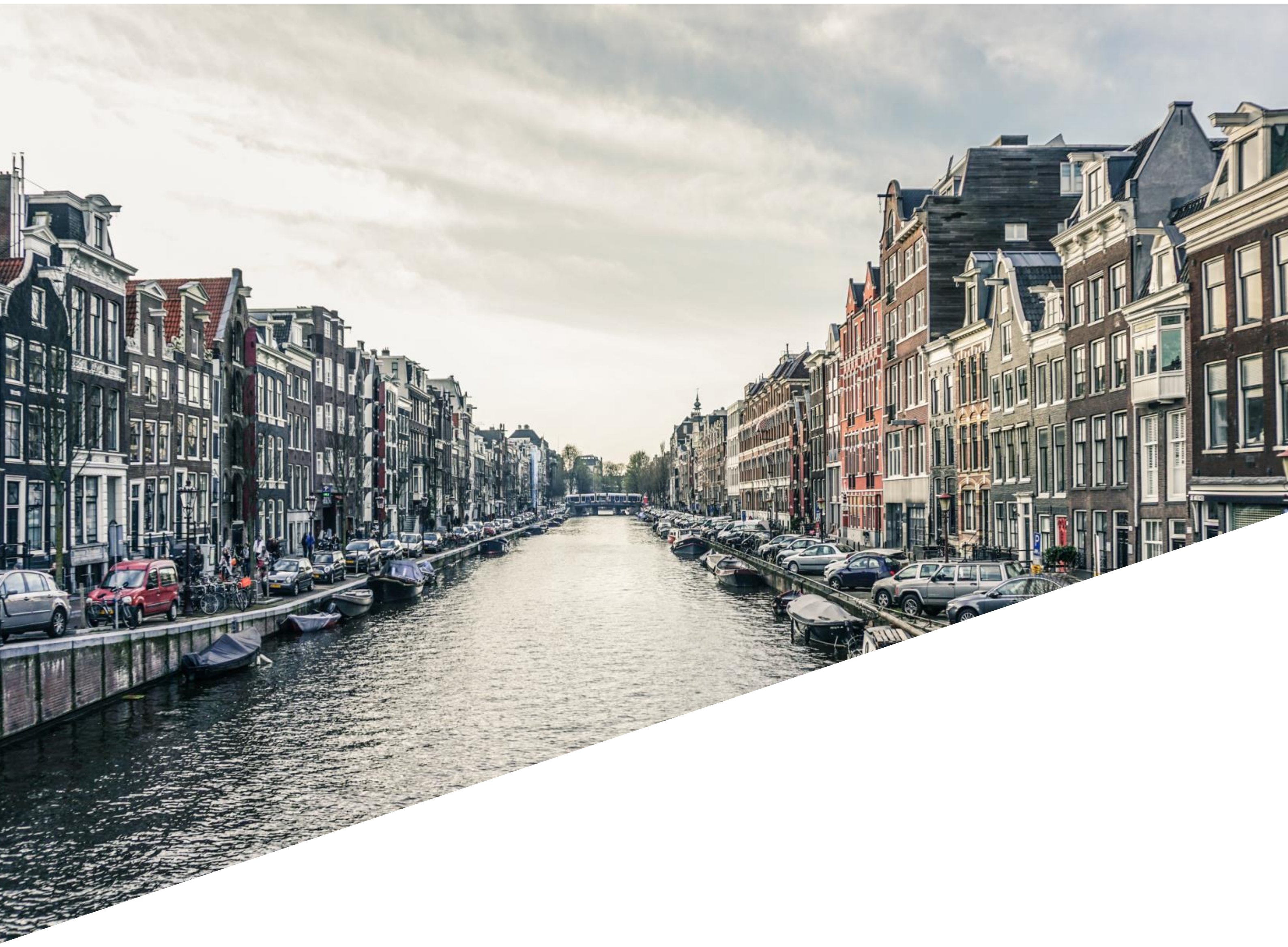

Retrospective analysis of water management and water governance in Amsterdam

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18-11-2020

Abstract

Most of the world's population lives in urban areas. Urbanization puts a lot of pressure on the city in terms of the environment, raw materials, infrastructure, and social and institutional changes. This pressure on urban areas creates challenges in the dynamics of cities, such as housing, drinking water, and wastewater. For a livable city, the water in the city has to be well managed. The water system is increasingly influenced by human and natural factors, which can cause changes in the water system. The capital of the Netherlands, Amsterdam is home to more than 800,000 people. Because of its geographic location, the city is closely linked to water. Due to developments in water safety, water quality, and robust water infrastructure, Amsterdam has developed into an attractive, economically healthy, and safe city that scores highly in the field of water management worldwide. In the future, Amsterdam has to continue its investment in the development and maintenance of the water system to meet its future challenges. For these future investments, it is important to research developments in the field of water management and governance and to gain knowledge from them. The following main research question was formulated from this:

How did water management and governance evolve in the city of Amsterdam from the year 1672 to the present and what can be learned from this to enhance a city's ability to address its water challenges?

The aim of the study is to understand: how water management and governance have historically developed in the city of Amsterdam, how this can be used to further improve water management, and how these experiences of Amsterdam and its partner cities, can help other cities to face their future developments and challenges. The research aims to narrow the information and knowledge gap by studying the past and its various transitions and developments. Therefore, the study conducts a retrospective analysis from 1672 to the present using the City Blueprint Approach (CBA), literature review, and interviews. The CBA outlines how water management and governance have developed over time and which challenges the city has faced. Another part of the research is to compare Amsterdam with its partner cities to find out what the similarities and differences are. This information is also integrated to advise "leapfrogging" trajectories to urban developers and other cities.

The analysis shows that Amsterdam has experienced several crises and challenges. Looking at when and how the water infrastructure has been constructed and policy has been implemented, it appears that this usually results from crises or international knowledge transfer because at these moments people realize that something needs to be changed or developed. To prevent a crisis it is important to have a long-term perspective, however, water managers and urban planners often focus on the short term, because the costs/benefits are easier to determine and seems to be cheaper. However, it is not always the most cost-efficient and effective trade-off in the long run.

Furthermore, an integrated approach is required in water management and governance, because it has been shown that the trends and challenges of the city are interrelated and co-benefits can be explored to find cost-effective solutions. Another driving force behind the development of water management in the city is cooperation and knowledge transfer with other cities and countries. Many water management developments in Amsterdam have been supported by knowledge transfer or financial support from other countries. Conversely, other cities learn through transfer of knowledge on how to best develop water management and governance in their cities. In general, it can be concluded that much knowledge can be obtained from the past and can be applied to meet present and future challenges.

Keywords: Integrated Water Resources Management, City Blueprint, Amsterdam, Retrospective analysis

Samenvatting

Het grootste deel van de wereldbevolking leeft in stedelijke gebieden. Urbanisatie zorgt voor een hoge druk op de stad betreffende milieu, grondstoffen, infrastructuur en sociale en institutionele veranderingen. Deze druk op stedelijke gebieden zorgt voor uitdagingen in de dynamiek van steden, zoals huisvesting, drinkwater en afvalwater. Het watersysteem wordt in toenemende mate beïnvloed door menselijke en natuurlijke factoren, die veranderingen in het watersysteem kunnen veroorzaken. De hoofdstad van Nederland, Amsterdam biedt onderdak aan meer dan 800.000 mensen. Door de geografische ligging is de stad nauw verbonden met water. Door ontwikkelingen in waterveiligheid, waterkwaliteit en robuuste waterinfrastructuur heeft Amsterdam zich ontplooid tot een aantrekkelijke, economisch gezonde en veilige stad die wereldwijd hoog scoort op het gebied van watermanagement. In de toekomst moet Amsterdam nieuwe investeringen doen om het watersysteem verder te ontwikkelen en te onderhouden om toekomstige uitdagingen het hoofd te bieden. Voor deze toekomstige investeringen, is het belangrijk om onderzoek te doen naar ontwikkelingen op het gebied van watermanagement en beheer en hieruit ervaring op te doen. Hieruit is de volgende hoofd-onderzoeksvraag opgesteld:

Hoe is de ontwikkeling van watermanagement en governance in de stad Amsterdam van 1672 tot heden tot stand gekomen en wat kan hieruit geleerd worden om het vermogen van een stad te vergroten om haar de wateruitdagingen aan te gaan?

Het doel van het onderzoek is om te begrijpen hoe watermanagement en governance zich historisch hebben ontwikkeld in de stad Amsterdam, hoe dit kan worden gebruikt om het waterbeheer in Amsterdam verder te verbeteren, en hoe de bevindingen gedaan in Amsterdam en haar partnersteden, andere steden in de wereld kunnen helpen om hun toekomstige ontwikkelingen en uitdagingen het hoofd te bieden. Het onderzoek beoogt de informatiekloof te verkleinen door het verleden en de verschillende overgangen en ontwikkelingen te bestuderen. Daarom wordt in het onderzoek een retrospectieve analyse uitgevoerd vanaf 1672 tot heden met behulp van de City Blueprint Approach (CBA), literatuuronderzoek en interviews. De CBA geeft weer hoe watermanagement en governance zich in de loop van de tijd hebben ontwikkeld en welke uitdagingen de stad heeft doorgemaakt. Een ander onderdeel van het onderzoek is om Amsterdam te vergelijken met haar partnersteden om te onderzoeken wat de overeenkomsten en de verschillen zijn. Deze verkregen informatie wordt geïntegreerd om 'leapfrogging' trajecten te adviseren aan stadsontwikkelaars en andere steden.

Uit de analyse komt naar voren dat Amsterdam meerdere crises en uitdagingen heeft meegemaakt. Kijkend naar, wanneer en hoe de waterinfrastructuur is aangelegd en beleid is geïmplementeerd, blijkt dat dit meestal het gevolg is van een crisis of internationale kennisoverdracht, omdat men op deze momenten inziet dat er iets veranderd of ontwikkeld moet worden. Om een crisis te voorkomen is het belangrijk om te kijken naar de lange termijn, echter waterbeheerders en stedenbouwkundigen focussen zich vaak op de korte termijn, omdat de kosten/baten beter te bepalen zijn en oplossingen goedkoper lijken te zijn. Echter, op lange termijn zijn dit niet altijd de meest kostenefficiëntie en effectieve afwegingen.

Daarnaast is een integrale aanpak nodig in watermanagement en beheer, omdat gebleken is dat de trends en uitdagingen van de stad met elkaar samenhangen en door oplossingen voor diverse problemen te koppelen ("koppelen is kassa") kosteneffectieve oplossingen mogelijk zijn. Een andere drijvende kracht achter de ontwikkeling van het waterbeheer in de stad is samenwerking en kennisoverdracht vanuit andere steden en landen. Veel ontwikkelingen betreffende waterbeheer die Amsterdam heeft doorgemaakt, zijn ondersteund door kennisoverdracht of financiële steun van andere landen. Omgekeerd leren andere steden door kennisoverdracht hoe zij het waterbeheer in hun stad het beste kunnen ontwikkelen. De algemene conclusie is dat uit het verleden veel kennis gehaald kan worden

die toegepast kan worden op toekomstige uitdagingen op het gebied van water management en governance in de stad.

Acknowledgment

I would like to thank my supervisors Kees van Leeuwen & Maarten Ouboter for their guidance and discussions during the research. I highly appreciate that they have shared their expertise and knowledge with me which made me even more enthusiastic in exploring the history of water management and governance in Amsterdam. Thanks also to the Waternet team who gave me valuable insights about the work. Although it was not in a normal situation, I was grateful to have the opportunity to gain some experience. Additionally, I would like to thank the interviewees and surveyors for their valuable input in the research. Finally, I am also grateful to my friends and family who have always supported and encouraged me.

Sannah Peters
November, 2020
Amstelveen, the Netherlands

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Acronyms/Glossary

TPF	Trends and Pressures Framework
CBF	City Blueprint Framework
GCF	Governance Capacity Framework
GWP	Global Water Partnership
OECD	Organization for Economic Co-operation and Development
IWRM	Integrated Water Resources Management
UN	United Nations
WWTP	Waste Water Treatment Plant
UNESCO	United Nations Educational Scientific and Cultural Organization
VOC	United East India Company

1. Introduction

1.1 Background

All around the world, demographic, technological, economic, and climate change trends have modified the environment that we live in and that sustains us (Cosgrove & Loucks, 2015). The majority of the global population lives in urban areas. According to the United Nations (UN), 55% of people live in cities and this will be 68% by 2050 (United Nations, 2018). The rapid growth in urban areas poses enormous pressure on the environment, necessitates social and institutional change, pollution control, and new visions on infrastructure development (Biswas & Uitto, 1999). These pressures bring about challenges in the dynamics of cities such as solid waste, housing, drinking water, and wastewater (Koop & van Leeuwen, 2017). Water systems are increasingly influenced by natural and human factors which may lead to changes in water availability and quality (Khatri & Tyagi, 2015; Koop & van Leeuwen, 2017). Moreover, water security in urban regions depends, more than ever, on improving the integrated management of water services and on taking a holistic management approach together with other resources, risks, and services (UNESCO, n.d.). As the population and the economy are gradually closed to or above the capacity of water resources, increasing attention is being paid to the relationships between urbanization and sustainable use of water resources (Fitzhugh & Richter, 2004).

While access to water services is usually adequate in cities in OECD member states, water networks are aging and require upgrading, in some cases urgently and extensively. This is often caused by inappropriate governance leading to e.g. funding gaps (Figure 1) with negative consequences for maintenance, health, and the environment (OECD, 2014). Infrastructure that is built and conceived years ago may be not adapted well enough to the current and future circumstances. For example, urban drainage is often not adapted to heavy rains which can lead to wastewater being released into the environment as a result of sewer overflows (OECD, 2014). Adapting existing infrastructure to meet current and future conditions is a challenge due to the high costs, new technologies, and complex systems (OECD, 2014). Therefore, it is important to thoroughly understand a city's water system, water management performance, and water governance capacities in order to select the best practices to address these challenges and opportunities in water management and governance.

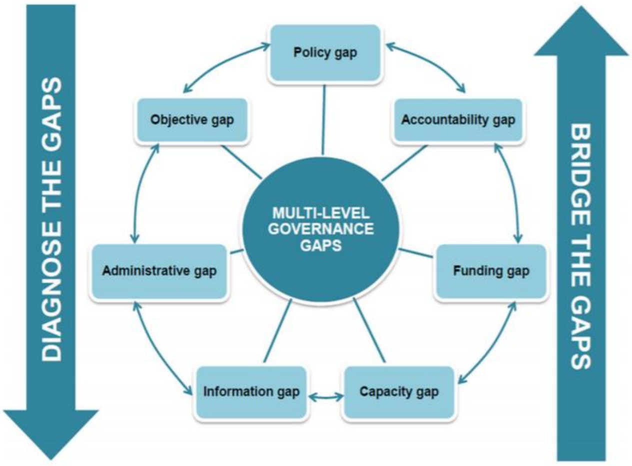


Figure 1: OECD multi-level governance framework (OECD, 2015)

Amsterdam, the capital city of the Netherlands, has lived closely with water for more than 700 years. The city is home to over 800,000 people (van Leeuwen & Sjerps, 2015). The city was founded in a strategic location on the edge of the river Amstel and close to the North Sea (IWA, 2016). The city is closely linked to water, even the name of the city refers to the adjacent Amstel, which terminates in the historic canals of Amsterdam (van Leeuwen & Sjerps, 2015). Investments in flood risk management, water quality, and robust water infrastructure have enabled Amsterdam to develop into an attractive, economically healthy, and safe city (IWA, 2016). Amsterdam has a leading international position in the field of integrated water resources management (IWRM), as it was number one for water in the European Green City Index (van Leeuwen & Sjerps, 2015; Gawlik et al., 2017).

The Netherlands and Amsterdam are used to coping with water challenges through past experiences and their connection to water. Due to the pressure of water (storm surges, intensive precipitation, drought), a water system has been created that offers a certain degree of protection and comfort. To keep the water system robust, efforts need to continue in the dynamic context of social, socio-economic, administrative, landscape, and climate developments. Better protection of critical flood infrastructure is key to the city's resilience strategy (IWA, 2016). Heavy rains have been more frequent in recent years, increasing the urgency in addressing this issue. The project Rainproof tackles this problem by bringing together the initiatives of private individuals and governments. Amsterdam has the ambition to be circular so another key challenge is the contribution to the circular economy from the water cycle. There are many opportunities for recovery and recycling of energy and resources from wastewater, surface water, or drinking water (IWA, 2016). These future challenges rely heavily on cooperation and stakeholder involvement, which is why water management and governance are extremely important.

In previous research of van Leeuwen & Sjerps (2015) the City Blueprint approach was used to examine the sustainability of IWRM of Amsterdam. Since then, the method has been reviewed and updated (Koop et al., 2017; Koop & van Leeuwen, 2015). More recently a second revision has taken place to include, amongst others, the World Bank Governance indicators in the Trends and Pressures Framework. The City Blueprint applied during the assessment of Amsterdam, is a set of 24 indicators consisting of eight categories; water security, water quality, drinking water, sanitation, infrastructure, climate robustness, biodiversity and attractiveness, and governance including public participation (van Leeuwen & Sjerps, 2015). Amsterdam is the best-performing city among the evaluated cities which can be explained by; (1) long-term vision and multi-level water governance approach, (2) integration of water, energy, and material flow, (3) the entanglement between urban quality and water management, and (4) the open communication to and feed-back from customers (van Leeuwen & Sjerps, 2015). However, Amsterdam does not score as best on all indicators, for example, surface water quality and biodiversity remain big challenges (van Leeuwen & Sjerps, 2015). Figures 2, 3, and 4 are the results of the current City Blueprint Approach (CBA) with its Trends and Pressures Framework (TPF), the City Blueprint Framework (CBF), and the Governance Capacity Framework (GCF), using the updated formats that will be explained further in Section 3.1.

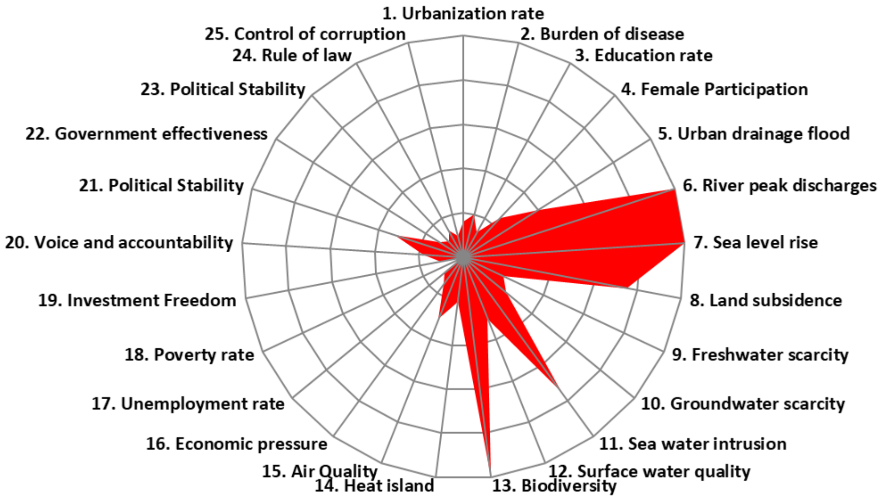


Figure 2: TPF Amsterdam

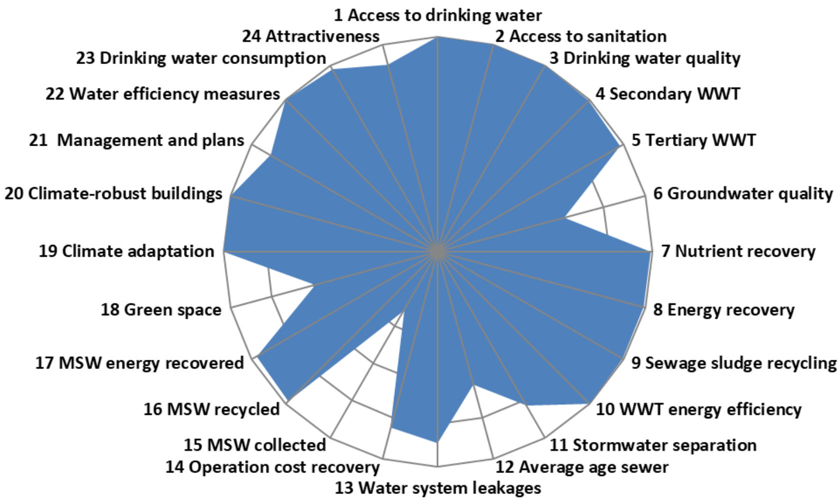


Figure 3: CBF Amsterdam

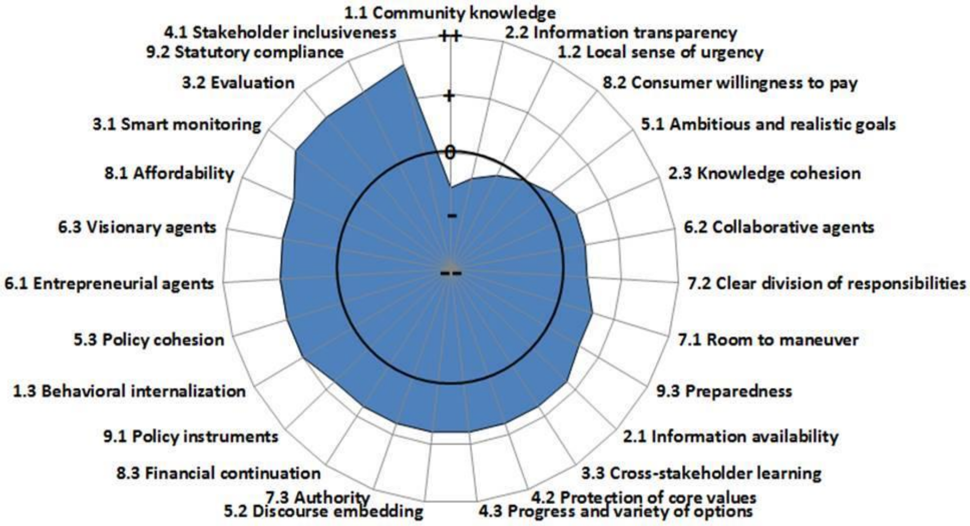


Figure 4: GCF Amsterdam

1.2 Problem Description & Knowledge Gap

Both water management in the municipality of Amsterdam and some tasks of the Regional Public Water Authority Amstel, Gooi, and Vecht are assigned to Waternet, a public integral water cycle organization (IWA, 2016). Waternet is the only water company in the Netherlands that covers the whole water cycle (Waternet, n.d.-b). Among other things Waternet is responsible for the supply of water (both for human consumption and for nature areas), the maintenance of the sewage system, appropriate groundwater levels, surface water, and water wastewater (Watershare, n.d.). Figure 5 shows the area Waternet is responsible for and the tasks per area and figure six displays the organizational structure of the Municipality, AGV, and Waternet. The city's unique water cycle approach has proved highly beneficial (van Leeuwen & Sjerps, 2015). In addition to quality and efficiency, Waternet is committed to sustainability, which they see as a driving force behind much of their research and innovation (Waternet, 2018).

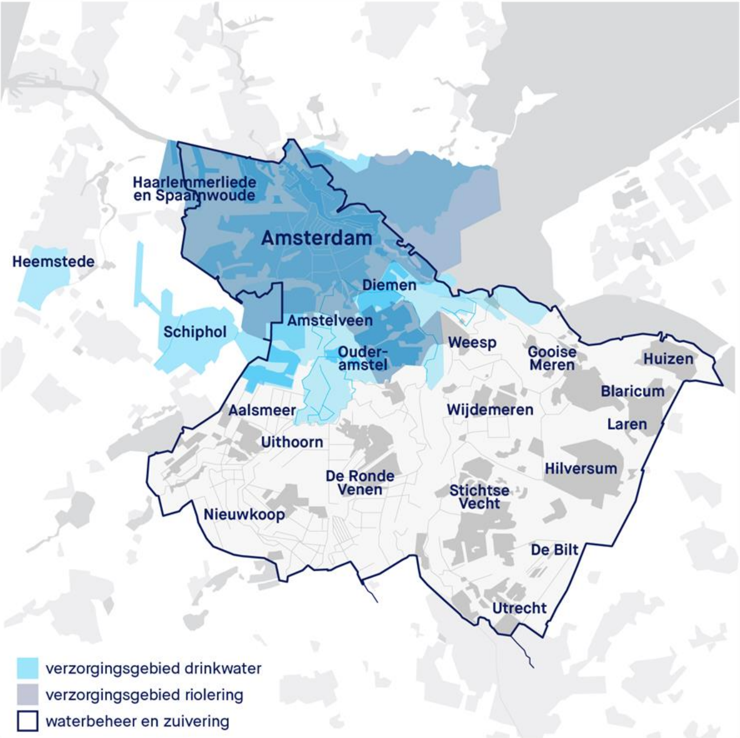
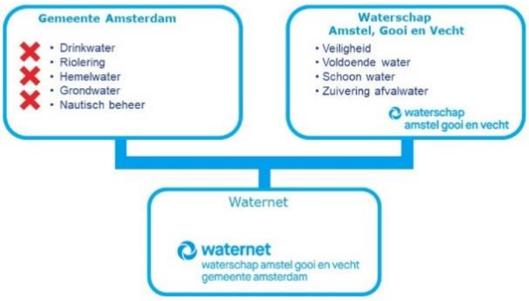


Figure 5: Service area (Waternet, n.d.-b)



Figuur 6: Organization structure

While the city ranks high in water management and governance, there are still things to improve in some areas. Looking to the future, new investments are needed to meet future challenges. "Water is indispensable. For us, as inhabitants, and for our companies. Water can also be a threat from which we must protect ourselves. At the same time, it is becoming increasingly clear that water can play a crucial role in tackling issues such as climate change and subsidence as well as making agriculture more sustainable." (Waternet, 2019).

The challenges ahead require continuous innovation. To make water management and governance future-proof, it is beneficial to look at linking options, a strategic approach to infrastructure renewal, the costs and benefits of it, to learn from the past and, last but not least, from other cities. Several major investments are expected to be made to meet future challenges and to improve aging infrastructures.

Waternet would like to know which steps were crucial in dealing with water in the city in terms of water management and governance. The project aims to conduct a series of retrospective analyses (looking back a couple of centuries) using the CBA combined with literature to investigate which crises Amsterdam was confronted with, how they addressed them, how they were financed and whether they were accompanied by governmental arrangements. Furthermore, Waternet want to compare the results with their partner cities (Berlin, Copenhagen, New York, Singapore, and Paris) to see if they followed the same trajectories and what the differences are.

Scientific knowledge is often fragmented and does not provide actionable insights that can help decision-makers achieve their goals and objectives (Koop et al., 2017). The gap in water governance between science, implementation, and policy has been widely acknowledged (OECD, 2011; Patterson, Smith, & Bellamy, 2013). The City Blueprint Approach provides three important frameworks that contribute to improve the connection between scientific knowledge, policy, and implementation (Koop et al., 2017). Moreover, the results of the historical analysis on the development of water management in Amsterdam and the comparison of partner cities will help to gain knowledge about best practices and transitions. Challenges and transitions from the past are learning experiences and offer the opportunity to gain more knowledge about certain actions.

The knowledge obtained can also be used to investigate possible 'leapfrogging' transitions for other cities. The ability of cities in developing countries to rapidly transition to sustainable practices on water management and governance will be critical to establish environmental sustainability and human health (Poustie, Frantzeskaki, & Brown, 2016). Leapfrogging based on international partnerships and experiences presents a possible means of achieving sustainability transitions in developing countries (Poustie et al., 2016). Little research has been done on the leapfrogging process and transitions and therefore this research will contribute to an initial understanding.

1.3 Research objective and framework

Urbanization is a major global trend and many cities are still to be built. Water is crucial for this development and implemented in the UN Sustainable Development Goal (SDG) 6: Ensure availability and sustainable management of water and sanitation for all (United Nations, n.d.). The aim of the research is to understand: how water management and governance developed historically in the city of Amsterdam, how this can be used to further improve water management in Amsterdam, and how these lessons from Amsterdam and its partner cities can help other cities in the world to meet their future developments and challenges. The study aims to narrow the knowledge gap by studying the past and its various transitions and developments. From the research aims, the following research question was derived:

Research question:

How did water management and governance evolve in the city of Amsterdam from the year 1672 to the present and what can be learned from this to enhance a city's ability to address its water challenges?

To answer the research question the following sub-questions are determined:

Sub-questions:

- SQ1: What major challenges in the field of water management and governance has Amsterdam encountered over the past centuries?
- SQ2: How did the water management and governance practices in the city Amsterdam develop based on these major challenges?
- SQ3: What can be learned from experiences in the partner cities of Amsterdam?
- SQ4: How can water management of Amsterdam be improved to meet current and future challenges?
- SQ5: Based on past experiences (SQ2 & SQ3) which leapfrogging trajectories can be suggested?
- SQ6: What can city developers learn from these experiences?

The research is organized into six chapters. The second chapter contains a literature review on the key concepts resulting in a preliminary conceptual framework. In chapter 3, the methodology of the research will be presented. Figure 7 presents an overview of the research framework. Chapter 4 presents the results of the study. Chapter 5 discusses the research and the results. Finally, chapter 6 provides the conclusion. The approach used in this research will integrate literature review, City Blueprint, comparative analysis, and interviews/questionnaires to answer the main research question.

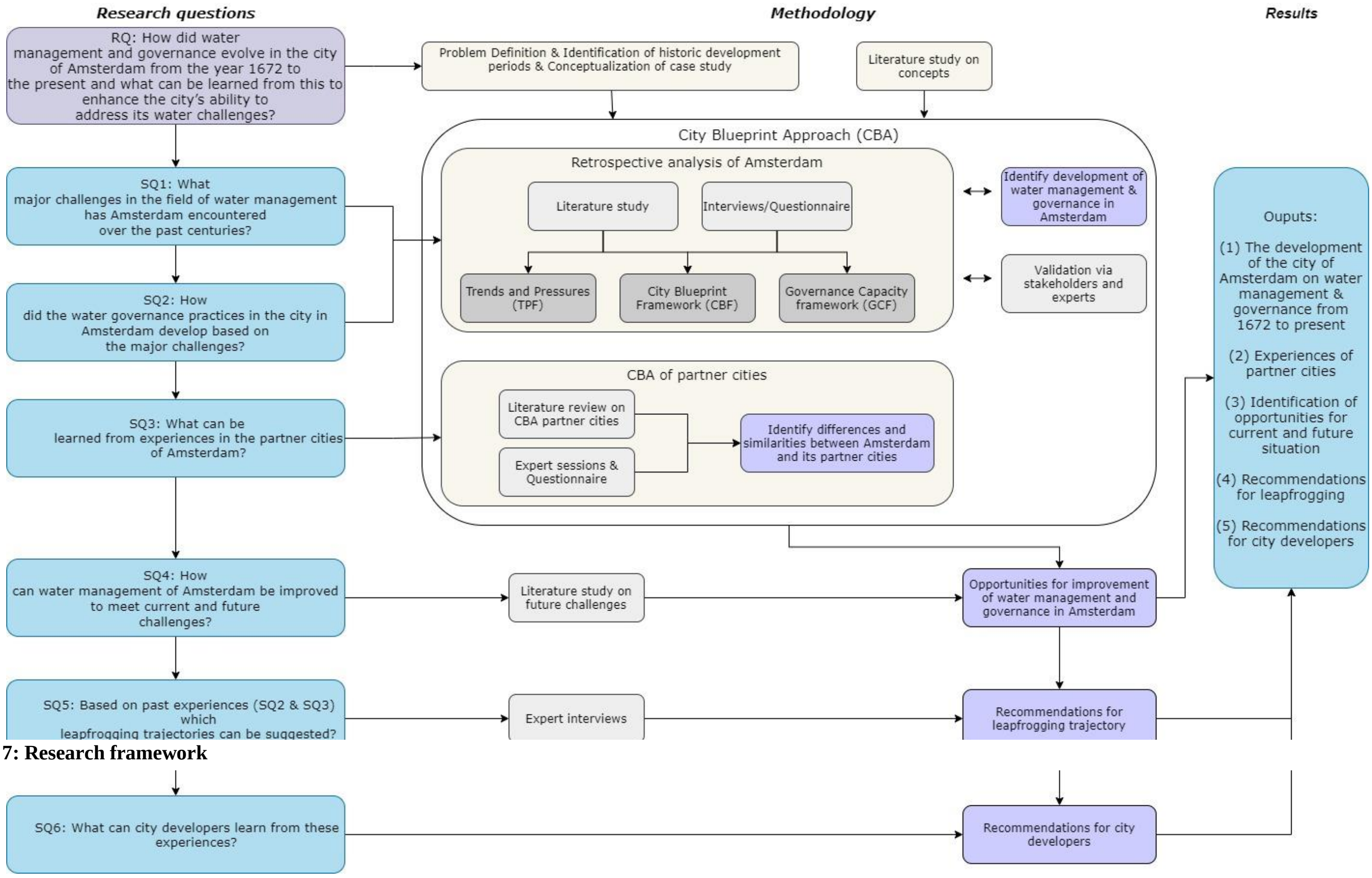


Figure 7: Research framework

2. Theoretical Framework

2.1 Integrated Water Resources Management (IWRM)

Nowadays there is no doubt about the value of integrated planning for sustainable development, although it takes time and effort to achieve it. IWRM provides a holistic framework for addressing different challenges on water resources across all stakeholders and scales (UN Environment, 2018). IWRM is defined by the Global Water Partnership (GWP) as: 'a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." (IWA, n.d.). The main goal of the framework is to ensure that water resources are developed, managed and used in an equitable, efficient and sustainable manner (UN Environment, 2018). IWRM is based on the understanding that water resources are an integral component of the ecosystem, a natural resource, and a social and economic good (GWP, n.d.). The framework generally consists of (GWP, n.d.; UN Environment, 2018):

- An enabling environment of policies laws and plans
- Institutional arrangements for cross-sectoral and multilevel coordination, and stakeholder involvement
- Management instruments such as data collection and assessments and instruments for water allocation that facilitate better decisions
- Financing for water infrastructure and ongoing costs of water resources management.

Implementation of the concept of IWRM has been shown to be challenging for some countries. IWRM is now much larger than in the past due to the adaptation of the Sustainable Development Goals. Furthermore, it is recognized for IWRM to mobile synergies among the goals (Essex et al., 2020; UN Environment, 2018) To achieve SDG 6, more focused on the mechanism for implementing and operationalizing IWRM is necessary (UN Environment, 2018). IWRM involves applying knowledge of different disciplines as well as insights of multiple stakeholders to devise and implement efficient, sustainable, and equitable solutions to water challenges (IWA, n.d.). An IWRM approach is an open, flexible process, bringing together decision-makers across the sectors that impact water resources, and bringing all stakeholders to the table to set policy and make sound, balanced decisions in response to specific water challenges faced (IWA, n.d.).

2.2 Water governance

Coping with current and future urban water management challenges requires robust public policies with measurable objectives at the right scale, based on clearly assigned tasks shared among the responsible authorities and assigned to regular monitoring and evaluation (OECD, 2015). Water governance contributes to the implementation and design of those policies. Water crises are often governance crises because the challenges go beyond infrastructure, hydrology, and financing; it's about who does what, on what scale, how, and why (OECD, 2011). The OECD (2015) defines water governance as: 'the set of rules, practices, and processes (formal and informal) through which decisions for the management of water resources and services are taken and implemented, stakeholders articulate their interest and decision-makers are held accountable'.

Tackling urban water challenges requires good governance, as it is about managing long-term uncertain, complex, and unknown risks that can have major consequences (Koop et al., 2017). Inadequate governance practices can lead to a reduction in development opportunities, reduced growth, political instability, risk ecosystems, societal disruption, and economic costs (IPCC-WGII, 2007; van Rijswick et al., 2014). There are multiple governance layers and stakeholders, sectors, and policies involved in the water governance process, each with different perspectives and agendas (Koop et al., 2017; OECD, 2011). Due to the complex system and uncertainties, a water governance approach is needed in which different values, applications, and interests of water are linked so that water policies are developed and implemented with the support of all stakeholders (van Rijswick et al., 2014). According to Koop et al. (2017), a process is needed that requires governance capacity to find integrated long-term solutions supported by flexible intermittent targets to foresee changing situations and adapt to emerging barriers.

A study of the OECD on water governance in seventeen OECD countries (OECD, 2011) revealed that challenges can be found at several levels, which are listed in Figure 1. According to the OECD, the biggest challenges are institutional fragmentation, poor implementation of multi-layered governance, ambiguous legislation, limited capacity at a local level, unclear allocation of responsibilities and resources, and fragmented financial management (Koop & van Leeuwen, 2017). However, it is important to overcome these challenges because building adequate governance capacities is a premise for sustainable futures of cities (OECD, 2015). Unfortunately, there is often no long-term plan and insufficient resources which restrains cities to measure their performance on governance capacity. Koop et al. (2017) have developed a governance capacity framework that enables cities to assess their water management capacity, enabling cross-city comparisons, and facilitating decision-making. The definition of water governance capacity is: 'the key set of governance conditions that should be developed to enable change that will be effective in finding dynamic solutions for governance challenges of water, waste, and climate change in cities' (Koop et al., 2017).

2.3 Historical water management developments in Amsterdam

In consultation with Waternet, eight important moments in the development of water and water management in Amsterdam were selected for this study. Figure 8 gives an overview of the timesteps and the most important developments during these timesteps. This research examines and assesses the development of water management and governance during these periods.

1672 – 1682	1780 – 1810	1845 – 1866	1872 – 1902	1930-1955	1970 – 1998 – 2006	2018 – present
• Development of structures for flood protection • Drinking water not accessible to everyone • Poor water quality • No sewage system • Flushing of the canals using the river IJ	• Poor drinking water supply • Start building of drinking water reservoirs	• Beginning of the industrial period • Drinking water supply from the dunes • Recycling of the waste	• High population growth and poverty • Second drinking water source • Start building sewage system • No flushing of the canals by using the IJ • Municipality responsible for water management	• Start dune filtration • Expansion of drinkwater system • Start building waste incenerator Amsterdam-noord.	• Surface water pollution act • National Administrative Arrangement on Water • Completion of sewage system	• Increasing use of area • Climate Change

Figure 8: Important periods and developments of Amsterdam

2.4 Leapfrogging

Traditional theories of development hold that the path to prosperity for emerging economies is to follow in the tracks of developed countries (Yayboke, Carter, & Crumpler, 2020). The theory is that if countries want to achieve the same goal as countries that score higher, they must follow the same set of steps that the high-scoring countries have taken. However, a new concept has been developed which is called 'leapfrogging'. Leapfrogging is when a country/city bypasses traditional stages of development to either jump directly to the latest technologies or explore an alternative path of technological development with new benefits and new opportunities (Yayboke et al., 2020). Figure 9 shows an example of a leapfrogging trajectory in greenhouse gas emissions.

Cities in developed countries have usually gone through several stages of development to reach the current level. The phases that normally have to be experienced are not always positive. Rather than having to endure these less than desirable stages, cities in developing countries can leapfrog stages to avoid making the same mistakes developed countries made in their past (Brodnik et al., 2018). So if cities look at the experiences other cities have gone through and follow a leapfrog strategy, they can bypass the stages they want to avoid and raise the level they want to reach faster. According to the research of Brodnik et al. (2018) cities in developing countries are particularly well-positioned to take these leaps forward because fewer resources have been invested in traditional urban water management, infrastructure, and institutions which make them more receptive to water sensitive practices.

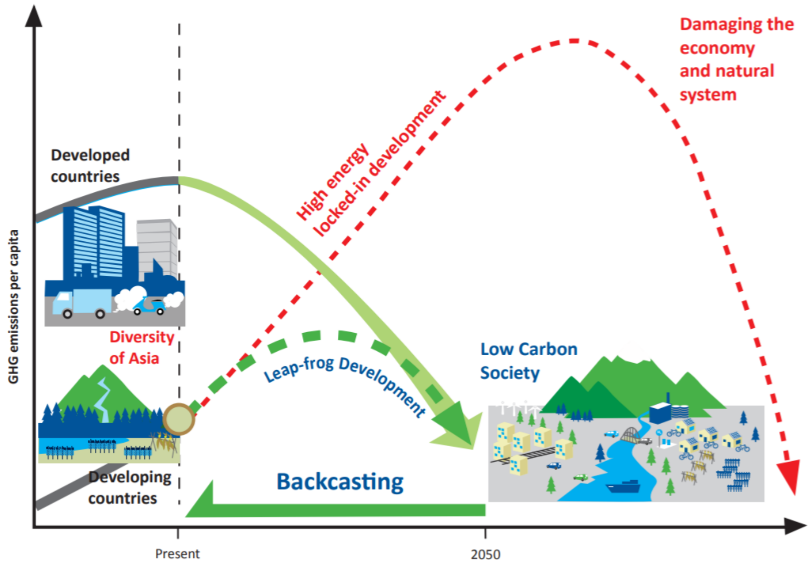


Figure 9: Leapfrogging GHG emissions (UNEP, 2016)

3. Methodology

This chapter will outline the research strategy and describe each activity that will be executed during the research. In section 3.1 the retrospective analysis is elaborated upon using the City Blueprint approach, section 3.2 describes the data collection process and section 3.3 outlines the comparison of the different cities. Figure 10 gives an overview of the research strategy per sub-question.

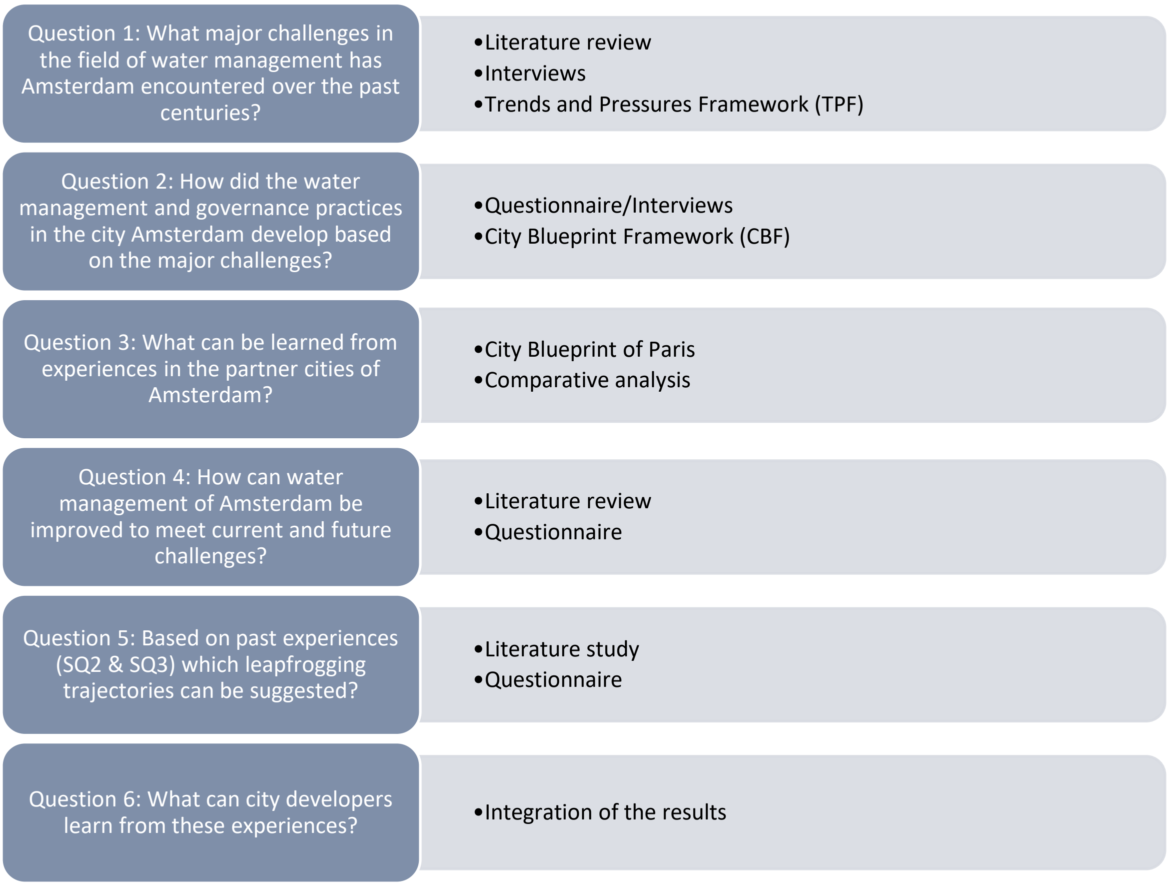


Figure 10: Overview of research strategy

3.1 Retrospective analysis

To answer the research question, the City Blueprint Approach (CBA) will be applied to the seven important historical periods which are defined in chapter 2.3. The CBA has originally been developed by van Leeuwen et al. (2012) and currently consists of three complementary frameworks (Figure 11); the main challenges of cities are assessed with the Trends and Pressures Framework (TPF). How cities are managing their water cycle is done with the City Blueprint Framework (CBF). Where cities can improve their water governance is done with the Governance Capacity Framework (GCF). In this research, we will use the TPF and CBF to perform a retrospective analysis. Over the years, the CBA has been reviewed and updated by Koop et al. (2015). The CBA helps to gather a better understanding of how water management and governance are developed during the time and what threats, weaknesses, strengths, and potentials have occurred. The present situation of water management and governance in Amsterdam (2018 – present) has been examined in previous research, which is why in this research the other five periods will be carried out.

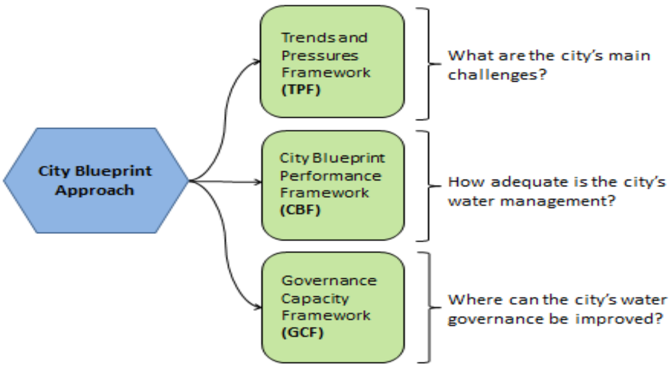


Figure 11: City Blueprint Approach (Koop & van Leeuwen, 2020a)

3.1.1. Trends and Pressure Framework (TPF)

The Trends and Pressures Framework indicators consist of a total of 24 indicators and are divided over the following categories: social, environmental, financial pressures, and governance. The 24 indicators are displayed in Table 1. The indicators show a comprehensive overview of the trends and pressures on water management and governance of a city. They are scored based on a scale from zero to ten (Table 2) which is divided into ordinal classes as a degree of concern. Therefore, a low score represents a lesser challenge for IWRM. A minor revision in the TPF took place in 2019 due to the inclusion of World Bank Governance indicators and air pollution in the TPF. In this research, we will look back in time and score each indicator in the selected periods to see how trends and pressures have evolved over time. Unfortunately, quantitative data is not available for many of the indicators or has been calculated differently. Therefore, the scores had to be calculated with the use of literature review and expert interviews which will be further explained in paragraph 3.3. Furthermore, in this study we have added an indicator from an earlier version of the framework, namely the quality of the surface water. Surface water quality has been added because the literature review showed that this indicator is important for the historical development of the water system in Amsterdam.

Table 1: Trends and Pressures Framework (TPF), according to Koop & van Leeuwen (2020)

Category	**Indicators**		**Indicator number**	**Score**
I SOCIAL	Urbanization rate		1	
	Burden of disease		2	
	Education rate		3	
	Female participation		4	
II ENVIRONMENTAL	Flood risk	Urban drainage flood	5	
		Sea level rise	6	
		River peak discharges	7	
		Land subsidence	8	
	Water scarcity	Freshwater scarcity	9	
		Groundwater scarcity	10	
		Sea water intrusion	11	
	Water quality	Biodiversity	12	
	Heat risk	Heat island	13	
	Air Quality	PM2.5/10	14	

III FINANCIAL	Economic pressure	15	
	Unemployment rate	16	
	Poverty rate	17	
	Investment freedom	18	
IV GOVERNANCE	Voice and accountability	19	
	Political Stability	20	
	Government effectiveness	21	
	Regulatory quality	22	
	Rule of law	23	
	Control of corruption	24	

Table 2: Degree of concern classes of the TPF scores according to Koop & van Leeuwen (2020)

TPF indicator score	Degree of concern
0 – 2	**no concern**
2 – 4	**little concern**
4 – 6	**medium concern**
6 – 8	**concern**
8 – 10	**great concern**

3.1.2. City Blueprint Framework (CBF)

The CBF framework (Table 3) consists of 24 indicators divided over 7 main categories (I Basic water services, II water quality, III wastewater treatment, IV Water infrastructure, V Solid waste, VI Climate robustness, and VII Plans, and actions (Koop & van Leeuwen, 2020a). It provides an overview of a city or region's strong and weak points which can be used for long-term strategic planning (Watershare, n.d.-b). The overview of the indicators of the CBF is presented in Table 3. The indicators are scored on a scale from zero to ten. The lower the score, the worse the indicator's performance. This study uses the revised version of August 2020 and therefore also updated the current CBF of Amsterdam. The CBF will also be carried out over the various periods (section 2.3) to illustrate the developments of water management and governance in Amsterdam. Data is not available for all indicators, but there is a lot of historical literature available from which the scores can be approximated. Moreover, the scores could be estimated by utilizing expert interviews which will be further explained in section 3.3.

Table 3: Indicators of City Blueprint Framework (Koop & van Leeuwen, 2020)

Category	Indicator	Score
I Basic water services	1 Access to drinking water	
	2 Access to sanitation	
	3 Drinking water quality	
II Water Quality	4 Secondary WWT	
	5 Tertiary WWT	
	6 Groundwater quality	

III Wastewater treatment	7 Nutrient recovery	
	8 Energy recovery	
	9 Sewage sludge recycling	
	10 WWT energy efficiency	
IV Water infrastructure	11 Stormwater separation	
	12 Average age sewer	
	13 Water system leakages	
	14 Operation cost recovery	
V Solid waste	15 MSW collected	
	16 MSW recycled	
	17 MSW energy recovered	
VI Climate adaptation	18 Green space	
	19 Climate adaptation	
	20 Climate-robust buildings	
VII Plans and actions	21 Management & action plans	
	22 Water efficiency measures	
	23 Drinking water consumption	
	24 Attractiveness	

3.2. Data collection

3.2.1. Literature study

To answer the research questions and collect data for the City Blueprint Analysis, a literature study was performed. The literature study provides substantiation and data for the TPF as well as CBF. In the literature study, quantitative as well as qualitative data will be collected. After which a first version of the TPF and CBF was made. As indicated in section 3.1. quantitative data is not available for all indicators, but there is much qualitative data available about the history of water in Amsterdam. The data extracted from the literature search is used to validate the experts' scores and to fill in missing scores. In addition, the literature search is used for background information and additional explanation. Furthermore, the literature study helps to identify the historical developments, opportunities for improvement, and possible ‘leapfrogging’ transitions.

To find literature and policy documents, websites such as Google Scholar and Web of Science were used. The following Boolean keywords have been used: Water Management AND Water governance AND Amsterdam. In addition to searching for literature in search engines, the inventory of the Amsterdam city archives was used to find documents from the various water management and governance organizations. Furthermore, literature from books from the inventory of Waternet has been used as well.

3.2.2. Expert interviews

In addition to reviewing existing literature and reports, interviews with professionals on the various issues were conducted to gain a deeper understanding of how water management and governance are developed in Amsterdam. The scores of the experts from the interviews are leading for the final scores, because the method does not fully match the past centuries and perceptions have changed over time. The methodology is based on the present and not aimed at assessing indicators from the past.

Various experts from Waternet, but also from outside the organization, were interviewed to give scores to the indicators and their perspectives and insights on the various themes. The interviews are semi-structured to ensure that all elements are exposed. Each indicator with the corresponding method and current score was explained to the interviewee. After that, the interviewees reported per period how the score for each indicator changed over time. The interviewees were also asked to explain why they assigned a certain score to an indicator. For the final scores, the average of all scores of the interviewee was taken.

3.3 Comparative analysis

Waternet has five partner cities with which they collaborate and exchange knowledge. This study compares the present situation of water management and governance in the partner cities of Berlin, Copenhagen, New York, Paris, and Singapore using the CBA assessments already made from previous studies. The City Blueprint Approach allows cities to be compared in terms of water management and governance. The comparison helps to map the differences between the cities and in which areas they can learn from each other. Cities can learn from each other's experiences and help each other to achieve resilient cities.

The City Blueprint of the cities of Berlin, Copenhagen, New York, and Singapore have already been analyzed in previous research. However, a City Blueprint of the city of Paris was missing, which is why it was included in this study to allow for a comparison with the other partner cities. Literature research is used to make a first draft of the frameworks of Paris. After which the frameworks were revised through interviews by email with professionals from the water sector in Paris.

3.4 Questionnaire

A questionnaire has been drawn up to answer sub-questions four, five and six. These sub-questions are mainly intended to give advice to Amsterdam, but also to other cities. In addition, information from the surveys is collected to recommend leapfrogging pathways (see section 2.4) and to give advices to city developers. The questionnaire is presented in appendix IV. The survey consists mainly of open-ended questions. The survey was distributed to 23 persons within Waternet. The selected persons have been chosen with the requirements that they probably have sufficient knowledge of past developments in their profession and they carried out projects in the Netherlands as well as abroad.

For the analysis of the questionnaire a thematic analysis has been used. A theme categorizes, but may not have rigid inclusion and exclusion criteria. The themes were chosen after reading all the responses. Thematic analysis is the process of identifying patterns or themes within qualitative data. although thematic analysis is used, in this study all answers are included in the results. None of the experts' comments and advice are excluded. This approach has been chosen because all the advice from the experts are important in formulating various recommendations and leapfrogging trajectories. Because of the new leapfrogging concept it is interesting to show all different perspectives.

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Results

4.1 Challenges that Amsterdam has encountered over the past centuries

The first part of this chapter describes, on the basis of literature research and interviews, the development of various trends and pressures that Amsterdam experienced from around 1672 to 2020. The trends and pressures are divided into the categories; social, environmental, financial, and governmental challenges. The second part of the chapter gives the scores of the TPF framework and their visualization.

4.1.1. Pressures & challenges that Amsterdam encountered

Social developments and trends

Urbanization

Until about 1660 there was an enormous population and economic growth in Amsterdam, which meant that the city had to be expanded considerably (Groen, 1978; Poortvliet, 2010). However, the plague epidemic in 1663 and 1664 killed many citizens, which slowed down the urbanization rate. Around 1600 the population of Amsterdam was estimated at approximately 200,000 people (Poortvliet, 2010). People lived closely packed in slums and alleys in the old center and working-class neighborhoods. These neighborhoods such as the Jordaan and the islands Vloyenburg, Uilenburg, and Rapenberg were overpopulated and the living conditions were poor, causing viruses to spread rapidly (Poortvliet, 2010). In the second period, 'The French era' (1795-1813), wars and economic downturn prevented further city expansion and the population of the city declined. The dense living conditions and poverty negatively affected population growth. The population growth was also stagnated because the population had to be accommodated within the tight city walls and there was not enough money available for further expansion of the city (ACRE, n.d.; Hogenes, 2020).

The industrial revolution started relatively late in the Netherlands and Amsterdam, which is why the population growth in the first half of the 19th century was not high compared to other European cities (ACRE, n.d.). The population growth and urbanization accelerated after 1850, in the late industrial period. Employment in the city increased due to more factories and industry, which led to more people moving into the city. To accommodate the population the city was expanded and its semicircular shape was completed. The Housing Act of 1901 tried to put an end to the bad living conditions of many people (Gemeente Amsterdam, n.d.-a). It became possible to expropriate and demolish bad houses and the local government introduced legislation in which minimum requirements for a house were set (Gemeente Amsterdam, n.d.-a). The legislation also laid down the appearance of a neighborhood and houses. Legislation allowed the municipality to exercise more control over urban expansion.

The population continued to increase rapidly until the early 1960s. Urbanization rate was really high because many people moved to the city in the hope of finding work and a better life (Gemeente Amsterdam, 2020). The population and thereby its urbanization also increased due to the fact that living and health conditions improved, which is why mortality decreased and the number of infants increased (Gemeente Amsterdam, 2020). There was a short interruption due to the second world war, however, it did not influence the overall population growth. When the war ended, there was a so-called 'baby boom' which caused the population to increase sharply again (Gemeente Amsterdam, 2020). After 1960, another period started, namely suburbanization, which caused the population in the city to decline. (ACRE, n.d.; Gemeente Amsterdam, 2020). Citizens preferred to live outside the city, where it was more quiet, there were more modern houses, and more space available. The number of births in the city decreased due to sub-urbanization, but also due to the introduction of the contraceptive pill, which became widely available. In order to combat the exodus from the city, the municipality increased housing production again from the early 1980s (Gemeente Amsterdam, 2020). In addition to sub-urbanization, however, there was an increase in foreign migration as many migrant workers moved to the Netherlands and usually settled in the cities (Gemeente Amsterdam, 2020).

After 1980, the population grew strongly again due to the emergence of ICT companies that established themselves in the city (ACRE, n.d.). Furthermore, since 2008 the number of inhabitants in the city increased unprecendetedly with an average of 10.000 inhabitants per year (Gemeente Amsterdam, 2020). The growth comes from both natural growth and migration (CBS & PBL, 2017). To accommodate all inhabitants the city is still expanding, however space is limited which is why the price per square meter is really high. The population growth trend is predicted to continue in the future (CBS & PBL, 2017). The Central Agency of Statistics (CBS) predicts that Amsterdam will have more than a million inhabitants by 2035. In March 2020, the coronavirus disease (COVID-19) broke out, which had a major impact on the population. The virus caused a decrease in the population because inhabitants migrated out of the city. It is not yet clear what impact the virus will have on population and urbanization in the future.

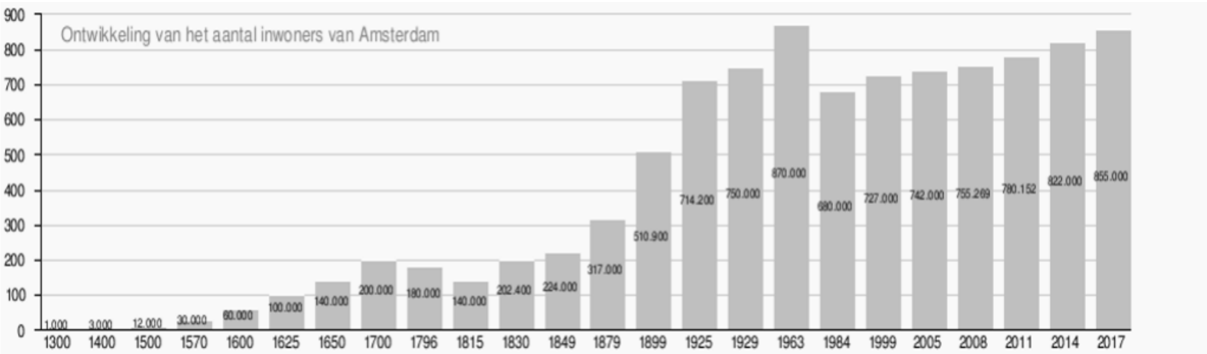


Figure 12: Population growth of Amsterdam

<u>Burden of disease</u>

In the 17th century, Amsterdam was ravaged three times by the plague, killing about 47,000 people in the city (Groen, 1978). The city then had between 120,000 and 200,000 inhabitants, so the plague has hit the inhabitants hard. The citizens who lived in the working-class neighborhoods were more prone to infectious diseases. However, in this period not only the working-class people were affected, but the wealthy upper class also suffered in major epidemics. More than 24,000 people died in 1663 and 1664 due to the plague, which is approximately one in eight citizens of Amsterdam (Gemeente Amsterdam, 2019e; Poortvliet, 2010). The bubonic plague was transmitted by fleas from rats, which were especially common there, while a second variant, the lung plague, spread easily from person to person in busy neighborhoods (Gemeente Amsterdam, 2019e). The plague encouraged the city council to improve the organization for solid waste collection and removal (van Melle, 2003). In 1666 a new tenant was allowed to take of the cleaning in the city, however, this did not work out well, which is why - after a few years - the city council took firm control of urban waste management (van Melle, 2003).

In the French period, the disease burden was very high due to poverty and a poor social safety net (Hogenes & Ouboter, 2020). Mr. Hogenes stated that as a result of the great poverty in the French era, living conditions were very difficult, which resulted in a particularly high infant mortality rate. Smallpox was the most threatening disease in Amsterdam in the eighteenth century (Gemeente Amsterdam, 2019f). Children in particular were affected by smallpox, one in ten children died of the disease before the age of ten (Gemeente Amsterdam, 2019f). The virus spread via the respiratory tract, hitting overpopulated neighborhoods the hardest. In 1803 the Amsterdam Society for the Promotion of the Koepok vaccination was founded (Gemeente Amsterdam, 2019f). The aim was to make cow-pox vaccination common among poor citizens to stop the spread of the virus.

The cholera epidemic in the 19th century also caused many victims. From 1832 to the end of the 19th century, thousands of civilians died of cholera (Gemeente Amsterdam, 2019c). The cause of the cholera epidemic was unknown, it was suspected that the "nasty fumes" from the filthy channels and the dirt were linked (Gemeente Amsterdam, 2019d). In 1883, the German researcher Robert Koch discovered the cholera bacteria, and the disease have since been known to spread through water (Groen, 1978). Many diseases such as the plague, cholera, and typhus are spread by bacteria through the water. Around 1880, the first public bathhouses were built in Amsterdam where you could shower (Poortvliet, 2010). In addition, the city council stimulated the construction of handwashing facilities in homes, schools, offices, and companies (Poortvliet, 2010). After the epidemic, drinking water companies were set up in all cities to better tackle the different types of diseases (Groen, 1978). In order to reduce diseases, it is important to provide better hygiene. The interview with Mr. Koning showed that at the beginning of the industrial period, the burden of disease was lower because of the lower population, but the social safety net was poor. In the late industrial period, however, the disease burden was much higher, as conditions were worse due to housing shortages and rising growth. Another factor causing a high burden of disease is poor working conditions in factories. Many people died or became disabled due to accidents (Hogenes, 2020). In 1874, a children's law was introduced prohibiting children under thirteen from working in factories (Hogenes, 2020). This was a big step forward for children's health. Furthermore, the Housing Act in 1902 improved the living conditions of the population, resulting in a more vital population (Hogenes, 2020).

In 1932, the municipality made a shower or bathroom compulsory for new buildings (Poortvliet, 2010). However, the supply of hot water was expensive, so it was often only used as storage. After the Second World War, the use of showers and baths at home became more familiar, the drinking water supply became properly regulated and more hygiene measures were taken, causing a decrease in the number of epidemics. In 1982 another virus emerged called AIDS (acquired immune deficiency syndrome). This virus can be transmitted through sexual contact, through blood and from mother to child (Gemeente Amsterdam, 2019b). In the 1980s and 1990s, people from Amsterdam in particular died of this virus because of the thriving nightlife for homosexuals (Gemeente Amsterdam, 2019b). Unfortunately the AIDS virus cannot be cured, but nowadays there is medication that reduces the risk of death. Furthermore, in 1999 the Legionella bacteria was found in the waters of Amsterdam which caused 32 people to die (Poortvliet, 2010). In 2006 there was another small outbreak in which 3 people died.

In March 2020, the COVID-19 virus made its appearance in the Netherlands. The virus mainly spreads from person to person through the air and touch, but has been observed in waste water and municipal sewage treatment plants in the Netherlands as well. The virus has made many victims, but since the virus is still prevalent, it is unclear how many people have been affected. In the future life expectancy of both women and men in the Netherlands is expected to rise. This trend is mainly due to preventive measures and the improvement and availability of health care services (Hoeymans et al., 2014). The National Institute of Public Health and the Environment (RIVM) expects by 2030 a continued decline in mortality from coronary heart disease and stroke. Dementia currently is an important illness, but from 2030 onwards, dementia will be a major cause of death. Furthermore, chronic diseases are expected to increase due to the aging population, early detection, and health care improvements, however, the number of active people will stay stable which means that people with chronic diseases not always experience burdens or they experience it less (Hoeymans et al., 2014).

Female participation

The Republic during the golden age was a trading nation and women also had their share in that trade as small traders and as merchants. Women were often able to earn a living independently in their profession. In industry, where many people were employed, there were large differences between the wages of men and women. Men's work was generally better appreciated and paid. In the field of business, on the other hand, people mainly performed independent work and the difference in pay was less important. The importance of maritime shipping meant that many men were absent. Women performed their duties in the absence of their husbands. Women also often held positions in the management of organizations. In addition, when the man died at sea, the widow became the family's breadwinner (Gemeente Amsterdam, 2019g). The women were independent and engaged in entrepreneurship. During this period women stood their ground in the unsafe and violent city, which is why they acquired the qualities of assertiveness and directness (Gemeente Amsterdam, 2019g). Women also often held positions in the management of organizations. However, women were not allowed to trade on the stock exchange, but in everyday life, they were often considered full-fledged citizens (Hogenes, 2020). Furthermore, opportunities for unmarried women, married women and widows on the labor market were not equal, which underlines the importance of distinction according to marital status.

Besides a big difference in the participation of women according to marital status, there was also a big difference in the lower and upper classes. In the lower classes people had to work to prevent poverty and to support their family. However, the fact that poorer women had to work more created a stereotype that if you are rich, you were not expected to work. Women who worked were considered indecent. There were plenty of jobs available for women, but because of their social status, they didn't work. There was a big difference between men and women in legislation. For example, women were not allowed to do financial business during their marriage. In legislation there was a clear gender role and a clear role for women in it. In the course of the 18th century the participation of women declined. One reason for this decrease, according to the interview with Mr. Hogenes, is that when there is less economic prosperity or a crisis, fewer women work because jobs were given to men. When fewer jobs are available, it can be seen that there is a wider gap between the participation of women and men

Despite the fact that not all women wanted to work because of social status, they did fight for women's rights. It did take a long time before these rights really came about (Mijnhardt & Kloek, 2001). Vote right for women was one of the laws. This law came into effect on September 28, 1919. From this date, the Netherlands has universal suffrage for men and women. Until the 1960s, the roles of men and women were firmly divided into traditional lines. Men and women had to get married. A woman took care of the house, her husband and their children and men supported their family financially (Mijnhardt & Kloek, 2001). Data from the second half of the nineteenth and twentieth centuries show that the labor participation of women in the Netherlands was lower than in other Western European countries (Mijnhardt & Kloek, 2001). This is due to the relatively high standard of living in the country. Many women could afford not to work. Moreover, there was a strong role for women in the household.

From the year 1960 a wave of protest started against the traditional division of roles (Holland Alumni Network, 2016). From that time, more and more women started working outside the home and continued to work even after she got married and had children (Holland Alumni Network, 2016). The feminist activist group that advocates for equal rights and opportunities for women is called the ‘Dolle Mina’s’(Atria, 2015). The group started in 1969 and is still around today. The action points of Dolle Mina are still relevant, because the emancipation has not yet been fully completed (Atria, 2015). In recent years it has improved, yet you still see differences, for example, in the difference in salary for the same work.

Education

Higher education in the Netherlands has a long tradition. The oldest university is that of Leiden. As a reward for the resistance against the Spaniards, the city received permission from the States-General in 1575 to establish such an institution (Dorsman & Knegtmans, 2020). In the sixteenth and seventeenth centuries, students from all over Europe came to Leiden. The academy was the main Protestant university and had three faculties: Theology, Law, and Medicines (Universiteit Leiden, n.d.). The main language of the classes was Latin. Initially, higher education was only available for men. Aletta Jacobs (1854-1929) was the first woman in the Netherlands to receive a university education, the first woman to become a doctor, and the first woman to obtain a PhD (Dorsman & Knegtmans, 2020). Due to the economic prosperity and many jobs in Amsterdam during the Golden Age, many highly educated people from abroad came to the city and many people came to practice crafts such as painting (Koning, 2020). The education facilities did not provide general education, but it was focused on crafts. The education system was only accessible to wealthy people, however, many people could read due to their religion. The protestant church encouraged people to read the bible so they had to learn to read (Koning, 2020). The University of Amsterdam already existed in 1632, but was then an illustrious school (Athenaeum Illustre), making it impossible to graduate or obtain diplomas here (Dorsman & Knegtmans, 2020). It was not until the nineteenth century that the school in Amsterdam officially became a university.

During the French period, the number of university enrollments fell as the economy stagnated and the labor market collapsed. Studying was reserved for a small, well-to-do elite (Dorsman & Knegtmans, 2020). Moreover, the influx of highly educated workers decreased. Due to the economic crisis, there was little money available to invest and finance the schools (Hogenes, 2020). In contrast, the government made the first education laws in this time period. The law of 1806 stipulated that primary schools must be accessible to everyone. Nonetheless, there was no compulsory education and church-bound schools were not allowed (Dorsman & Knegtmans, 2020).

At the beginning of the industrial revolution, the enrollments in education grew, however more manpower in factories was needed, which is why many did not go to higher education (Koning, 2020). At the end of the industrial period, the government implemented children's rights. Children were not allowed to work in the factories anymore, which is why school enrollment increased. Compulsory education was introduced on January 1, 1901. Children from 6 to 12 years old had to go to school or be home schooled (Rijksoverheid, 2020). The compulsory school age was later extended by four years and the supervision of the institutions was regulated by government and by law. The constitution put an end to the "school war" between public and special education in 1917: from that time on, the government funded both public and special education (Rijksoverheid, 2020). Furthermore, the government established in their education department 1918: Ministry of Education, Culture, and Science (Rijksoverheid, 2020).

During the Second World War many educational institutions were closed by the Germans. Dutch universities experienced astonishing growth after the Second World War. The enormous increase in scale is evident from the growth in the number of students, employees, and budget (Dorsman & Knegtmans, 2020). The higher education participation rate increases enormously after 1945, mainly thanks to the large increase in female students (Centraal Bureau voor de Statistiek, 2010). Before 1945, it was mainly men who attended higher education and women stayed at home. Another reason for the strong growth in higher education participation is related to the rapid build-up of the welfare state, because many highly educated people were needed (Centraal Bureau voor de Statistiek, 2010). This also led to a reduction of inequality in educational opportunities. The universities became more accessible to larger groups and due to the implementation of a scholarship scheme in the sixties and seventies more young people could afford to go to higher education. Nowadays, The Netherlands has a binary system for higher education. In addition to university education, there is a broad range of higher professional education with its orientation on the labor market. In the last decades, the country has more and more higher educated people. In 2009 nearly 10 percent of the population up to the age of 65 had a university degree, thirty years ago this was less than 3 percent (Centraal Bureau voor de Statistiek, 2010). However, a downside is that the enormous increase in the number of students in higher education causes a shortage of technically trained personnel. Another negative aspect, according to Mr. Hogenes, is that the digitalization of education has compromised the quality.

Environmental trends and developments

<u>Flood risk</u>

The concept of dikes arose through private initiatives (Poortvliet, 2010). The citizens connected mounds with earth walls so that the land was also protected against high water between the works. However, there were problems because people had to maintain the dikes themselves. For this reason maintenance has been taken over by the water board, which people had to pay for. Until the 16th century, the maintenance of the sea dikes that protect Amsterdam was the responsibility of private individuals. With the emergence of the Zuiderzee, many dike breaches and storms made the maintenance of sea dikes expensive. Maintenance was not paid for by all stakeholders, only a few had to pay for it. The last dike in Amsterdam became municipal property in 1862,

Floods due to sea-level rise was, and still is, a concern for the city. The city and its surroundings have been hit by severe floods several times over the centuries (Hogenes, 1997). Due to the growth of the city, the flood defenses were moved in the 17th century. However, the city was ravaged by severe floods in 1651 and 1668. Flooding caused much damage in the city, like cellars, alleys, and warehouses were flooded and dikes collapsed. Mayor Hudde decided to build the Amstelsluizen in 1673 and to raise dikes to cope with floods. In 1675, however, there was another violent storm that broke some dikes and flooded areas. In the 19th century, there were still eleven high water situations, although the overall damage was low. After the construction of the Oranjesluizen in 1872, there is no tidal connection in the IJ, which reduced the risk of flooding. Furthermore, the Afsluitdijk was completed in 1932, making the Zuiderzee the IJsselmeer. Floods were rare in the 20th century. In 1960 there was one flood due to a broken water pipe and in 2003 there was a dyke breach due to extreme drought.

The first locks were built at the end of the Middle Ages for sake of transport over the boundary between the more constant water level in the city and the tidal levels in the IJ. The excess water was discharged through drainage sluices. Locks were not only important for protection against high water but also ensured that the canal water could be refreshed.

Nowadays Amsterdam no longer has to deal with spring and low tide due to the construction of the North Sea Canal, but due to free flow during low tide in the Northsea ("spui") a tidal wave is daily observed in the city.

<u>Water level</u>

The surface water level in the city is kept constant as much as possible. The groundwater level in Amsterdam is on average higher than the surface water (Poortvliet, 2010). The fixed water level is very important for the city as the houses in the city are on stilts, because the soil consists of weak peat soil (Poortvliet, 2010). Especially for the old houses with wooden foundations in the middle, the water level is very important, because when the level drops, the wooden foundation starts to rot and the houses sink. The surface water level is maintained so that the water table does not drop too far. The water level can be closely monitored via monitoring wells.

Outside the canal belt, drainage is a bit more complicated. In these neighborhoods, the ground level for the construction of the neighborhood is not the same everywhere. In the developments of the 19th century, streets are raised, but not the gardens due to cost savings. This makes it difficult to keep the water level in the gardens under control and special private polder sewerage has been installed in these neighborhoods. The polder sewerage often does not function properly because homeowners do not maintain them properly and they are very old. Private individuals are responsible for this, but such collaboration is difficult to achieve. In 2007 Amsterdam decided to tackle several private polder sewers.

<u>Water quality</u>

The city's prosperity during the golden age increased not only the population but also pollution. The pollution clogged canals and partly increased the demand for drinking water (Hogenes, 1997). To prevent pollution of the canal water, the canals were flushed, but in the summer, refreshment was only possible from the IJ (Hogenes, 1997). A negative influence of the renewal with seawater is that the canal water became increasingly salty, making it unsuitable as drinking water. Around 185 the general practitioner Sarphati found the connection between clean drinking water and the sick. Many sick people had little or no access to clean drinking water. Moreover, an additional odor nuisance was caused by the poor quality of water. The canals served as open sewers, which caused a lot of odor nuisance, especially in warmer periods (Hogenes & Ouboter, 2020).

The water quality in Amsterdam during the French and industrial periods was of bad quality. Although people were not allowed to throw their sewage and waste into the channels, the channels still remained heavily polluted. Additionally, the poor water quality in the canals and the polluted environment by industry caused a lot of odor nuisance. Furthermore, the development of the industry caused a lot of air pollution. Moreover, industrial companies polluted the waters of Amsterdam. Water quality was poor in all periods until 1921. The first water purification plant was built in 1921, which greatly improved water quality (Hogenes, 2020; Koning, 2020). Sewage was constructed in new developments after 1872. In the thirties of the 20th century the city center was sewered using a combined system for waste water and stormwater. Post war developments, Nieuw West, Rivierenbuurt and Buitenveldert had a separated sewage system, waste water being treated in treatment plants. In 1970, the surface water discharge law was introduced. The law prohibits the discharge of waste, polluting, and harmful substances into surface water in the entire Dutch territory without a permit. The canal zone was connected to sewage, December 1987. A further improvement of water quality was reached by moving the waste water treatment plants to the West of the city, downstream. Especially, oxygen depletion stopped. Most days the water is free from pathogens resulting in swimming water quality. However, if you look at figure 13, the ecological water quality in the city is not yet optimal, and a lot can be achieved in this area. The challenges in further bringing back the emissions focus on the quality of inflowing Amstel water. Improvement of the water quality in the canal zone is depending on a gain in structural diversity and regulating of pressures by boat traffic and covering of the water surface by scaffoldings etc.

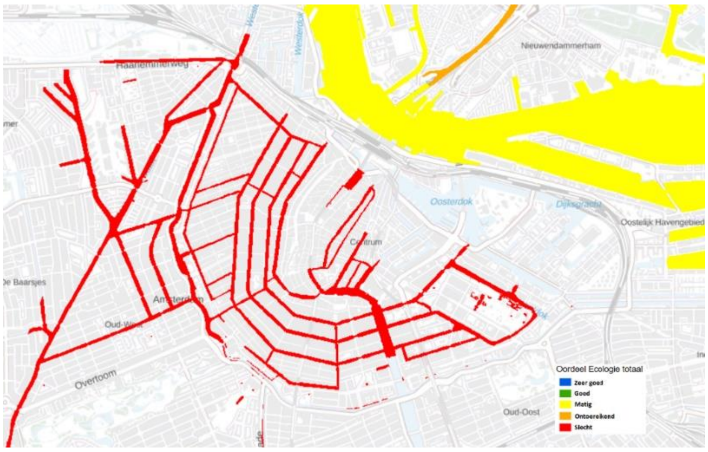


Figure 13: Ecological quality of surface water in Amsterdam

Financial trends and developments

The foundation of the Republic of the Netherlands made it possible to start up economic enterprises: a chartered, joint-stock monopoly, which was called the United East India Company (VOC), which might be the first international corporation (Andeweg & Irwin, 2014). The city of Amsterdam accounted for more than half of the new company's capital but was not allowed to supply half the number of administrators for fear of domination (Gemeente Amsterdam, n.d.-a). The VOC made Amsterdam the financial center of Europe and the Netherlands was a world leader in science, law, and arts. Amsterdam became a metropolis and enjoyed explosive growth in wealth and population throughout the 17th century (Gemeente Amsterdam, n.d.-a). The financial prosperity that the VOC brought enabled Amsterdam to develop into the city it is today. Sufficient capital was available which is why the economic pressure was low. The city owned many shares in the VOC, which meant that the city itself owned a lot of capital and could therefore invest. There was a lot of employment and therefore poverty was average. The West India Company (WIC) was founded in 1621 which ruled in areas like Suriname and Brazil. Furthermore, the Netherlands has always been a country that invests a lot. The first banks were founded around 1600. According to Mr. Koning (2020), the Dutch are always investing, even in difficult times.

At the end of the seventeenth century, a turnaround took place in the economy of Amsterdam when the French occupied the country (Gemeente Amsterdam, n.d.-a). Foreign trade broke down because several countries no longer trusted the republic and the Netherlands had to pay for the French occupation itself (Koops, 2020). The economic downturn meant that less employment was available, which led to a sharp increase in poverty. The 18th century was a century of rising poverty due to growing unemployment (Overmeer, 2012). The state shares of the Netherlands fell on the stock exchange in the years 1795 to 1797 to 20 percent of their original value (Koops, 2020). In 1800 the VOC was dissolved, which is why the economy was again based on trade and finance (Andeweg & Irwin, 2014). During this century, a law was introduced to combat poverty, but the law stated that helping the poor was the responsibility of charities (van Heest, 2012). The government itself did not have to helped the poor, rather the church was very important in providing help to the poor.

During the next era, industrialization took place which created some new impulses to the economy, but also social unrest (Gemeente Amsterdam, n.d.-a). However, at the beginning of the era the economic development was not going that fast. With this development, the number of poor workers, including children, and slums grew (Overmeer, 2012). the liberals wanted to introduce a free market, but that turned out not to work (Overmeer, 2012). The rich got richer and the poor got poorer. The wealthier people did not want to control poverty, but it was in their best interest that companies provide better living conditions for workers (Overmeer, 2012). Poverty had to be limited to some extent, but mainly to keep the economy going (Overmeer, 2012). Changes came after 1870. The opening of the Suez Canal and the German unity gave the Amsterdam economy new impulses, trade with the Dutch East Indies was liberalized, and the diamond industry developed strongly (Gemeente Amsterdam, n.d.-a).

In the 20th century, people were more concerned about poor people. In 1912 a poverty law was enacted that combated poverty, but the primary task remained with private agencies, only if that was not enough the government would help (van Heest, 2012). After the second world war, the perspectives on taking care of the poor and the economy changed. This is why the Christian, Socialist and Liberal parties have jointly established the welfare state: the Emergency Old Age Provision Act (1947), the General Widows and Orphans Act (1961), and the General Assistance Act (1965) (Overmeer, 2012). After the great depression in 1930, the government wanted to make sure that enough jobs were made available to the population, so the government itself started creating jobs (Andeweg & Irwin, 2014). To achieve this and ensure economic recovery, it was necessary to restore the country's trade position. That is why the government created good conditions for companies to invest. The policy worked well, the economy grew strongly and therefore the employment of immigrants was necessary to fill all the jobs (Andeweg & Irwin, 2014).

From 1960 employment in the industrial industry fell, but these were replaced by government, social, and community services, such as education (Andeweg & Irwin, 2014). At the end of the century, employment shifted to the service sector and transport (Andeweg & Irwin, 2014). in 1980 there was a further shortage of jobs, prompting the government to introduce early retirement measures and encourage part-time work, and wage cuts were offset by a reduction in working hours (Andeweg & Irwin, 2014). The eighties and nineties are dominated by urban renewal and the recovery of the Amsterdam economy. The old city will retain its residential function, but the business community will also have plenty of development opportunities again. One example is the development of the area around the 'Zuidas' where concentrations of offices and companies arise.

Nowadays the economy of the Netherlands is quite strong. Despite the small size of the country, Netherlands is 4th largest exporter of goods in the world and 2nd largest exporter of agricultural products (Simpson, 2012; Workman, 2020). The country is one of the most open economies in the world. However, in recent decades economic prosperity and employment have fluctuated strongly. In addition, the economy can be affected by crises. That is why it is difficult to predict, for example, what influence the COVID-19 crisis will have on the Dutch economy.

Trends and developments in governance

The Golden Age of the city and the Netherland started around 1580 and lasted approximately until 1700 (Paping, 2014). The Netherlands became the first modern Republic which included a union of seven sovereign provinces and, according to the treaty, decisions were to be taken unanimously (Andeweg & Irwin, 2014). This did not always work properly, but it was the starting point of consensus and democracy in the Netherlands. Until 1795, the Netherlands was a republic consisting of a federation: the Republic of the Seven United Netherlands (Het koninklijk huis, n.d.). It was a league of independent states forming a state based on a joint treaty. During this time, the city of Amsterdam was ruled by four mayors who directed all other civil servants (Neefjes, 2016). Private individuals (of companies) worked also in the civil service and ordinary citizens helped with the enforcement of the regulations (Neefjes, 2016). So, at this time there was no clear distinction between government and companies which is why companies could influence the policies of the municipality. The municipality indicated within which frameworks the civil servants had to work and the officials were required to take an oath, however, you could only become a civil servant if you were baptized so not all people were equal during this time (Neefjes, 2016). The oath helped to fight corruption because if officials committed fraud they were not allowed to work in that position again or you were punished differently, although there was still some corruption and fraud happening (Neefjes, 2016).

'The 'French period', as the Napoleonic occupation is referred to, left an important imprint in the political institutions of the country'(Andeweg & Irwin, 2014). The French first maintained the Netherlands as a republic, but later Napoleon Bonaparte founded the Kingdom of Holland with his brother Louis on the throne. The Netherlands was changed from a Republic to a monarchy. In the 18th century, the Dutch Republic gradually lost status as a world power to England and France. The growth of Amsterdam stagnated as a consequence. For 18 years, Amsterdam became the capital and royal residence during the French occupation. When the French left in 1813, the Netherlands became an independent country again. Amsterdam was formally still the capital, but all the actual political capital functions moved back to The Hague. During the French period, the constitution, provinces, and administration were regularly changed due to discontent (Mijnhardt & Kloek, 2001). Amsterdam had to settle for economic, financial, and cultural capital functions. However, the French era was mainly dominated by impoverishment, which meant that little investment was made. A major step was taken in 1798, namely the creation of the first modern Dutch constitution (Mijnhardt & Kloek, 2001). Centralism became the ideology, causing provinces to lose their autonomy. Moreover, the constitution made every inhabitant of the republic equal (no more hierarchy). Furthermore, there was freedom of speech, press, and religion. Another important influence was the division between church and state.

It took until the 1870s before economic growth returned. Roughly between 1870 and World War 2, Amsterdam enjoyed a 'second Golden Age', which again was tightly connected to colonial trade. The opening of the Suez Canal enabled a faster and easier trading route with the East Indies, and German unification gave a significant impulse to the economy of its western neighbor the Netherlands. The Amsterdam harbor was made more accessible by sea when the North Sea Canal was opened. Economic growth (including finally also industrialization) went along with rapid population growth. Finally, the city walls were broken down and city extensions beyond the outermost canal around the inner city were allowed. This resulted in areas like De Pijp and Oud-West, once built for working-class and lower-middle-class people, but nowadays very popular as residential, working, and leisure locations for the 'creative class'. Some decades later, a more luxury southern extension (Oud Zuid) was realized, establishing the high-status axis from the inner city canals southwards that still exists today. Starting in the early 20th century, an increasing part of new housing construction was social housing, resulting from the political dominance of the social democrats in the city council throughout most of that century.

After the occupation of Germany in 1945 is often seen as the 'rebirth' of the country. The war produced greater support for parliamentary democracy. There was a greater appreciation of domestic institutions and led to the acceptance of a larger role for the state (Andeweg & Irwin, 2014). Which resulted later in the establishment of the welfare state. After 1960, the Netherlands underwent a major transformation in society and religion, making the Netherlands one of the most progressive countries (Andeweg & Irwin, 2014; van Doorne & Steur, 2018). Dutch political leaders drew the same conclusion: in a pluralistic and rapidly changing society, keeping the reins loose was the best option. Good government means that one should ensure that things do not get out of hand and a strong realization of the limits of one's own ability to keep a tight reign on societal affairs (Andeweg & Irwin, 2014; Kennedy, 1995).

From 1980 to about 2000, there was room for conservative-liberal ideas: high taxes hinder economic growth, government regulation curtails entrepreneurship, and the smaller the state, the healthier the community (van Doorne & Steur, 2018). The philosophy was that the market is better at safeguarding public interests than the government. The change of mind is characterized by the oil crises (van Doorne & Steur, 2018). In the period 2000 up to and including the present time, in addition to the market government, additional ways of promoting public interests are being sought (van Doorne & Steur, 2018). The answer lies mainly in socialization: the citizen, the community. It is up to society itself to promote public interests: people generally have a better understanding of the problems and how they can be addressed. Moreover, according to the reasoning, people are more willing and better able to take care of action themselves. Part of the powers of the national government was transferred to local authorities, with which the strengths of local communities had to be strengthened (van Doorne & Steur, 2018). Furthermore, technological developments have also created a change in political participation during recent years.

Overview of trends and developments from 1672 to the present

In Table 4, the crucial trends and developments are outlined with the help of keywords. Looking at the table, it is clear that the developments and trends go from crises to crises. There is a certain crisis going on in every time period. Furthermore, it can also be seen that there are certain interconnections. For example, in the periods when poverty was greater, you also see that the burden of disease is often higher. Another clear connection is that between urbanization and economic stability. In times of economic prosperity, urbanization tends to be higher, as there is more money available to invest and more jobs.

Table 4: Overview of trends and developments

	1672 – 1682	1780 – 1810	1845 – 1866	1872 – 1902	1930-1955	1970 – 1998 – 2006	2018 – present
Social	▪ High population growth ▪ Plague epidemic ▪ High female participation ▪ Increase in highly educated people ▪ Craft education	▪ Stagnated growth ▪ High infant mortality ▪ Low female participation due to poverty ▪ Lower participation in education	▪ Average growth ▪ Cholera epidemic ▪ Increase in female participation ▪ Lower education due to work pressure	▪ City expansion and growth ▪ High burden of disease because of working and living conditions ▪ Increase in female participation ▪ Compulsory education children	▪ High urbanization growth ▪ Strong decrease in the burden of disease ▪ Low female participation ▪ Growth in higher education due to reconstruction	▪ High urbanization growth ▪ Stagnated burden of disease ▪ 'Dolle Mina' movement ▪ Growth in higher education	▪ Moderate growth ▪ Stagnated burden of disease ▪ Towards full women's participation ▪Good education system
Environmental	▪ High flood risk ▪ Disturbing water quality ▪ Odor nuisance	▪ High flood risk ▪ Polluted waters ▪ Odor nuisance	▪ Intermediate flood risk ▪ Pollution to waters ▪ Poor air quality	▪ Intermediate flood risk ▪ Polluted surface water ▪ Poor air quality	▪ Reduced flood risk ▪ Improvement of water quality ▪ Medium air quality	▪ Low flood risk ▪ Improvement of water quality ▪ Improvement of air quality	▪ Low flood risk ▪ Improvement of water quality ▪ Improvement of air quality
Financial	▪ Financial prosperity ▪ Low unemployment ▪ Churches responsible for poor relief	▪ Extreme poverty ▪ High unemployment ▪ Not enough capital available for poor relief	▪ Start of the industrial period ▪ Large gap between poor and rich ▪ High poverty	▪ Flourishing industry ▪ New impulses in the economy ▪ Higher employment ▪ Less poverty	▪ Great depression ▪ Job creation by government ▪ Start of the welfare state	▪ Shift in primary working sector ▪ Great growth in economy and employment ▪ Inclusion of immigrants	▪ Strong fluctuation in economic prosperity ▪ Influence of crisis
Governance	▪ Republic of the Seven United Netherlands ▪ VOC & WIC ▪ Influence from the church and the private sector	▪ French occupation ▪ Start republic	▪ Central government position ▪ Less hierarchy	▪ Political dominance of the Social Democrats ▪ Introduction of legislation	▪ Establishment of the welfare state ▪ Progressive governance	▪ Conservative-liberal thinking ▪ More power to the market	▪ Socialization ▪ National government → local authorities

4.1.2. Trends & Pressures framework

The final scores of the TPF framework indicators are shown in Table 5 and 6. The scores were calculated based on five interviews, after which the interviews were averaged for the final scores. For some indicators, there were outliers in the scores because the interviewee gave the scores from their perspective, but taking the average of all interviews it canceled out the outliers. Furthermore, compared to the literature study, the scores correspond to the trends and developments that Amsterdam has gone through.

Critical developments and trends are reflected in the scores and the literature review:

- Urbanization fluctuates over time. When economic pressure, unemployment, and poverty decreases, urbanization increases. The more economic prosperity the city has, the more attractive it is for people to settle in the city.

- An epidemic or virus is visible in the burden of disease indicator. Amsterdam has had a few epidemics such as the plague and cholera. Over time you can see crisis to crisis developments and higher scores for this indicator.

- Economic prosperity positively affects the education rate.

- The interviews and scores show that in times of a governmental crisis, female participation is lower (e.g. French occupation and second world war). In general, the participation of women in the Netherlands is lower than in other countries. This is probably because many work part-time.

- The sea has always had a lot of influence on the sea. Initially, it was tidal action and later after the construction of the North Sea Canal, the pressure shifted to sea level rise.

- In recent years there has been a reduction of the pressure on surface water quality and air quality. The two indicators are often related because water pollution creates odor nuisance.

- The economic indicators vary strongly over time. Often this fluctuates based on different crises. These indicators are also difficult to predict in the future due to the strong fluctuation.

- In the researched periods, the government was generally well regulated, which is why governance indicators did not create high pressure for the city. This is also evident from the literature review. From the time of the VOC there have always been some regulations. If not by the government, the ecclesiastical and civil institutions often took it upon themselves to regulate.

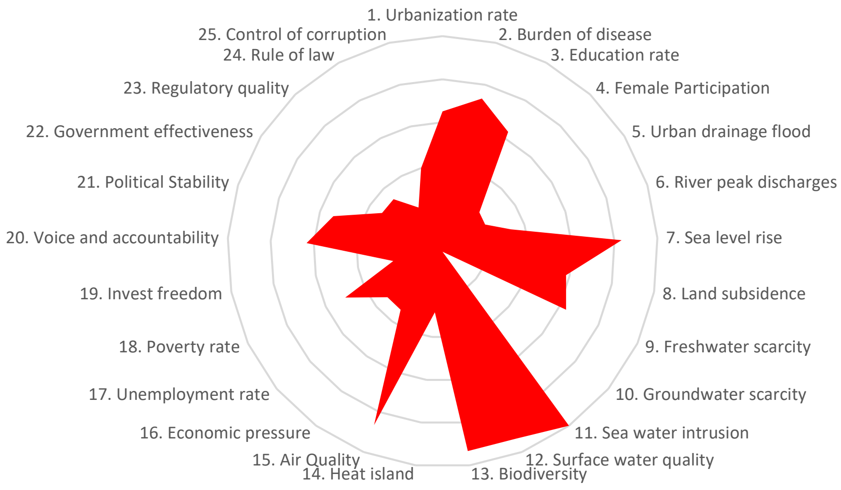
Table 5: TPF scores

	1672 – 1682	1780 – 1810	1845 – 1866	1872 – 1902	1930-1955	1970 – 1998 – 2006	2018 – present
1. Urbanization rate	6.5	0.0	5.5	9.0	9.0	6.0	3.3
2. Burden of disease	7.3	4.0	5.7	4.7	3.5	2.4	2.0
3. Education rate	6.3	8.2	8.0	8.7	4.5	2.5	2.5
4. Female Participation	2.5	7.0	5.5	5.0	7.0	5.1	2.8
5. Urban drainage flood	2.3	2.0	4.0	4.3	1.5	3.0	3.6
6. River peak discharges	3.3	3.3	3.7	3.7	5.3	7.5	10.0
7. Sea level rise	8.3	8.3	8.3	6.2	9.0	10.0	10.0
8. Land subsidence	5.8	5.8	5.8	6.7	7.5	7.5	7.5
9. Freshwater scarcity	6.3	6.3	6.0	5.3	3.0	4.3	4.3
10. Groundwater scarcity	0.0	0.0	0.8	2.7	2.8	2.5	2.5
11. Sea water intrusion	10.0	10.0	10.0	8.7	7.5	7.5	7.5
12. Surface water quality	9.3	8.7	9.3	9.3	8.0	5.3	3.0
13. Biodiversity	9.3	9.3	9.3	9.7	9.5	9.7	9.0
14. Heat island	2.8	2.5	3.2	3.3	2.8	2.7	3.4
15. Air Quality	8.7	7.7	8.7	9.5	6.8	3.5	2.5
16. Economic pressure	3.3	8.0	6.3	6.3	5.0	2.2	2.0
17. Unemployment rate	3.3	6.2	4.8	4.0	4.0	3.7	3.0
18. Poverty rate	5.0	7.5	6.0	6.0	6.0	3.0	3.0
19. Invest freedom	2.3	9.0	4.3	4.7	5.0	2.3	2.0
20. Voice and accountability	6.3	8.3	7.2	7.3	4.0	1.6	1.8
21. Political Stability	5.3	8.3	4.0	4.7	6.5	3.1	3.3

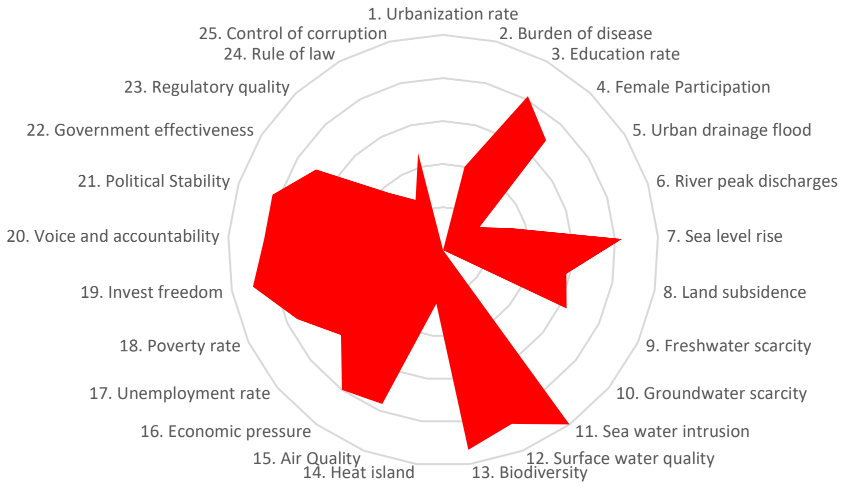
22. Government effectiveness	3.3	7.0	4.7	3.7	3.5	1.9	1.3
23. Regulatory quality	3.3	3.7	4.3	4.3	3.0	1.4	1.0
24. Rule of law	2.3	2.7	3.0	3.3	1.0	1.3	1.4
25. Control of corruption	4.0	4.7	3.3	3.0	2.0	1.6	1.0
TPI	**5.1**	**5.9**	**5.7**	**5.8**	**5.1**	**4.4**	**3.7**

Table 6:Retrospective analysis – TPF – Amsterdam – 1672 to the present

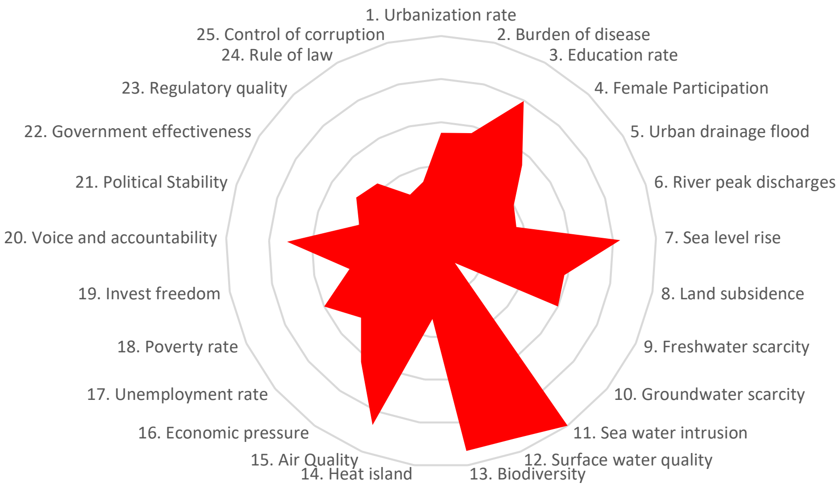
1672 – 1682



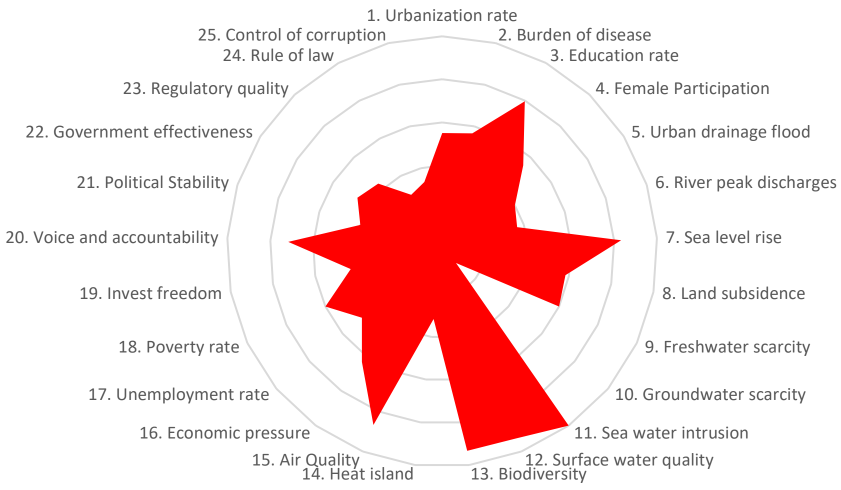
1780 – 1810



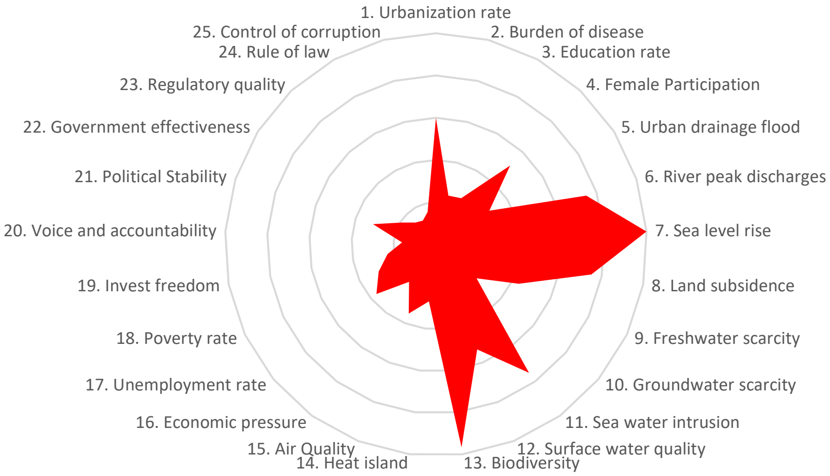
1845 – 1866



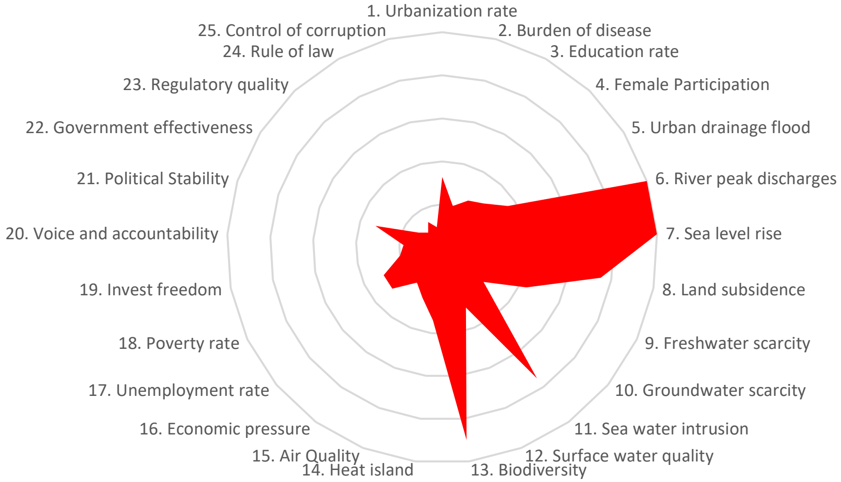
1845 – 1866



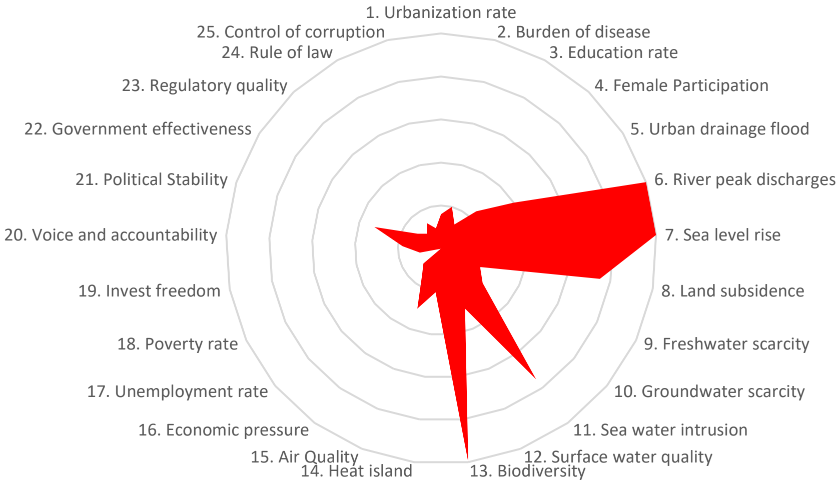
1930-1955



1970 – 1998 – 2006



2018 – present



4.2 Development of water management and governance in the city of Amsterdam

The city has seen many developments in the field of water management and governance. In Figure 14 the development of the CBF is visualized. What can be seen is that the more recent the more blue the city became, which indicates that Amsterdam improved its water management and governance during these times drastically. In this chapter more knowledge on the developments and the associated reasons will be shared which explains the seen developments of Figure 14. Literature research and interviews have been used to describe the developments in the category concerned for each period. The chapter is divided into: drinking water and health, wastewater treatment and treatment, solid waste, green space, and climate adaptation and planning and operation. Subsequently, the scores of the CBF are displayed, after which the development of the various indicators is mapped.

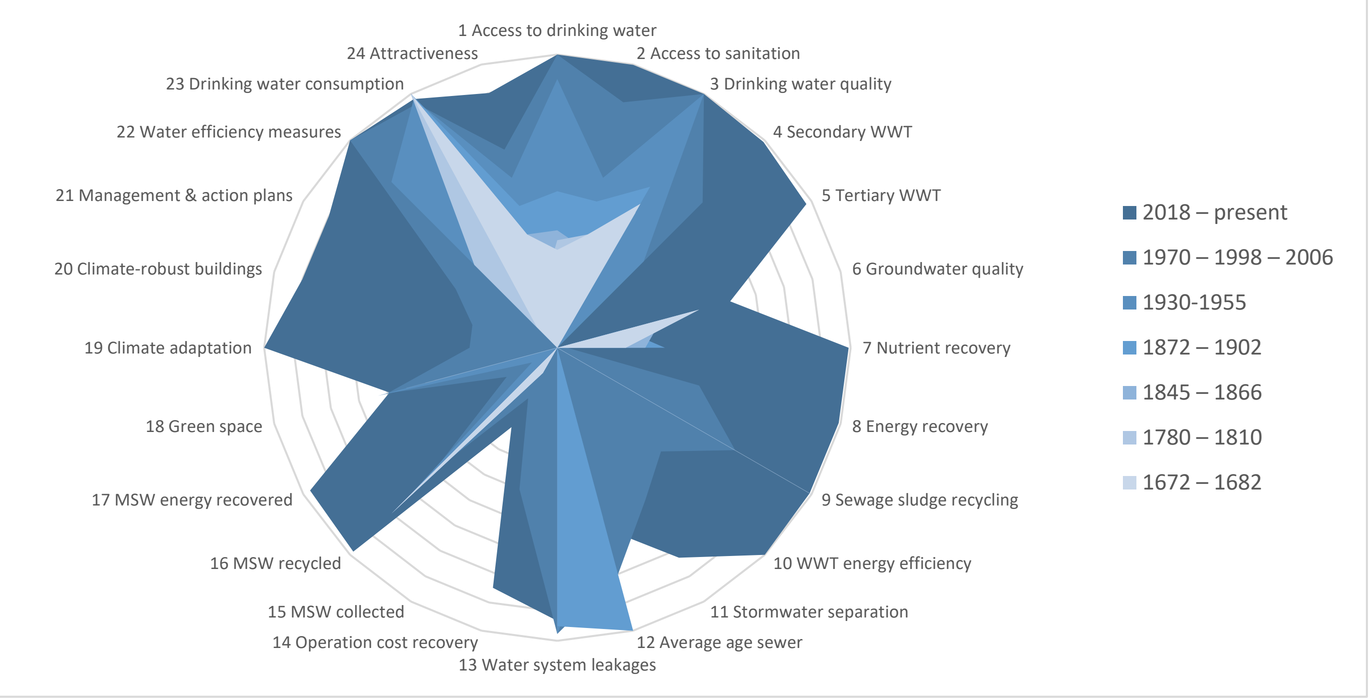


Figure 14: Development of CBF - Amsterdam

4.2.1. Drinking water and health

Fetching water by boat

In the beginning citizens were able to drink surface water e.g. the river Amstel. The channels and rivers were not polluted and there were many fishes in the water (Poortvliet, 2010). Only in harsh winters the provision of water was endangered. However, due to the increase of the population it became more difficult to keep the surface water clean. Which is why breweries in the city started to get drinking water from the Haarlemmermeer and the Vecht by boat (Groen, 1978). The drinking water was not only for the breweries' use, but they also sold it to the citizens. However, only rich people could afford water, so poorer citizens had to drink water from canals and rain barrels (Groen, 1978). Drinking water supply by ships was hampered in winter when the rivers were frozen (Maurik & de Baar, 1993). An icebreaker pulled by horses had to clear the waterway, but it was exhausting work and maintenance costs were high. Due to the water shortage and the great effort of icebreakers, the price of water in winter was very high, which meant that poorer people had less access. Dr. Sarphati saw that many sick people did not have access to clean drinking water. Therefore, Mayor Hudde (17th century) and Sarphati (19th century) built water tanks at public buildings and churches so that more drinking water was available for everyone

(Groen, 1978; Maurik & de Baar, 1993). However, this was not enough, especially in dry periods and the quality was not always good.

Challenges in providing water

Plans were regularly made to search for drinking water in the deep soil layers, but the drilling did not produce good results (Groen, 1978). There were many plans, but they did not get further than the establishment of the 'Versch-Water Societeit'. After a few harsh winters and problems with the drinking water supply by ship, the municipality became involved which resulted in the establishment of the organization 'Versch-Water Societeit'(Bokma, 1996; Maurik & de Baar, 1993). When the public administration got involved all kinds of rules and regulations were introduced and an agreement was made with the beer brewers. From then on the breweries fetched water for their breweries and the city's drinking water supply came into the hand of the public administration. The "Versch-Water Society" continued to fetch water from the river the Vecht, observing very punctually all strict regulations regarding the cleaning of the ship, and the regular water provision (Bokma, 1996). The large ships could not bring water into the canals due to their size, so the water was transferred to smaller ships that carried the water to the citizens. In the period 1825-1850 approximately 40 ships and 240 smaller boats were active. In 1806 the city council met the brewers by installing fresh water tanks (Groen, 1978). The twelve freshwater tanks were allowed to be rented by the brewers so that they had a reserve stock when the daily supply decreased. In 1789, the city council had underground drinking water cellars and tanks built that they filled with water from the Vecht to meet water demand (Poortvliet, 2010). The need for a supply of fresh water was fueled by incursions by the Prussians (1787). The drinking water status of Amsterdam from 1850 and before that is also seen in a number of developing countries. It takes a lot of effort to break the circle, which stands in the way of bringing good plans together and sufficient money (Groen, 1978).

First drinking water pipe

France and England were ahead in the development of drinking water infrastructure, but Amsterdam lagged behind (Groen, 1978). There were many initiatives, plans and even organizations that had all kinds of ideas about water supply, but due to lack of capital or cooperation from the city council, these failed. Amsterdam did not implement a drinking water system until 1850. The English and French ensured that Amsterdam made a breakthrough in the drinking water system. With the supply of capital in the form of English pipelines and machines and the perseverance of Jacob van Lennep, a drinking water pipe was constructed from the dunes at the coast to the city of Amsterdam (Biemand et al., 1983). Drinking water was obtained from the dunes where Jacob van Lennep, Ferdinand Huyck and other noble lords owned property. They founded the dune water company, which is responsible for the drinking water supply from the dunes to the city. A canal of 3500 meters long, 13 meters wide and 3.5 meters deep has been dug to supply drinking water from the dunes to Amsterdam (Groen, 1978). The canal ended in a bowl 'het Oranjewater', after which the water was pumped up with a steam engine and then transported to Amsterdam via a 23-kilometer pipeline system. The project was led by the English engineers John Aird, Charles Burn and Bland William Crocker.

December 12, 1853 was finally the day on which the first buckets of dune water could be collected in Amsterdam (Willemspoort). Shortly afterwards, the dune water supply system within the city began to advance. On April 7, 1854, the company announced that it would supply water to some neighborhoods (Biemand et al., 1983). The houses could subscribe to dune water pipes in the house. In 1866 there were 56 taps in the city where you could get a bucket of water. Some citizens were still concerned about the quality, but in 1854 some doctors declared that the drinking water was of sufficient quality to drink safely (Groen, 1978). Until 1870 ships remained active in fetching water from the Vecht, but this gradually ended. Dune water was of great hygienic importance, which was shown in the years of the previous years in the fight against cholera. In 1866, a Christian foundation was set up to provide free water to poorer residents of the city, which has contributed significantly to the preventive fight against cholera (Poortvliet, 2010). Because the demand for dune water continued to increase, an increase in the extraction and construction of a second pipeline from Leiduin (pumping station) to Amsterdam was necessary. The company had to borrow 1,700,000 guilders for the elaboration of this plan.

Increase of water consumption

The consumption of dune water increased strongly from 1853, there was a very strong population growth, and almost every house had a tap in the house, causing problems for the dune water company with the water supply (Biemand et al., 1983). The dune water company could not maintain the pressure of the water supply network in Amsterdam in the summer, so something new had to be developed. This development took a very long time due to all kinds of circumstances and much consultation. In 1885, the municipality granted the dune water company a new concession with the obligation to construct a pipeline for the supply of water from the river Vecht (Biemand et al., 1983). However, the water from the Vecht was not seen as suitable drinking water, which is why a double pipeline network was installed in the city. Which you can still see from the various manhole covers in the city. The water from the Vecht could not be supplied for domestic use, but was intended for the fire brigade, sewerage and industry (Biemand et al., 1983). In the concession of 1885, the municipality stipulated that the dune water company had to transfer a large part of its income to the municipality (Maurik & de Baar, 1993). This arrangement caused financial and technical problems for the company. The demand for dune water continued to increase, so capacity had to be increased. On July 6, 1889, an emergency measure was passed authorizing the dune water company to supply Vecht water in case of need for housing, but only for bath appliances, water boxes and garden sprinklers. Since 1885, part of the municipal council wanted the drinking water supply to become a municipal company (alderman Willem Treub). On May 1, 1896, the dune water company was taken over by the municipality of Amsterdam and the name was changed to municipal water pipes 'Gemeentewaterleidingen' (Biemand et al., 1983).

Water infiltration in the dunes

Further expansion was necessary due to population growth. However, many ideas were rejected because of health or other risks (Poortvliet, 2010). The municipal company decided out of necessity to significantly expand the dune water extraction in Leiduin and to construct new transport pipelines between Leiduin and Amsterdam (Groen, 1978). In 1916, Noord-Holland was ravaged by a major flood, as a result of which the municipal company supplied water to other cities for years (Biemand et al., 1983; Groen, 1978). The water supply has been increased by more intensive extraction of the deep dune water, as a result of which the deep fresh water supply has been consumed. In order to meet the demand, a start was made in 1932 with the supply of water from the Loodrechtse plassen (de Moel, Verberk, & van Dijk, 2012).

Ir. Bierman had studied Amsterdam's water supply during the war years. After the war he presented the report 'Report 1948' to the municipal councilor (Groen, 1978). In this report, a proposal has been made to construct a pipeline between the Amsterdam-Rhine Canal and the dune water extraction to supplement the dunes with river water. After the Second World War, the water supply in Amsterdam was given a firm foundation by carrying out plans indicated in the reports of the municipal council in 1940 and 1948 (Groen, 1978). The new plans include infiltration of the dunes and improvement and extension of the lake's water supply system. These plans were conceived and quickly implemented due to the rapid growth of the city and the growing water consumption. For this plan, the municipality and the province had to work together, which is why on December 14, 1950 a company was founded called N.V. Watertransportmaatschappij Rijn-Kennemerkland (WRK) (Groen, 1978).

From 1957, the WRK takes in water from the Rhine, after which it is filtered and then transported to the dunes (Poortvliet, 2010). The water from the Rhine replenishes drinking water in the dunes.

improvement of water quality

In Leiduin, the capacity has been increased to 54 million m^3 per year through modernization and expansion of the filter company (de Moel et al., 2012). In 1961 the old steam pumping station was decommissioned and a new pumping station with an electrically driven pump was put into use. In addition, a new transport line was built. Furthermore, in 1963 was an International Rhine Commission established in consultation with governments of various countries to make agreements to keep the river rhine healthy (Poortvliet, 2010). In the following years, the company's extraction capacity was increased by the construction of new infrastructure. The river Rhine became increasingly polluted and saltier, partly due to intensive agriculture and industry. The various drinking water companies that use Rhine water are joining forces and trying to tackle the problem at home and abroad (Poortvliet, 2010). In addition, the companies build in several treatment steps to be able to supply drinking water of good quality.

Most countries add chlorine to the drinking water to kill the bacteria and viruses, however the byproduct of chlorine can be carcinogenic (de Moel et al., 2012). Which is why drinking water company Gemeentewaterleidingen chose not to include chlorine in the process. From 1983 onwards, the company succeeded in providing reliable drinking water without adding chlorine. In times of emergency, however, there is always a chlorine dosage available (Poortvliet, 2010). Over the years, almost the entire dune area has become the property of the municipality of Amsterdam and has become a protected water extraction area (de Moel et al., 2012). The area around Leiduin is used as a nature reserve for recreationists. In recent years, Waternet has been fully engaged in the integration of water extraction and nature management (de Moel et al., 2012).

4.2.2. Wastewater disposal and treatment

Before the sewer system

Until the 19th century, it was very common to dump excrement and dirt into the canals via gutters. The canals in Amsterdam were an open sewer system (Werkman, 1982). As early as 1481 there were complaints in the city about the dirt and the stench. Despite the availability of partitions under the bridges, the situation did not improve. The water quality in the canals was poor because the wastewater was connected to the canals. Due to the open sewage system, diseases spread quickly and the odor nuisance was enormous (Werkman, 1982). To get the sewage out of the city, the canals were flushed by the tides (Smit, 2000; Werkman, 1982). The channels that were not flushed properly were dredged or were filled up (Poortvliet, 2010). Filling of canals is closing a canal in the city to ease up the traffic and to improve the air quality. Complaints about odor nuisance increased in the 19th century. This was due to the growing population in the city, who all lived within the Buitensingelgracht, (Poortvliet, 2010). In summers when the water level is lower, the odor nuisance was unbearable. In other European cities, sewers were installed at that time, but Amsterdam was left behind (London 1840, Hamburg 1842, Paris 1850) (Poortvliet, 2010). There was also a gradual understanding that poor hygiene conditions could be the cause of recurring epidemics of infectious diseases (diphtheria, tuberculosis, typhus, measles, red spark, and malaria). Infant mortality was very high and the city was more often ravaged by cholera or smallpox outbreaks. There were no sanitary facilities, only cesspools are buckets. There was some kind of sewerage, but most of it ended up in the canals. Furthermore, the industrial revolution exacerbated the problem with the discharge of wastewater from factories into surface water (Poortvliet, 2010; Werkman, 1982).

First attempt: The Liernur sewage system

The wastewater system got a better structure after the establishment of the Public Works Department (Dienst der Publieke Werken) in 1850. Because of the plan to build a North Sea Canal and the cholera epidemic of 1866, the municipality began to discuss and make plans for a sewerage system (Poortvliet, 2010). A solution had to be found for the discharge of wastewater as the construction of the North Sea Canal stopped the flushing system. In 1870, for the first time the Liernur sewer system came into operation (Smit, 2000). Before the municipality started applying this system, this initiative was already carried out on a small scale by private individuals. This system is the first large-scale sewerage plan in the city. In the system, feces is collected in reservoirs within a closed pipe system by means of vacuum and removed from there (Smit, 2000). It was collected at a central location, after which the feces could be used as fertilizer for the agricultural sector. In 1913 (decision 1906) the Liernur sewage system was discontinued because it did not meet the discharge of rainwater and domestic water (Smit, 2000). Water use increased due to the construction of the water supply. This made the feces too liquid which is why the system no longer functioned properly.

Construction of modern sewage system

In 1906 it was decided to build a mixed sewer system outside the city center (Riolering en waterverversing, 1976). The new main sewer brings in the water under the influence of gravity. The grqavity sewage system ended at the pumping station at Zeeburgerdijk 50, after which it was pumped to the IJsselmeer via a pressure pump (Smit, 2000). A mixed sewer system was chosen, because in terms of hygiene it does not matter which system was selected, moreover it is also much cheaper than a separate sewer (Smit, 2000). The collected wastewater was discharged into the Zuiderzee, later IJsselmeer without pre-treatment. Overflow of the sewage system was still discharged into the canals and the city center was also directly connected to the canals.

The wastewater to be processed fluctuated strongly due to the changing population and prosperity (Smit, 2000). After 1866, more wastewater had to be processed, because the city center was then also connected to the sewer system. The main reason for the construction of sewers in the center was the Environmental Hygiene Policy Document in 1977 (Smit, 2000). The construction of sewerage in the city center has been co-financed by the government work fund as an attempt to combat unemployment during the economic crisis. In 1926 the first large-scale wastewater treatment took place because of the construction of a wastewater treatment plant (WWTP) in Amsterdam west. In addition, the discharge took place by means of a separate sewer system. Another five WWTPs were constructed because of the large amount of wastewater from the fast-growing city (Smit, 2000).

After the Second World War, major changes took place in the field of wastewater. The quality of the sewage system was not only assessed on the basis of its importance for public health, the environment also received increasing attention. During this period many technical developments were made for wastewater drainage and improving the quality of the water. The new vision on the quality of waste and surface water increased investments in the sewer system. Citizens were willing to use financial resources to improve wastewater system. Moreover, the municipality was forced to invest due to the tightening of environmental standards. In 1977 a sewage treatment plant was constructed in the east, ending the discharge of untreated water (Smit, 2000).

Improvement of the wastewater system

By 2005 a new project started, the WWTPs in the East and the South could no longer comply with the new effluent discharge and environmental requirements (Ellenbroek & Persoon, 2006). Therefore, the public water authority of Amstel, Gooi and Vecht (AGV) and the municipality decided to build one new centralized WWTP in the Amsterdam West Port Area (van Nieuwenhuijzen, Havekes, Reitsma, & de Jong, 2009). In the new WWTPs, new technologies are being used which is why it operates well and produces a high-quality effluent. The treatment process removes nutrients at minimal chemical input, energy consumption is minimized, and the energy content of the sludge and biogas is utilized by the Waste and Energy Enterprise Amsterdam (AEB) (van Nieuwenhuijzen et al., 2009). The project is one of the largest infrastructure projects in Amsterdam in recent years. It was also labor-intensive work because a lot had to be constructed and adjusted (Ellenbroek & Persoon, 2006). Another project that has ensured that virtually no untreated wastewater ends up in the canals is the project 'Schoon Schip'. In collaboration with the municipality and Rijkswaterstaat, Waternet has worked to connect all houseboats to the sewerage system (Waternet, 2016)

4.2.3. Solid waste

Throughout the centuries, Amsterdam has always outsourced waste processing, taken it back into its own hands and then outsourced it, and so on (Kleijn, 2019). In 1673 the management of solid waste passed to the regents of the poor chapel orphanage. The chapel orphanage is a semi-governmental institution. The orphanage could use an extra source of income because due to the plague epidemic the organization had a lot of work to do. The municipality hoped that they could lower the subsidy to the orphanage, but they also tried to reduce the dirtiness on street. The orphanage could barely cope with the work: dirt remained on the street, residents complained, shortages ran up, reorganizations followed (Kleijn, 2019).

In 1804 the municipality outsourced the solid waste service to Nicolaus Sieburg and Martinus van der Aa (Kleijn, 2019). For 40 years they kept the streets clean, but there was little profit to be made which is why the company went bankrupt. In 1848, the contract to collect waste was taken over by the Association for Agriculture and Land Development run by Samual Sarphati (Kleijn, 2019). Sarphati probably had good intentions, but he also looked at the gains to be made. For example, he sold the residents' feces to the farmers. His goal was three-fold: to promote public health, improve agricultural land, and create employment (van Melle, 2003). Sarphati's second initiative was to set up a street sweeper service in 1850 to reduce pollution on the streets (van Melle, 2003).

The association did not last long, because the municipality took matters into its own hands again. A private urban cleaning service ' Dienst der Stadsreiniging' was established in 1877 (Kleijn, 2019; van Melle, 2003). The amount of solid waste was accelerated due to rapid population growth. on May 21, 1913, the city council decided that the municipal waste would be processed in a waste incinerator to be built in Amsterdam-Noord. The purpose of the incinerator was not only to get rid of the waste but also to produce electricity by converting heat into 'green' electricity (van Melle, 2003). five years later, the incinerator was commissioned with some delay as a result of the First World War. In 1919 the first incineration plant in Amsterdam was put into operation. The released energy could be used and the leftover remains used as building material (van Melle, 2003). In 1969 the old installation was replaced by a new installation with more combustion capacity.

In 2001, the city established six waste-collecting places where bulky household waste, hazardous waste, and electrical appliances are collected (van Melle, 2003). The waste collecting places are used to increase the reuse of bulky waste to a ratio of 70% (van Melle, 2003). Waste is no longer an annoying side effect of urban life: waste is an excellent raw material for the recycling of useful materials and "clean" energy generation (Kleijn, 2019). Profit can be made by recycling waste. In Amsterdam, the Municipal Waste Management Service was renamed Afval Energie Bedrijf (AEB) in 2003, which became independent in 2014 in order to develop into "the producer of sustainable energy in Amsterdam" (Kleijn, 2019). Moreover, the AEB expanded opened new furnaces and even started to import waste from abroad; one-sixth of all Dutch waste was processed in Amsterdam (Kleijn, 2019). In 2006 AEB entered into a partnership with Waternet. The collaboration, therefore, creates different synergies. The residual heat from the combustion gases can be used to make the treatment process more effective, the sewage treatment can run on the 'green' electricity generated by the incineration of waste, and the energetic yield of biogas, which is released during the purification of the sludge, can increase by a third (van Melle, 2003).

4.2.4. Green space and climate adaptation

Amsterdam has never had a low proportion of green/blue in the city. In the VOC and French time, Amsterdam scored well on greenery in the city, because the area that was cleared for city expansion was not fully built yet (Koning, 2020). During the industrial period, the population increased which is why the city expanded and became more compact (Koning, 2020). This caused a decrease in the share of green space in the city. However, in 1864 the Vondelpark was built in the middle of the polder providing citizens a place to enjoy nature (Poortvliet, 2010). The park is used intensively, causing the water quality to deteriorate (Poortvliet, 2010). From 1999 to 2010, large-scale renovations were carried out in the park to improve biodiversity and water quality (Poortvliet, 2010). The large city expansion in the course of time is shown in figure 15. The city also has other forests and green areas, such as the Amsterdamse Bos. Jacobus Pieter Thijsse created the forest in 1990 because he was concerned about the greenery in the city. The forest was created from 1927 to 1964. The Amsterdam forest makes a major contribution to the city, not only for nature but also for recreation Amsterdam.

The percentage of blue surface in the city is high, due to how the city is developed. From a historical perspective, the abundance of water was not only for the benefit of transport and drainage, but it also had great aesthetic value. Ever since the 17th, citizens prefer to live by the water and make frequent use of it (Poortvliet, 2010). The proportion of green space in the city can still be improved, which is why more and more attention has been paid to this in recent years. In 2007 the government adopted the national adaptation strategy. On January 1, 2014, Waternet started a program in collaboration with the municipality: Amsterdam Rainproof. The aim of the program is to make Amsterdam rainproof by 2050 (Amsterdam Rainproof, 2020). In addition to Rainproof, the municipality and Waternet do all kinds of climate adaptation projects. Moreover, Waternet is a water cycle company, which is why they integrate climate adaptation in all the projects.

Figure 15: City expansion of Amsterdam (Waternet, 2015)

4.2.5. Planning and operations

Ever since there was civilization in Amsterdam, there has been an administrative organization that cares about water. It starts with dike management and later also water level management. Water boards are established step by step. At the end of the seventeenth century, water management in Amsterdam was well organized. This was mainly due to Mayor Joan Hudde. In the disaster year of 1672, Hudde was appointed mayor and reappointed twenty times between that year and 1703 (Groen, 1978). Mayor Hudde made the city council take all kinds of decisions to keep the water system under control, such as the Hogesluis, the Amstelsluizen, mills, and various bridges (Groen, 1978). The construction of sluices made it possible to better regulate the water levels in the canals, so that dirty city water can be drained and cleaner water can flow into the canals from outside. During all the periods, the water tasks remain under municipal service (Poortvliet, 2010).

In 1970, the Pollution of the Upper Water Act was drawn up by the government. The law makes the province responsible for the purification of wastewater. As a result, the Zuiveringsschap Amstel- en Gooiland (1973) was established at the Amstel en Vecht water board in North Holland (Groen, 1978). The municipality retained its active purification task and the ability to collect pollution tax. In 1990 new legislation was introduced, the Water Management Act, which further delineated the water tasks. The city must hand over its water management tasks and wastewater treatment to the regional public water authority of Amstel, Gooi and Vecht (AGV). After much consultation, the Water Management and Sewerage Service (DWR) was established, which includes the tasks of both the municipality and the AGV tasks (Hogenes, 1997; Poortvliet, 2010). In 2006 Amsterdam decided to transfer the drinking water tasks to AGV, which resulted in the establishment of Waternet. Waternet was founded by the water board and the municipality and carries out tasks integrally. In other cities, all tasks are assigned to different organizations, but in Amsterdam, everything is housed in one organization. In the beginning, many were hesitant about the functioning of such organizations, but today it is often seen as an example for other cities (Poortvliet, 2010).

4.2.6. City Blueprint Framework

The final scores of the CBF framework indicators are shown in Table 7. When the data was available and the methodology of these indicators was applicable to the past times, the score was determined on the basis of the data. However, if the CBF method is not applicable to the past or if data are missing, the scores are determined on the basis of the interviews. The scores of the interviews were calculated based on five interviews, after which the interviews were averaged for the final scores. Furthermore, the scores were compared to the literature review the scores correspond to historical trends and developments. With the above method it is possible to sketch in a holistic view how water management has developed over the past centuries

Most important developments are reflected in the scores and the literature review:

- The turning point in the drinking water supply was the construction of a water pipe to the dunes. The quality of drinking water from the dune water has always been good
- Drinking water pipes have been of good quality since construction. As a result, there have been relatively few leakage losses over time.
- Construction of a mixed modern sewerage system starts in 1904. The old city center was not connected.
- After 1930 the separate sewerage system was used. This system was just not over applicable.
- In recent decades, houseboats have also been connected to sewerage
- The sewage system is often maintained and there is a policy to replace it every few years
- The first WWTP was built in 1921.
- Since 2006 there has been much improvement in the field of WWTPs and the recovery of substances from wastewater.
- Waternet is investigating in various projects how they can make the water cycle fully circular.
- Collecting waste from citizens remains a challenge for the city. It has improved a lot in recent years, but there is certainly much room for improvement here.
- Recycling waste has declined over time. She used to recycle almost everything. In the recent period, the AEB has managed to increase the score again. They now almost completely recycle everything.
- Extracting energy from waste processing is also almost maximal thanks to the new approach.
- The proportion of green and blue spaces in the city can be improved. After the second war, the share increased due to the construction of parks to create employment. However, it has not improved much in recent years.
- In 2007 the cabinet adopted the national adaptation strategy.
- On January 1, 2014, Waternet started a program in collaboration with the municipality: Amsterdam Rainproof. The goal of the program is to a rain-proof city by 2050.
- In 2006 there was a pinnacle in IWRM. Waternet was founded and became the first water cycle company in the Netherlands.
- Drinking water consumption has not been high in all periods, so it always scores almost maximum.
- The city has always been attractive to tourists, but after the construction of the sewage system it has become a lot more attractive due to the cleaner water and better air quality

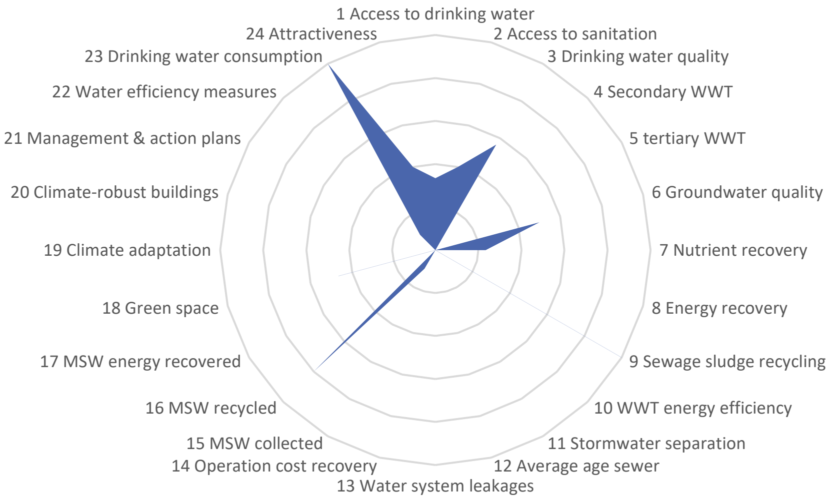
Table 7: CBF scores - Amsterdam

	1672 – 1682	1780 – 1810	1845 – 1866	1872 – 1902	1930-1955	1970 – 1998 – 2006	2018 – present
1 Access to drinking water	3.3	3.7	4.0	5.3	9.2	10.0	10.0
2 Access to sanitation	4.0	4.0	3.5	5.2	6.0	8.7	10.0
3 Drinking water quality	5.7	5.3	5.3	6.3	10.0	10.0	10.0
4 Secondary WWT	0.0	0.0	0.0	0.0	4.2	7.0	9.9
5 Tertiary WWT	0.0	0.0	0.0	0.0	0.0	3.0	9.8
6 Groundwater quality	5.0	5.0	3.7	2.3	2.7	3.7	6.1
7 Nutrient recovery	2.3	2.3	3.0	3.7	0.0	0.3	9.9
8 Energy recovery	0.0	0.0	0.0	0.0	0.0	5.0	9.9
9 Sewage sludge recycling	10.0	10.0	10.0	0.0	6.0	7.0	9.9
10 WWT energy efficiency	0.0	0.0	0.0	0.0	0.0	5.0	10.0
11 Stormwater separation	0.0	0.0	0.0	0.0	0.0	6.0	8.3
12 Average age sewer	0.0	0.0	0.0	10.0	6.0	8.0	6.4
13 Water system leakages	0.0	0.0	9.8	9.5	9.8	9.8	9.3
14 Operation cost recovery	0.0	0.0	0.0	0.0	0.0	5.0	8.5
15 MSW collected	1.0	1.0	1.0	1.0	1.0	2.0	3.1
16 MSW recycled	8.0	8.0	8.0	8.0	7.0	6.0	9.8
17 MSW energy recovered	0.0	0.0	0.0	0.0	1.0	2.0	9.7
18 Green space	4.7	5.3	4.3	4.0	6.3	6.0	5.9
19 Climate adaptation	0.0	0.0	0.0	0.0	0.0	3.0	10.0
20 Climate-robust buildings	0.0	0.0	0.0	0.0	0.0	3.0	9.0
21 Management & action plans	0.0	0.0	0.0	0.0	0.0	4.0	9.0

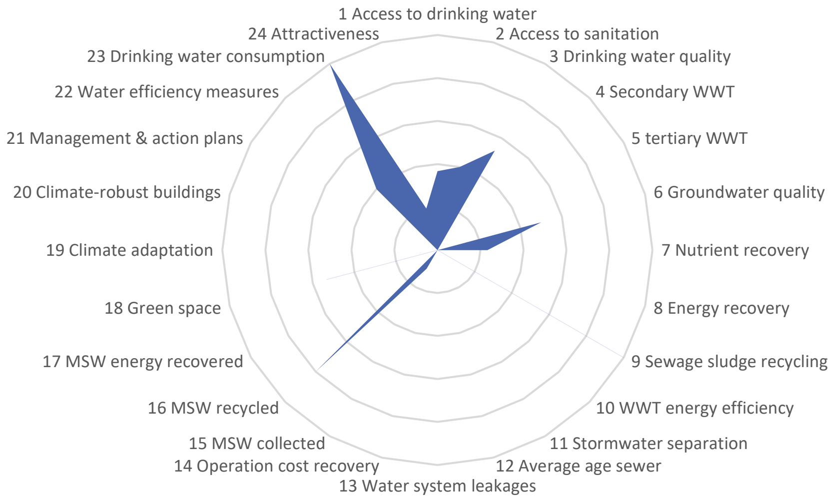
22 Water efficiency measures	1.0	4.0	4.0	4.0	8.0	10.0	10.0
23 Drinking water consumption	10.0	10.0	10.0	10.0	9.8	9.6	9.8
24 Attractiveness	4.0	2.0	4.0	5.0	6.0	7.0	9.0
BCI	**1.1**	**1.2**	**1.4**	**1.5**	**1.9**	**4.3**	8.7

Table 8: Retrospective analysis – CBF – Amsterdam 1672 - 2020

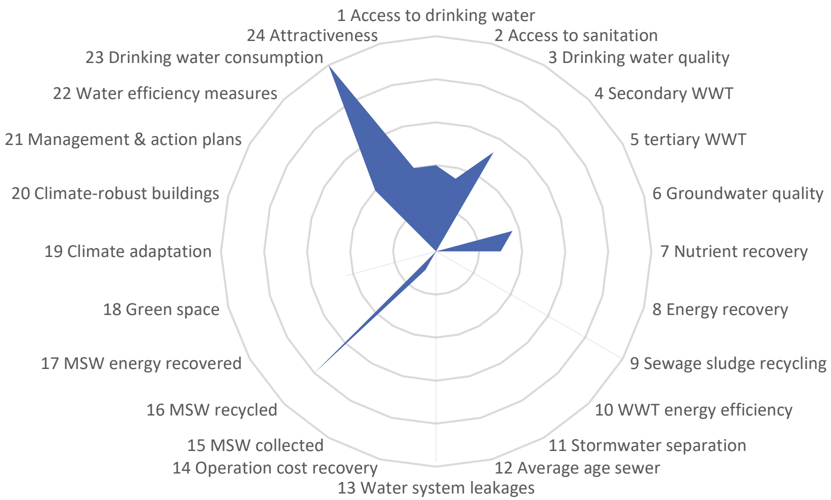
1672 – 1682



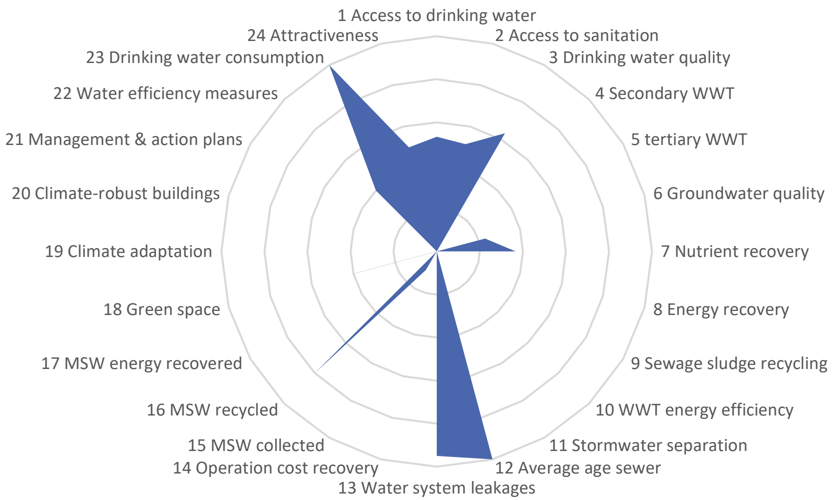
1780 – 1810

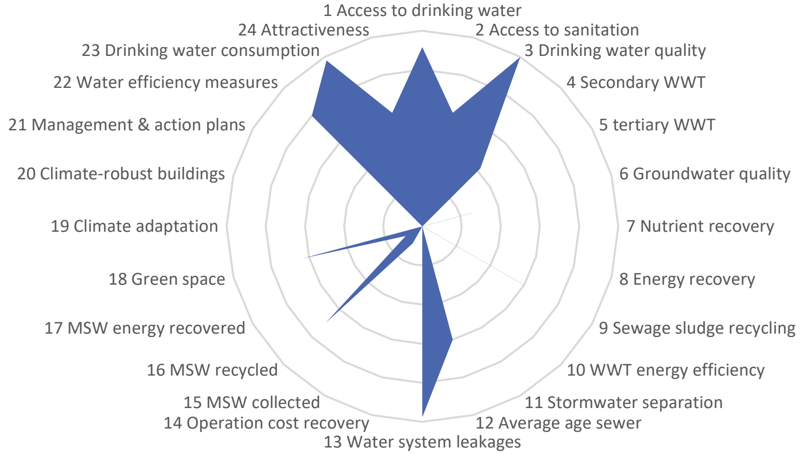
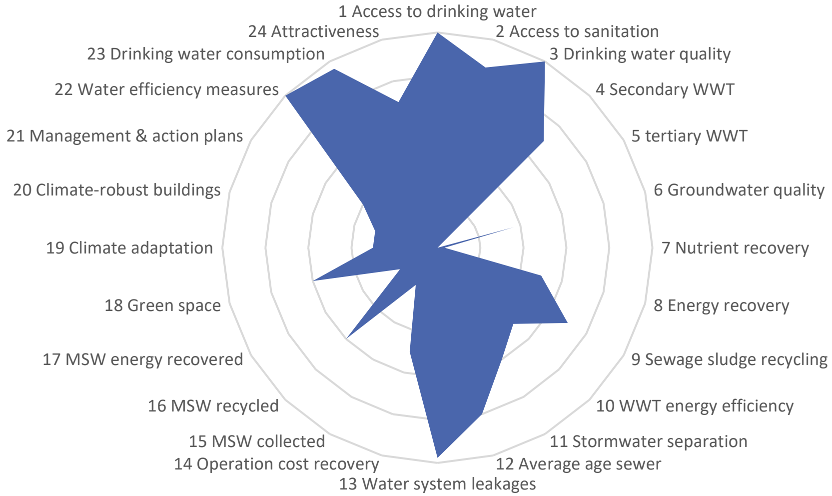


1845 – 1866



1872 - 1902



1930-1955	1970 – 1998 – 2006
	

2018 – present

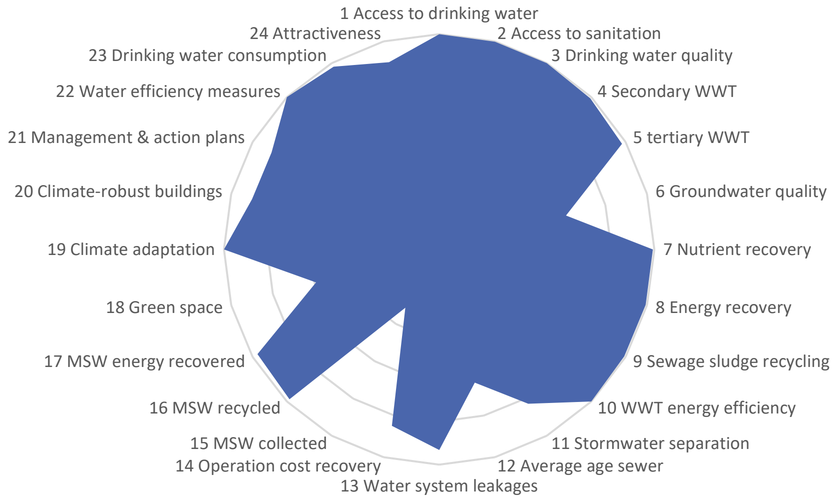


Figure 1: retrospective analysis - CBF

4.3 Differences and similarities with partner cities

Currently, 125 cities have been assessed with the City Blueprint approach. Waternet's partner cities; Berlin, Copenhagen, New York, Paris, and Singapore have also been assessed by the framework. Before the study, the CBA of Paris was missing, so at the start of the study, the city of Paris was assessed in terms of IWRM using CBA. The scores and data for Paris are presented in Appendix III.

Table 9 shows the differences and similarities in trends and pressures between the different cities. The more red color of the indicator indicates greater pressure on the city. The table shows that there are no large differences between the cities in the social indicators. Every city experiences little pressure from the social category. Moreover, the financial situation in the cities is also mutually comparable. The cities are all the capital of developed countries, therefore the financial situation of each city is good. The governance indicators also put little pressure on cities according to the TPF. A difference can be seen in indicator 19 Voice and accountability and indicator 20 Political stability. Singapore scores higher on vote and accountability, but lower on politics compared to the other cities. This can be explained by the way the government is organized in different cities. Singapore has a more centralistic and authoritarian form of government with limited freedom of the press, freedom of expression, and political activism, while the Netherlands, for example, has a more public administration (van der Wal, 2019)

There are some differences between the cities, especially in environmental trends and pressures. These differences arise partly due to different geographic locations. Amsterdam is below sea level, which means that sea-level rise and water intrusion score maximum, while Paris is not close to the sea, which means that this city is not under any pressure from these indicators. A similarity between the cities is that they have little trouble with groundwater scarcity and air quality. On the other hand, you see that many cities have a problem with urban drainage. Both New York and Paris score maximum and the other cities experience a moderate level of concern. Biodiversity is also a challenge for most cities due to limited space and infrastructure. In European cities, you see greater pressure on biodiversity compared to cities outside Europe.

Table 9: TPF scores partner cities Waternet

Categories	City	Amsterdam	Berlin	Copenhagen	New York City	Paris	Singapore
Social	1 Urbanization rate	2	1	1	2	2	3
	2 Burden of disease	2	2	2	2	2	2
	3 Education rate	1	3	2	1	3	1
	4 Female participation	2	3	2	3	3	3
Environmental	5 Urban drainage flood	4	5	4	10	10	4
	6 River peak discharges	10	8	5	0	0	10
	7 Sea level rise	10	0	3	3	0	8
	8 Land subsidence	8	3	3	5	0	3
	9 Freshwater scarcity	2	4	3	3	3	8
	10 Groundwater scarcity	3	3	3	3	3	3
	11 Sea water intrusion	8	0	8	8	0	3
	12 Biodiversity	10	10	6	3	10	0
	13 Heat risk	2	3	3	8	5	5
	14 Air Quality	3	4	3	1	2	5
Financial	15 Economic pressure	2	2	0	0	3	0
	16 Unemployment rate	1	1	2	1	4	2
	17 Poverty rate	0	3	0	0	0	0
	18 Investment Freedom	1	2	1	2	3	2
Governance	19 Voice and accountability	2	2	2	3	3	5
	20 Political Stability	3	4	3	4	5	2
	21 Government effectiveness	1	2	1	2	2	1
	22 Regulatory quality	1	2	2	2	3	1
	23 Rule of law	1	2	1	2	2	1
	24 Control of corruption	1	1	1	3	2	1
TPI score		**3.3**	**2.8**	**2.5**	**2.9**	**2.9**	**2.9**

The indicators of the CBF indicate how adequate water management arranged is in a city. Looking at Table 10, it can be concluded that Amsterdam and the partner cities all score very well on basic water supply. Each city scores a ten in terms of access to drinking water and sanitation and drinking water quality. This means that the population in the cities all have access to drinking water and sewage. Besides, the available drinking water is of very good quality.

However, a big difference can be seen in water quality. Each city scores well in the field of secondary and tertiary wastewater treatment. In New York City, however, there is still room for improvement in this area. Many interesting differences can be seen in the wastewater treatment category. Although the majority of the population in almost every city is connected to secondary and tertiary WWT, there are big differences in what the city does with the residual products of the WWT and how efficiently they work. The cities of Berlin, Copenhagen, and Singapore are well connected to secondary and tertiary WWT, but all three cities score poorly in terms of nutrient recovery. This means that the WWTP in those cities is not efficient in removing nutrients from the wastewater. On the other hand, all WWTs in the cities score well in extracting energy from the wastewater system and the system is very energy efficient. Furthermore, the cities of New York and Paris score lower in terms of sewage sludge recycling or reuse.

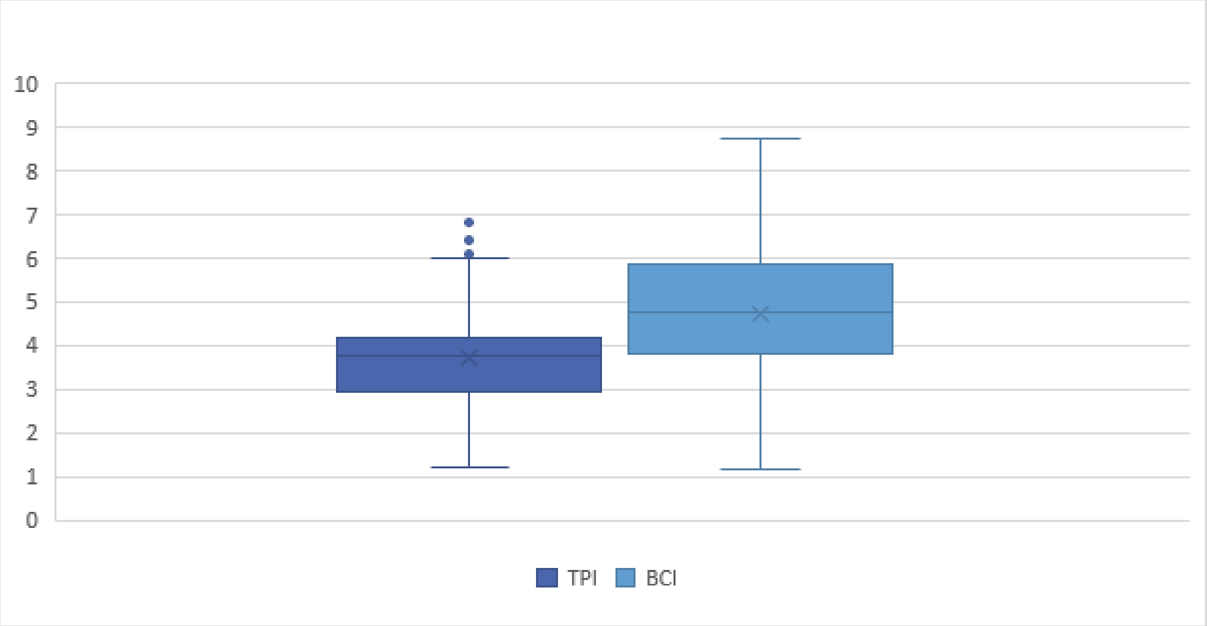
There are many differences between the cities in the category of water infrastructure. Not every city has a separate sewer system where stormwater and wastewater are separated. Amsterdam, Berlin, and Singapore have largely separate sewers, but Copenhagen, New York City, and Paris often have a mixed sewer system. The water system leakage is generally low in all cities. The operational cost recovery indicator is important because the higher you score, the more money is available to invest. Copenhagen and Amsterdam score well in this area.

In the cities, there is still much to be gained in the solid waste category. The scores are quite low, especially for waste collection. Only Singapore scores well on all three indicators in this category. Amsterdam and Copenhagen both score a 10 on solid waste recycling and energy recovery, but the waste production (solid waste collected) is high. In the climate adaptation category, you can see that this theme is discussed and implemented in every city. In this category there is only a big difference in the green spaces in the city. Singapore scores perfectly in the field of green space, while New York scores very low. New York can learn something in this area from how Singapore achieves a score of ten. The cities score very well in the plans and actions category. Only the city of New York consumes more drinking water per person compared to the other cities.

Table 10: CBF scores partner cities Waternet

Categories	City	Amsterdam	Berlin	Copenhagen	New York City	Paris	Singapore
Basic water services	1. Access to drinking water	10	10	10	10	10	10
	2. Access to sanitation	10	10	10	10	10	10
	3. Drinking water quality	10	10	10	10	10	10
Water quality	4. Secondary WWT	10	10	9	7	8	10
	5. Tertiary WWT	10	9	9	4	7	10
	6. Groundwater quality	6	6	6	3	9	9
Wastewater treatmen	10. Nutrient recovery	10	3	0	7	8	0
	11. Energy recovery	10	10	9	7	9	10
	12. Sewage sludge recycling	10	10	8	1	3	9
	13. WWT Energy efficiency	10	10	9	10	10	9
Water infrastructure	17. Stormwater separation	8	8	1	4	0	10
	14. Average age sewer	6	4	6	0	0	9
	16. Water system leakages	9	10	8	8	8	9
	15. Operation cost recovery	8	3	10	3	2	4
Solid waste	7. Solid waste collected	3	2	5	0	4	7
	8. Solid waste recycled	10	8	10	4	8	7
	9. Solid waste energy recovered	10	4	10	2	9	9
Climate adaptation	18. Green space	6	4	4	1	2	10
	19. Climate adaptation	10	10	10	10	10	10
	21. Climate robust buildings	9	10	10	10	10	10
Plans and action	22. Management and action plan	9	10	10	10	10	10
	23. Water efficiency measures	10	10	9	10	10	10
	20. Drinking water consumption	10	10	10	5	9	10
	24. Atractiveness	9	10	10	10	10	10
BCI score		**8.7**	**7.2**	**7.1**	**4.7**	**6.1**	**8.1**

In Figure 15, all TPI and BCI scores of all 125 cities are calculated using CBA and are outlined in a box plot. Looking at Amsterdam and its partner cities, all cities score a fairly low TPI score. Which means that the pressure of the indicators on the water system and society is low. Amsterdam falls within the first quartile, but the other cities are below the first quartile. Compared to all cities, the partner cities score very well in the BCI scores. New York scores about the average of all cities, but the rest of the cities are all above the third quartile and Amsterdam even scores the highest score of the data set.



Figuur 16: Boxplots TPI & CBF

4.4 Amsterdam's water future

Trends and pressures are constantly changing. To be able to anticipate the future, it is important to make a good prediction. Based on the interviews, scores were given for the indicators for the year 2030. These trends and explanations for the city of Amsterdam are shown in Table 11.

Table 11: TPF scores for the year 2030

Category	Indicator	Score	Trend	Explanation
Social	1. Urbanization rate	4.3	↑	The urbanization rate is expected to increase (CBS & PBL, 2017). It is unclear which effect COVID is going to have on the urbanization rate.
	2. Burden of disease	2.3	↑	According to Hogenes & Ouboter is the burden of disease slightly increasing due to COVID and the aging population. However, Mr. Koning expects that the indicator will decrease in 2030 because more resources will be available for the disabled so that they can participate more in society
	3. Education rate	3.3	↑	The interviewees expect a small increase in 2030 because budget cuts have made things unclear. Moreover, there is a shortage of qualified teachers.
	4. Female Participation	2.8	↓	It is expected that more females will participate in the labor market, because of a shortage of employees. Moreover, women are becoming more and more independent.
Environmental	5. Urban drainage flood	3.2	↓	Waternet is working hard in preventing urban drainage floods in the project Rainproof. Many measures are being taken to increase water infiltration in the city.
	6. River peak discharges	7.5	↓	The interviewees did not fully agree with the way this indicator is calculated. The scenario outlined is not possible, because the Amstel hardly drains and the chance from the IJ is also very small. That is why the interviewees score this indicator lower in 2030.
	7. Sea level rise	10.0	–	The pressure of SLR will remain the same since this process cannot be stopped that fast.
	8. Land subsidence	7.5	–	Waternet spends around 100.000 euros annually for land subsidence (AGV, 2019). From 2019 Waternet started with a strategy to slow down land subsidence. In addition to the strategy, the water board also determines new water levels in the 'nota peilbeheer' to decrease the subsidence rate (AGV, 2019).
	9. Freshwater scarcity	2.7	↓	In the future, Waternet will use more seepage water for dune infiltration which is why the freshwater will become less scarce.
	10. Groundwater scarcity	1.0	↓	According to the interviewees, hardly any groundwater is abstracted in Amsterdam because it is brackish water. And if there is groundwater abstracted, it is for infrastructure, but the amount is very low.
	11. Sea water intrusion	9.0	↑	In the future, the intrusion of seawater may increase due to the enlargement of the sea sluices and the failure of the pumps.
	12. Surface water quality	2.5	↓	According to the interviewees, agriculture around Amstelveen is becoming less intensive, which means that eutrophic substances are decreasing. Moreover, the treatment plant in Amstelveen is considered to be relocated or improved, causing better surface water quality. However, climate change could have a negative impact due to more sewer overflows and stagnant water.

	13. Biodiversity	8.3	↓	Hopefully, measures will increase biodiversity, but according to Mr. Ouboter, the policy of the municipality of Amsterdam concerning boats has a big effect on biodiversity.
	14. Heat island	3.6	↑	Heat stress is likely to increase as a result of climate change. Waternet and the municipality are taking measures to increase the proportion of green/blue.
	15. Air Quality	2.3	↓	Air quality is expected to improve in the future as a result of the policy for fewer cars in the city.
Financial	16. Economic pressure	2.3	↑	Economic pressures are likely to increase slightly as a result of the effects of COVID.
	17. Unemployment rate	3.3	↑	A slight increase is expected due to the economic consequences of COVID.
	18. Poverty rate	3.5	↑	According to the interviews, it will probably increase slightly due to the recent economic change.
	19. Invest freedom	3.3	↑	The future is deteriorating because there is less room to invest (bureaucracy) and ethical investing is increasingly playing a role.
Governance	20. Voice and accountability	2.3	↑	Some of the interviewees indicate that there will be less free speech in the future and that censorship will increase.
	21. Political Stability	3.5	↑	An increase in polarization and populism is expected.
	22. Government effectiveness	2.0	↑	Government effectiveness is declining due to inefficient policy and political pressure.
	23. Regulatory quality	2.0	↑	Decline is expected due to legislation and less freedom due to ICT.
	24. Rule of law	1.5	↑	Increasing pressure due to overregulation.
	25. Control of corruption	1.7	↑	The pressure remains the same because corruption has always been and always will be. It is impossible to lower the score further.

Future challenges and developments

The survey with experts from Waternet asked what the most important new challenges and developments in the field of water management and governance they expect in the coming years. Below, the most important developments are described under different themes.

Climate change

Most of those surveyed indicated that they consider the effects of climate change as the most important development for the coming years. The effects are already visible in the water system. Climate change is expected to increase the frequency, intensity, and impact of extreme weather events. More and more severe precipitation events are expected which affects the sewer system and drainage system. The sewer system has a certain capacity. If the capacity is exceeded, discharges into surface water take place, which is not good for the water quality and affects the ecosystem. There have been several overflows in 2020, and this is only expected to increase in the future. A solution must be found for this in the future. In addition, more and more dry and warm periods are expected which, during droughts, put more pressure on the water supply and affect the surface water. During warm periods people use more water which creates more pressure on the water system and affects the groundwater level. Due to the foundation of the houses, the groundwater level must be kept constant. If the level gets too low, there is more chance of subsidence. Due to the uncertainty about the effects of climate change on the system, it is important that the assets are robust and future-proof

Circular economy

One of Waternet's objectives is to manage the water cycle with 50% less environmental impact by 2030 through the use of raw materials and to achieve a fully circular economy by 2050 (no use of primary raw materials and no waste production) (Waternet, n.d.-a). Both the AGV water board and the municipality of Amsterdam want to make innovative use of the wastewater chain as a system that not only transports water but also functions as potential energy and raw material source (Waternet, 2020). Wastewater contains useful raw materials, such as phosphate, and it contains energy in the form of biogas and heat. In addition to extracting raw materials, the water system can also be used for alternative energy sources.

The construction of a new sanitary and wastewater system is necessary to achieve the objective. New sanitation is all about maximum recovery and local reuse of raw materials and energy. For this, the wastewater in the houses must be separated into a black water flow (from the toilets) and gray water flow (from the bathroom, washing machine, etc.). To this end, the traditional wastewater sewer is replaced by a multiple sewer system. With a new sanitary system, efficient local water treatment is possible and raw materials, heat, and energy can be recovered and reused as much as possible.

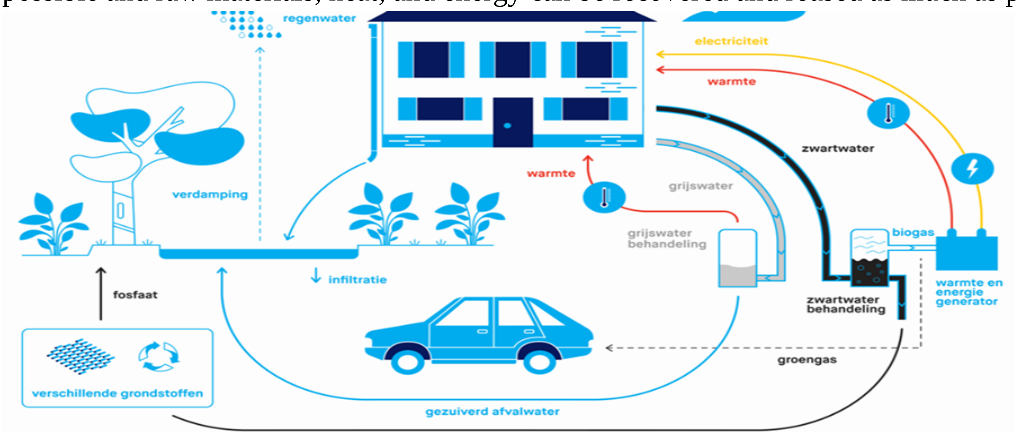


Figure 17: Principle of New Sanitation (Strucker, 2016)

Increasing pressure on the water system

The population continues to grow in Amsterdam, increasing the pressure on the water system. More people are using drinking water and sanitation but also surface water. However, space is limited, which poses challenges for water management and the municipality. Everyone wants to use the water and has the right to use the water. However, this collides with the sustainable use of water and the environment. An example is the use of the canals. The pressure on the canals is enormous due to the many functions. People want to live there (houseboats), citizens want to sail there, tour boats for tourists (commercial), aesthetic value for the city, drainage, cooling of the city in summer, biodiversity, etc. The question is still about how to deal with different user services and values.

Experts indicated in the study that the current production and distribution capacity may no longer be sufficient in the future. In addition, there is also the use of space in the subsurface. There are many cables and pipes in the subsurface. When creating a new system or expanding a system, it is difficult to find space underground.

Short-term vision

Projects and policy are often more focused on the short than the long term. Looking at the past, this has always been the case and will also pose a problem in the future. When making policy and cost-benefit analyzes, it is easier to investigate what effects this has in the short term rather than in the long term. Investments are often expensive when you look at the short term, but when you consider how robust and future-proof an asset is, the investment might be cost-effective in the long term.

Water infrastructure is the most expensive infrastructure. In the coming years, more pipes will have to be replaced, which will increase the pressure on maintenance and personnel. Money has been made available for the replacement task, but there is a shortage of employees. In the survey and interviews, it was indicated that they were not allowed to hire new ones while the workload on the team is increasing. Furthermore, according to the interviewees, the extra personnel are less technically trained, while technical knowledge is often lacking. Nowadays, more attention is paid to processes instead of specific steps.

The interviewee was also asked how water management and policy in Amsterdam can be improved to meet future and current challenges. Below is the experts' advice for future water governance and management outlined:

- Smart water management, the development involving more intensive cooperation in the region, is of vital importance in dealing with the original. The nexus between different themes are becoming increasingly important which is why more coordination between different stakeholders is vital.
- Strategy from a technical perspective: strategic water management. Management must focus on business operations and seek advice from strategic water management, instead of determining its own strategy with insufficient knowledge.
- Maintaining a water cycle organization.
- Long-term policy: not only looking at capital but also at long-term effects and sufficient and well-trained personnel.
- Water management and governance policies should not be related to political parties. Policy in water management is for several years, while politics is constantly changing, so policy should be less politically influenced. More direction from the city instead of politics.
- More attention to water in urban development. Water must come first for the habitability of cities. Currently, urban planning and design are still miles away from water management. Integrating visons are necessary for urban development.

- Stimulating citizen participation. to create more awareness among the population for water, it is important to get citizens to think along and to stimulate initiatives from the citizens.
- Improvement of biodiversity in cities. Greening the city is important for several challenges in the city. The greening of the city ensures, among other things, better drainage and reduces the heat effect.

4.5 Recommendations for city development and leapfrogging trajectories

There are many lessons to be learned from the past that can help the city, but also other cities facing rapid urban development. The retrospective analysis, interviews, and survey reveal several important lessons for urban development. The first thing is that development often follows a disaster or other unforeseen events (*reactive management approaches*). The system is constantly under pressure from many users and values. It is unclear when a disaster will occur and it is difficult to estimate how a disaster will develop, therefore it is better to avoid a crisis (*proactive management approaches*). A crisis can have disastrous consequences for public health (plague, cholera, etc.). It is very important to remember that water management and governance contribute greatly to public health and the quality of life in the city.

The growing population affects the entire city, including the water system. Urbanization influences drinking water, wastewater, solid waste, biodiversity, usage pressures, etc. When developing a city, every aspect of the water cycle must be taken into account. The pressure of use on the water requires regulation (spatial planning), not everything is allowed everywhere. The city tends to give developers and initiators free space and may lose its regulatory control and quality. Furthermore, all citizens want to use water, but according to most of the interviewees, more and more water is being privatized, when it should be a common good. Making water private in the city reduces the quantity and quality of water for the citizen. Therefore, it is important to find a balance between different users in the city and to combine different visions. According to one of the surveyors: "Multifunctional use of space is increasingly necessary due to lack of space in public space".

In addition to human influences on the water system and the city, it is also important to consider natural pressures and trends. More challenges in water management are expected due to, for example, sea-level rise, and climate change. As an urban planner, these challenges cannot be ignored, because water is everywhere and if you ignore it a disaster will happen. In order to cope with flooding challenges, it is important that a stand has sufficient drainage capacity via the sewer, but also space for water and greenery in the city. This is why in urban development plans the proportion of green and blue space should be taken into account. According to the surveyors and interviewees, this is necessary because of drainage, infiltration, climate adaptation, and the quality of life in the city. Moreover, if you change something in the water cycle, it affects other parts too. Therefore, there must be sufficient background knowledge before a project is implemented. If there is insufficient knowledge about the location, you will have to deal with unforeseen circumstances or the problems will be shifted elsewhere

Another aspect that is often overlooked in urban development is subsurface. Pipes and cables are laid underground during the construction of a new system or infrastructure. However, space is limited, making it difficult to store everything in the underground. Besides, the ground must be cleared during the maintenance of the pipes and cables, which causes a lot of inconvenience above ground. Provide underground space for the necessary systems that do not necessarily have to be under the main roads and ensure that it is properly ordered.

Another challenge seen with most developments is that the government is reluctant to invest because of the uncertainties and costs. However, investments are needed to improve the city and its systems. Many investments in water infrastructure are expensive, but in the long term it is often cheaper and the management saves money. So, dare to invest. In addition, involve managers in development projects, because some developments in the city have been carried out as a project outside the management organization. This can lead to management problems in the long term. Additionally, include citizens in decision-making, this will create more awareness and support. Looking at the past many developments started from citizen initiatives which are why communication with the citizens is crucial for the success of a project.

If the city council and water managers of the city now looked back to the past, they would probably have done a few things differently. The ideas of how they would have done something differently or perhaps taken a completely different path are important in finding leapfrogging trajectories. Other and new cities learn from the way Amsterdam has set up its water management and governance, but for these cities leapfrogging trajectories are very important, because then they can avoid the obstacles and problems that Amsterdam faced. Cities learn from trials and error, but if they transfer this knowledge to other cities, then they do not have to run into the same mistakes. That is why the surveyors were asked what they would advise if Amsterdam should be built now considering; construction of water infrastructure, and water management. In the next three paragraphs, the ideas of the surveyed will be summarized.

4.5.1. Water infrastructure

Below is a list of the type of water infrastructure that would be recommended with the knowledge the surveyors now have:

- Preservation of the city with a mixed sewer system. With the knowledge of now, we would choose a separate system. However, building the ring of canals has been a brilliant choice, typical of 17^{th}-century governance. The surveyor thinks that we would not have been able to do that in the same way. Nowadays we would maximize profit from the housing. In short: we have something to learn from the past.
- Provide a system that carries sufficient water storage capacity. The storage capacity was and is far too small. It does not always have to be in the form of surface water, but it can also be on roofs, etc.
- Provide a good foundation for houses to prevent damage due to the fluctuation of the groundwater level.
- Consider making tunnels for cables and pipelines so that with maintenance not always the streets have to be opened with all the inconvenience that comes with it.
- Separate the collection of black and gray water.
- Provide drinking water to citizens via pipelines
- Build reservoirs to collect sufficient water for larger applications (sprinklers, bath, etc.)
- Drain rainwater where possible via the street and open waters instead of pipes.
- Ensure sufficient groundwater replenishment via infiltration pipes and drainage pipes where necessary.
- Consider the location of the city, the location is not always suitable for building a city.
- The canals system still provides its worth in terms of drainage. Do not cluster all the drainage to one concentrated pool. Looking back the filled-in canals at the end of the 19^{th} century are now needed again.
- Better distribution of the distribution pumping stations, in terms of capacity.
- Consider a new design for the primary distribution network
- Built in such a way that it is easily adaptable/expandable. Existing systems are often built on for expansion of the city. This is often cheaper in the short term, but it is not aimed at the longer term, as bottlenecks arise that will become more and more difficult. Building on existing systems is at a certain point suboptimal With the urban expansion, you could opt for new future-proof extensions of the infrastructure.
- Connect directly to other infrastructure such as roads, tram lines, ICT, etc.. This is cost-beneficial in the long term.

- Make sure to use more permeable pavement and add more green to the city.
- Enforce the separate sewerage system in the whole city.
- Be less dependent on underground infrastructure for rainwater drainage.

4.5.2. Water management

The surveyors also advised on how they would manage the water system, what visions they would adopt, and how they would implement it. In the list all the ideas of the surveyors are listed:

- Ensure that you can discharge water in two directions. In the case of Amsterdam, that would be the North Sea and Markermeer/Ijsselmeer.
- Do not build leaky reclaimed land: Groot-Mijdrecht, Nieuwe Bullewijk, Horstermeer and Bijlmermeer, so that our hinterland would remain fresh.
- Implement integrated management of the water chain. This approach is unique in the Netherlands and should certainly be retained because it leads to higher efficiency, service provision, and sustainability.
- Take an integrated approach, also at the macro level.
- Provide sufficient own personnel for the maintenance of the system and to solve difficult problems. This will give more specific area knowledge and in case of a national problem enough own capacity. Moreover, it also ensures a higher service level.
- There should be enough asset managers across the entire water chain, including for the recovery of raw materials and energy.
- Build the city higher so you have fewer drainage problems.
- Ensure a sufficient flow of water.
- Focus on the short term. Develop more attention for strategic operation and maintenance, apart from the attention for changing the systems in projects. Constant evaluation of the system functioning will lead to a more efficient operation of existing assets.
- Link drinking water, groundwater, surface water, water quantity, and quality.
- Educate and raise awareness amongst the population.
- Control the connections to the sewer better. Make sure that there are no incorrect connections from wastewater to rainwater and vice versa.

4.5.3. Water governance

Lastly, the surveyors were asked to advise on how they would organize water governance in the city. For example, who should be responsible and what kind of policy should we make. All suggestions from the experts are given in the list below:

- The governance in the 17th century was ideal: water technology and city administration were closely linked (Hudde). An administrative layer that talks about the water and take decisions together is the modern variant. Considering water in conjunction (drinking water, wastewater, surface water, groundwater, precipitation water, evaporation/heat) is beneficial for the water system. Furthermore, the municipality should take the water cycle company more seriously.
- Integrated approach.
- Implement long-term policy (such as drinking water requirements) for all components. Moreover, align personnel policy with this, instead of as now short-term personnel policy and long-term asset policy.
- There should be one responsible administration for water tasks and no fragmentation. Over the centuries the water tasks in the Netherlands have become too fragmented.
- Link water governance with other agendas of the municipality
- Communicate the information and data well to the public by means of accessible websites.

- Focus on good behavior of the citizens and the business community.

4 Discussion

The aim of this study was to investigate how water management and governance evolved in the city of Amsterdam from the year 1672 to the present using CBA. This chapter evaluates the usability of CBA for retrospective analysis of IWRM in cities, discusses the limitations and strengths of the research, and proposes directions for further research.

5.1 Using the City Blueprint Approach for retrospective analysis

The CBA allows you to see at a glance how water management has changed over time. The TPF applied in different periods shows which pressures dominate and, based on the CBF, which subsequent actions have been taken to reduce these pressures. The analytical framework has proved useful for assessing water management and governance in the different historical periods. The comprehensive framework is described in detail, after which it can be applied to different cities and, as this research shows, also in different time scales. However, it is challenging to assess how water management and governance have changed over time and why this has changed. The complexity of the urban water system, the historical information provision, and the different perceptions about the indicators in the past make it difficult to apply the framework as such, as contexts and perceptions continuously change.

The connectivity between the indicators of both the TPF and the CBF is important to consider. For example, if the risk of flooding is high, which puts a lot of pressure on the city, the city usually implements measures in which the surface is paved. However, these measures are usually not good for the amount of green space which will reduce the biodiversity. It is therefore important when comparing cities on how well they are doing in the field of IWRM using the CBA method to look closely at the link between pressures and the measures.

The framework approach is based on contemporary times and the methodology is not tailored to assess the indicators in other time periods. For example, the experience and drinking water have changed over time. The water that people drank in previous centuries will not meet the recent quality requirements, but for the people who lived during the past centuries, the water quality may have been sufficient. Another example is the poverty rate, in the methodology they use the percentage of the population living below the poverty line of 1.9$ per day. The methodology is correct for the present time, but if you look at the history, the poverty line fluctuates, so it is not correct to use the methodology when scoring previous periods. Therefore, the scores of the TPF and CBF in the study are based on the interviews. Appendix I shows the scores of each indicator calculated with the current method in the periods versus the average score based on the interviews. The scores deviate significantly, but this can be explained by the fact that the CBA method is not fully applicable in the analysis.

Another point of discussion is the standardization of the indicators in the CBF. The indicators of the CBF are standardized according to the min-max method which is explained in the CBA questionnaires (Koop & van Leeuwen, 2020a,b). In historical context these minimums and maximums are constantly changing, making it unsuitable to use them for the other periods. For this study, the scores are therefore mainly based on the interviews described in the previous section. Nevertheless, the CBA provides an overview of how water management and governance have changed over time and provides learning experiences for the city and other cities. The method is therefore suitable for sketching the bigger picture, but less suitable for the details

For the results of the study and the answers to the research question, it is not a problem that the CBA method has been deviated from. The nature and concept are the same, only the scoring method has been changed. A holistic overview of what has happened per period in the field of water management and why these developments have taken place are sufficient to draw learning experiences. It is important to map these learning experiences in order to see how the city of Amsterdam has developed in this area.

Often only the future of a city is investigated, but you can learn many learning moments from the past that are also important to include in future plans. Cities can learn important practical lessons from the practices of other cities.

5.2 Research strengths and limitations

For this study, multiple interviews were conducted to score the indicators of the TPF and CBF in the different historical periods. The number of interviews could have been more, nevertheless it is not expected that the outcome of the holistic overview would be different. The stakeholders that were interviewed had a lot of knowledge about the historical events and could also justify them. In addition, the scores were checked and justified by means of literature research and review. There is a lot of qualitative information available on the subject in the past centuries. However, quantitative data is often lacking. Furthermore, when completing the scores, it is important that the interviewee has a good overview of the events and knowledge of all areas of water management and governance. For the research it is important that the interviewee has a good picture of the history and not a superficial picture. That is why only people who meet the knowledge requirements were interviewed.

A qualitative study was conducted for the leapfrog concept and advice for urban planners. The number of surveys appears to be low, but an extensive selection was carried out in advance to select people who carried out their projects in the Netherlands and abroad in different fields of water management. The extensive selection was necessary to select people with sufficient experience to share knowledge and advice on this subject

5.3 Further research

In order to give good advice on which leapfrog trajectories can be suggested for other cities, it is important to conduct a retrospective analysis in several cities. Because the learning experiences of other cities are important to compare with Amsterdam to investigate whether each city has followed approximately the same trajectory or whether there are large differences in decision-making and why they have taken a different route. Moreover, each city has different pressures that have caused cities to make different decisions. To get a complete picture of which decisions are strategic in which situations further research is recommended in different cities.

In this study, the scores of the different partner cities of Waternet were compared, but due to the limitation of time, it was not possible to investigate how the cities arrived at different scores and what decisions were behind this. It would be interesting to see what differences in strategies and developments each city has encountered in terms of water management and what underlying reasons and pressures were. Moreover, it is recommended to make the CBA method more suitable for assessing the indicators in a historical context. While the current approach provides a holistic view, it can be improved by examining how best to calculate past scores and how to incorporate the different levels and perspectives of each time. Another point of recommendation is to add an indicator for the quality of the surface water to the CBF. The quality of the surface water gives a good indication of how the city deals with water management and this indicator has been of great importance for the development of water management in Amsterdam over time.

Another recommendation is to conduct further research into historical developments in water management and water policy. There are still many lessons and knowledge to be learned from the past. This is why it is important that more historical research is done and that this is properly preserved, because the data and data of today can be very important for the future. The literature study showed that there is a lot of qualitative data available, but less quantitative, so it is advisable to properly document the data from the past and present in a database.

6 Conclusion

This study aimed to learn from past challenges and developments in water management and governance in the city of Amsterdam. In order to do so, the study addressed the following research question:

How did water management and governance evolve in the city of Amsterdam from the year 1672 to the present and what can be learned from this to enhance a city's ability to address its water challenges?

Amsterdam faced many challenges that had their effect on society and the infrastructure. These challenges have had an impact on the development of water management and how to water infrastructure is set up. The research showed that especially the social and economic indicators are the driving force behind a certain development. City council and government have not been a limiting factor during the time due to its stability and carrying capacity when needed. The environmental indicators such as seawater intrusion and land subsidence are important for the city, but because this has been a challenge since the Netherlands was founded, people have learned to live with this problem. The land is designed in such a way to deal with water. Furthermore, looking at the indicator surface water quality you often see this is the cause of a challenge, but the consequence such as a high burden of disease and urbanization are the driving force behind a change of the system.

If you look at how and when water infrastructure was built in the city, you can see that it was usually built as a result of a crisis or an international knowledge transfer. It is difficult to predict and avert a crisis in advance. Moreover, we often look at the short term instead of the long term. When constructing water infrastructure or water management, it is crucial to look at the long term, as it is expensive and essential for the quality of life in the city. However, solutions are often only sought in the short term, because the costs and benefits are easier to oversee. That is why a crisis is needed to make the city and the government realize that change is needed. Investing in preventive measures and initiatives appears to be effective in reducing the pressure on the city, system, and society. This can be seen during the cholera epidemic in 1865. Due to the construction of a clean drinking water supply, Amsterdam has fewer deaths from the cholera epidemic than in other cities. In addition, problems could have been prevented by looking more at the long term in developments and policy.

Challenges have been resolved in the past, but for example, the long-term impact on the environment has not been taken into account. There is now a lot of attention to biodiversity and green space in the city, but this should have been recognized in advance. When constructing a system in cities, it is useful to look at the problem from all sides, because it is all part of the entire water cycle. Assessing and solving with an integrated vision is therefore positive for the long-term solution. An integrated approach investigates more the long-term effects and also considers the side effects of problems. From the past it can be noted that citizens and individuals were essential for the city to meet the water challenges, therefore it is important to create awareness among the population and to include them in decision-making. Many initiatives and solutions for water problems are initiated by individuals and citizens. Water affects everyone in the city. It is a necessity of life, we live with it, we use it. It can be seen that in water management one cannot do without the other.

Another reason for the development of water management in the city is cooperation and knowledge transfer from other cities and abroad. This can be seen, for example, in the construction of the drinking water supply in Amsterdam. The Englishmen have played a major role in this. They not only transferred knowledge but also contributed financially because the Dutch government did not help. The drinking water system was developed under the guidance of private individuals and the Englishmen. Many of the initiatives to solve challenges in the city started with citizens' initiatives and private individuals. Financial capital, knowledge, and good mutual cooperation are essential in the construction and implementation of water infrastructure and management.

Hence, we can conclude an integrated vision, long-term goal, and the transfer of capital and knowledge with other cities and countries is essential in enhancing a city’s ability to address its water challenges. Moreover, much more can be learned from the past for the future. The past is the present.

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Appendix I: Retrospective analysis Amsterdam

INDICATORS TPF (CALCULATED WITH THE METHODOLOGY)

1. Urbanization rate

Calculation:

X = Urbanization rate (%)
Score urbanization rate = [(**X**– 0.0) / (4.6 – 0.0)] * 10

Score:

The urbanization trend started early in the Netherlands, already around 1400 was the country heavily urbanized, with about a third of the population living in towns (Paping, 2014). The coastal region experiences rapid urbanization between 1500 and 1650 due to the economic growth and trade during the Dutch Golden age. During the golden age urbanization rates of over 55% took place. The economic and population center shifted in this period from the inland to the coastal region. After 1700 a long phase of de-urbanization started in the region, the rate fell from 46% in 1700 to 37% in 1850 (Paping, 2014). In this period the Dutch population stagnated which resulted in the decline of the urbanization rate.

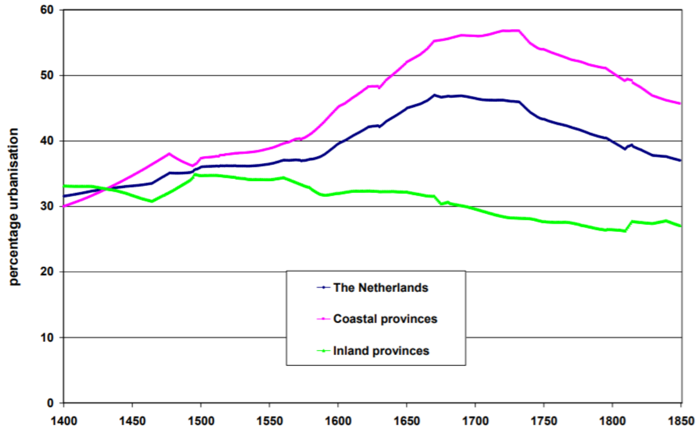

Figure 18: Urbanization in the Netherlands 1400-1850 (Paping, 2014)

	Percentage	Score	Final Score	Source
1672 – 1682	0.85714	1.863347826	1.9	(CBS & PBL, 2017)
1780 – 1810	-1.169589474	-2.542585812	0	(CBS & PBL, 2017)
1845 – 1866	1.384	3.008695652	3	(CBS & PBL, 2017)
1872 – 1902	3.05835	6.648586957	6.6	(CBS & PBL, 2017)
1930-1955	0.470588235	1.023017903	1	(CBS & PBL, 2017)
1970 – 1998 – 2006	1.48	3.209242068	3.2	Worldbank
2018 – present	0.74	1.608695652	2.2	Worldfactbook
2030	1.19	2.579710145	2.6	(CBS & PBL, 2017)

2 Burden of disease

Calculation:

DALY = Years of premature death + Years lost due to disability

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.

DALY per 100.000 people	Score	Degree of concern
0 - 8.000	0	No concern
8.000 - 16.000	1	
16.000 - 24.000	2	
24.000 - 32.000	3	Little concern
32.000 - 40.000	4	
40.000 - 48.000	5	Medium concern
48.000 - 56.000	6	
56.000 - 64.000	7	concern
64.000 - 72.000	8	
72.000 - 80.000	9	Great concern
81.000	10	

Score:

The burden of disease data from the WHO is available from the year 2000 to 2019. Before the year 2000 no data is available. Therefore, scores in earlier periods should be determined based on interviews. In the future life expectancy of both women as men in the Netherlands is expected to rise. This trend is mainly due to preventive measures and the improvement and availability of health care services. The RIVM expects by 2030 a continued decline in mortality from coronary heart disease and stroke. By 2030, dementia will be a major cause of death. Furthermore, chronic diseases are expected to increase due to ageing population, early detection, and health care improvements, however the number of active people will stay stable which means that people with chronic diseases not always or less experience burden. The projections of the RIVM shows us that in 2030 the highest disease burdens will be: coronary heart disease, mental illness, and diabetes. In 2030 the indicator will remain the score of 2 because of the longer life expectancy and stable experienced burden of disease.

	Data	Score	Source
1672 – 1682			
1780 – 1810			
1845 – 1866			
1872 – 1902			
1930 - 1955			
1970 – 1998 – 2006	21969	2	(Hoeymans et al., 2014)
2018 – present	18770	2	(Hoeymans et al., 2014)

3 Tertiary Education

Calculation:

TPF Score = [1- (X - min)/(max - min)]*10
X = World Bank value
Min = 6.4% (average of the lowest 10% of the countries)
Max = 96.6 % (average of the highest 10% of the countries)
NB All values of x > 96.6% score 0. All values < 6.4 % score 10
Where to get the data
World Bank http://wdi.worldbank.org/table/2.8

Score:

	Data	Score	Source
1672 – 1682			
1780 – 1810			
1845 – 1866			
1872 – 1902			
1930 - 1955	9.589491631	9.646	CBS
1970 – 1998 – 2006	59.63	4.0984	CBS & Worldbank
2018 – present	85	1.286	Worldbank, 2017

5 Urban drainage flood

Calculation:

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 (EEA 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. Lower 10% of all European cities assessed is 31.7%, top 10% has a share impermeable area of 69.6%.

Score:

	Data	Score	Source
1672 – 1682			
1780 – 1810			
1845 – 1866			
1872 – 1902			
1930 - 1955	9.589491631	9.646	CBS
1970 – 1998 – 2006	59.63	4.0984	CBS & Worldbank
2018 – present	85	1.286	Worldbank, 2017

6 river peak discharge

Calculation:

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	Level of concern
0 – 5	0	No concern
6 – 10	2.5	Little concern
11 – 20	5	Medium concern
21 – 40	7.5	Concern
40 – 100	10	Great concern

Score:

Over the centuries, Amsterdam has suffered from flooding from storm surges and peak discharges. the city started early on with measures and adaptations in the environment to protect itself. The chance of flooding from the rivers is very low, but the method assumes that no measures have been taken. If the environment had not been adjusted, Amsterdam would score a ten in every period.

	Score	Source
1672 – 1682	10	Literature
1780 – 1810	10	Literature
1845 – 1866	10	Literature
1872 – 1902	10	Literature
1930 - 1955	10	Literature
1970 – 1998 – 2006	10	(EEA, 2012b)
2018 – present	10	(EEA, 2012b)

7 Sea level rise

Calculation: 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).

Urban area affected (%)	**Score**	**Level of concern**
0 - 5	0	No Concern
5 - 10	2.5	Little concern
10 - 20	5	Medium concern
20 - 40	7.5	Concern
40 - 100	10	Great concern

Score:

The city of Amsterdam scores for the indicator sea level rise in all time periods a 10. this is due to the location and elevation of the city. The city is below sea level so without taking protection measures the city would be flooded.

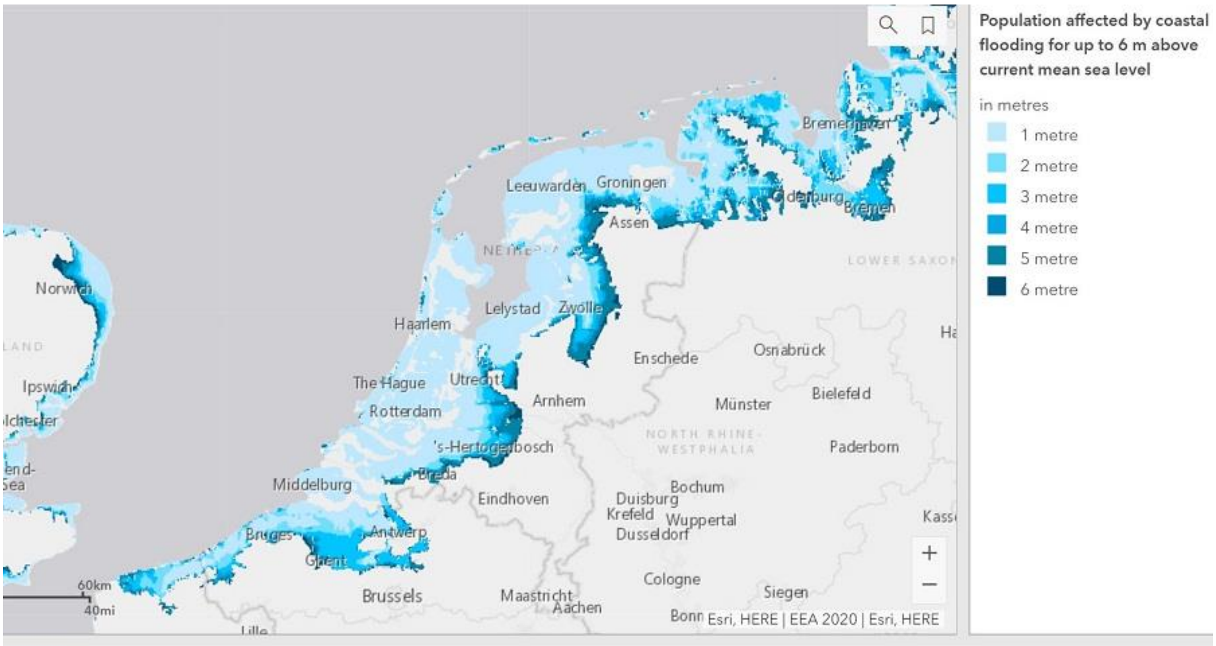

Figure 19: Population living within the respective height above mean sea level (in metres) (CReSIS/Eurostat, 2020)

Timeperiod	Score	Source
1672 – 1682	10	Literature
1780 – 1810	10	Literature
1845 – 1866	10	Literature
1872 – 1902	10	Literature
1930 - 1955	10	Literature
1970 – 1998 – 2006	10	Literature
2018 – present	10	Literature
2030	10	Literature

8 Land subsidence

The city of Amsterdam faces already for more than eight centuries which is due to the reclamation period (Gemeente Amsterdam, n.d.-b). Peat lands were dewatered, causing the soil to settle, resulting in soil subsidence. To live in the city, the ground height had to be raised already in 1200, but the extra layer of ground creates more pressure which accelerates the decline (Gemeente Amsterdam, n.d.-b). Changes in groundwater level, soil accumulation and soil compaction can intensify subsidence (Gemeente Amsterdam, n.d.-c). The city is raised by about five meter. Looking at the past, Amsterdam has always scored a 7.5 for the indicator land subsidence. With the current state of the art, soil subsidence will also score 7.5 in 2030. Hopefully, the measures taken will reduce the score in the future.

Many buildings in the city are build on wooden pilings because of soft ground beneath Amsterdam (Gemeente Amsterdam, n.d.-c). Subsidence and a change in groundwater level have a negative impact on the foundations and the houses. especially the houses in the center of the city are more likely to suffer foundation problems and the associated infrastructure damage. To prevent damage, the city invests in many measures, but they cannot stop the process of subsidence. Not only the city and the citizens have to invest in measures, but also waterboard AGV and Waternet are investing in measures such as adapting the groundwater level to the main functions and to avoid damage. The additional costs / damage to infrastructure in the urban area of the Netherlands due to soil subsidence is estimated at 1.7 to 5.2 billion euros (van den Born et al., 2016). The repair costs of foundations in the Netherlands are estimated at a minimum of 16 billion euros (van den Born et al., 2016). Waternet spends around the 100.000 euro annually for land subsidence (AGV, 2019). From 2019 Waternet started with a strategy to slow down land subsidence. In addition to the strategy, the water board also determines new water levels in the 'nota peilbeheer' to decrease the subsidence rate (AGV, 2019).

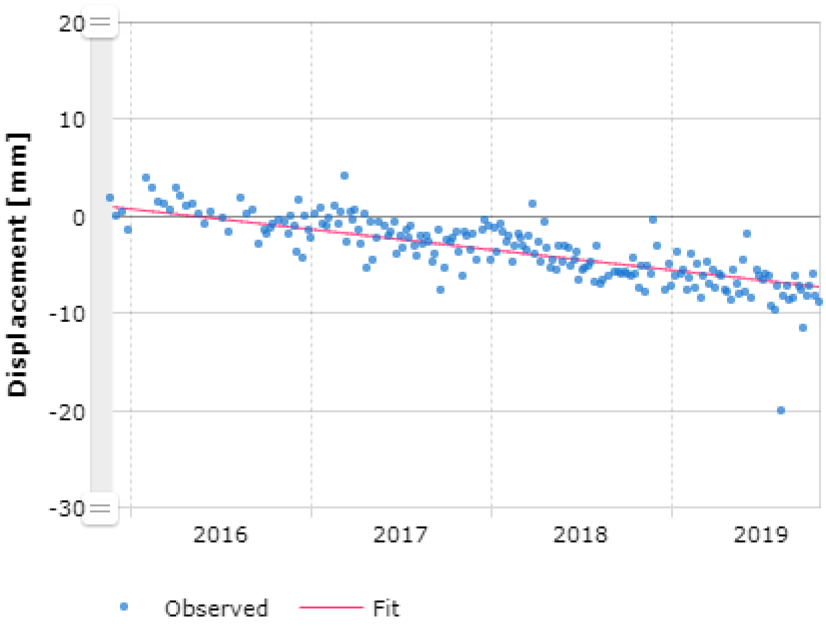

Figure 20: mm subsidence per year (Bodemdalingskaart.nl, 2020)

Timeperiod	Score	Source
1672 – 1682	7.5	Literature
1780 – 1810	7.5	Literature
1845 – 1866	7.5	Literature
1872 – 1902	7.5	Literature
1930 - 1955	7.5	Literature
1970 – 1998 – 2006	7.5	Literature
2018 – present	7.5	Literature
2030	7.5	Literature

14 Air quality

Principal: The measurement of air quality consists of the measurement of particular matter.
Calculation:
X_1 = PM2.5
X_2 = PM10
If there is only a value for X_1 than use:
$[(X1-5.1)/(63.6-5.1)]* 10$
If there is only a value for X_2 than use:
$[(X2 - 9.5)/(118.9 - 9.5)] *10$
If X_1 and X_2 are both available use:
$[(X1-5.1)/(63.6-5.1)]* 5 + [(X2 - 9.5)/(118.9 - 9.5)] * 5$
World Health Organization (2018) WHO Global Ambient Air Quality Database (update 2018) https://www.who.int/airpollution/data/cities/en/

Score:

	PM10	PM2.5	Score	Source
1672 – 1682	N/A	N/A		
1780 – 1810	N/A	N/A		
1845 – 1866	N/A	N/A		
1872 – 1902	N/A	N/A		
1930 - 1955	N/A	N/A		
1970 – 1998 – 2006	30.6	N/A	1.9	(CBS, 2015)
2018 – present	21	13	1.2	(WHO, 2018)
2030	20.7	22	1	(Gemeente Amsterdam, 2019a)

15 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. We use the Gross national income per capita Atlas method in USD

Calculation method
TPF score = 10 – [(X – min) / (max – min)*10]
where:
X = GDP per capita per year (US$)
min = 583 US$/cap (average of lowest 10% of the values)
max = 61327 US$/cap. (average of highest 10% of the values)
NB All values of x > 61327 score 0. All values < 583 score 10
Score:

	Data	Score	Source
1672 – 1682			

1780 – 1810	73.92	10.08380745	Dutch GNP and its components
1845 – 1866	110.78	10.07773937	Dutch GNP and its components
1872 – 1902	135.97	10.07359245	Dutch GNP and its components
1930 - 1955	1068	9.920156723	Worldbank
1970 – 1998 – 2006	44863.40	2.7103253	Worldbank
2018 – present	52447.831	1.461735974	Worldbank, 2019

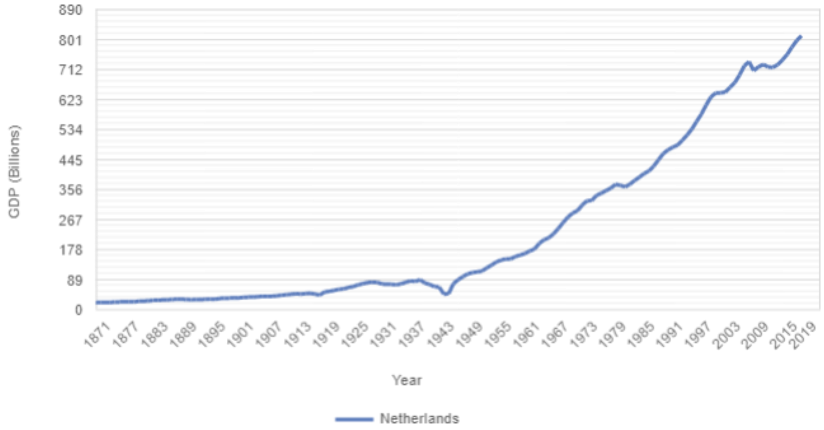

Figure 21: GDP Netherlands (Smits, Horlings, & Zanden, 1913)

16 Unemployment rate

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

Calculation method

TPF Score = [(**X** - min)/(max - min)]*10

X = Unemployment rate (%)

min = 1.4% (average of lowest 10% of the values), max = 18.2% (average of highest 10% of the values)

NB All values of x > 18.2% score 10. All values < 1.4 % score 0

Figure 22: Unemployment, 1800-1913 (%) (Centraal Bureau voor de Statistiek, 2010)

	Data	Score	Source
1672 – 1682			
1780 – 1810	2.76	0.80952381	Twee eeuwen beroepsbevolking, cbs
1845 – 1866	4.65	1.93452381	Twee eeuwen beroepsbevolking, cbs
1872 – 1902	3.46	1.226190476	Twee eeuwen beroepsbevolking, cbs
1930 - 1955	1.26	-0.083333333	Twee eeuwen beroepsbevolking, cbs
1970 – 1998 – 2006	5.00	2.144047619	Worldbank, 2006
2018 – present	3.197	1.069642857	Worldbank, 2019

17 Poverty rate

Principal: Percentage of people that is below the poverty line of 1.9 *US$* a day.

Calculation

TPF Score = [(**X** - min)/(max - min)]*10

X = Poverty rate (%)

min = 0 % (average of lowest 10% of the values)

max = 59.9 % (average of highest 10% of the values)

NB All values of x > 59.9% score 10.

Score:

	Percentage	Score	Data
1672 – 1682			
1780 – 1810			
1845 – 1866			
1872 – 1902			
1930-1955			
1970 – 1998 – 2006	0.1	0.016694491	Worldbank
2018 – present	0.1	0.016694491	Worldbank

18 Investment Freedom

Calculation:

The Investment freedom index evaluates a variety of investment restrictions (burdensome bureaucracy, restrictions on land ownership, expropriation of investments without fair compensation, foreign exchange controls, capital control, security problems, a lack of basic investment infrastructure, etc.). Points are deducted from the ideal score of 100 for each of the restrictions found in a country's investment regime. High scores are obtained if the investment freedom is low.

TPF Index score = (100 – X) / 10

Data: https://www.theglobaleconomy.com/rankings/herit_investment_freedom/ Or: https://www.heritage.org/index/ranking?version=439

Score:

	Percentage	Score	Data
1672 – 1682			
1780 – 1810			
1845 – 1866			
1872 – 1902			
1930-1955			
1970 – 1998 – 2006	0.1	1.0	(Heritage.org, 2020)
2018 – present	0.1	1.0	(Heritage.org, 2020)

19 – 24 Governance indicators of the World bank

Data are available from 1998 from the database of the World Bank. Previous periods should be consulted through literature research and interviews.

INDICATORS CBF

1 Access to drinking water

Calculation:

X = Percentage (%) of total urban population with access to potable drinking water.

Indicator 7 = $\frac{\mathbf{X}}{\mathbf{10}}$

Score:

1682	Drinkwater from the river Vecht. Transported by boats. Score=3
1810	Saving drinking water in tanks. Score = 4
1866	Start of dune water system. Score=5
1902	The demand for dune water continued to increase, so capacity had to be increased. Expansion of water pump station. Score= 8/9
1955	Expansion of water pump station. Infiltration of river water in the dunes. Score=10
2006	In Leiduin, the capacity has been increased to 54 million m3 per year through modernization and expansion of the filter company. Score=10
Present	10

2 Access to sanitation

Calculation:

X = Percentage (%) of total urban population with access to proper sanitation facilities.

	Percentage	Score	Data
1672 – 1682			
1780 – 1810			
1845 – 1866			
1872 – 1902	• Construction of liernur system (1870 - 1906) • Construction of modern sewer system (1990)	3	Literature
1930-1955	Construction rainwater sewage (1955)	8	Literature
1970 – 1998 – 2006	From 1986 all houses are connected to the sewage system	9	Literature
2018 – present	Connection of boats to sewage system	10	Literature

3 Drinking water quality

Calculation:

The result is expressed as a percentage of the samples meeting the applicable standards.
X = Total number of samples meeting standards
Y = Total number of samples

Indicator 9 = X/y * 10

Score:
The quality of the drinking water has been good since the construction of dune water in 1853. Before that, the quality was of poor quality. The water from the Vecht was drinkable, but was not purified. If there was no drinking water from the Vecht available, citizens had to drink water from the canals or drinking water tanks.

	Score	**Data**
1672 – 1682	3	Literature
1780 – 1810	3	Literature
1845 – 1866	10	Literature
1872 – 1902	10	Literature
1930-1955	10	Literature
1970 – 1998 – 2006	10	Literature
2018 – present	10	Literature

4 Secondary WWT

Calculation:

How to calculate
X = Percentage of population connected to secondary sewage treatment. We assume that there is only tertiary treatment after secondary treatment has been done.

Definition secondary WWT: 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).

Indicator 4 = X/10

Score:
The first WWTP was in 1921. The scores after that must be determined on the basis of interviews.

	Score	**Data**
1672 – 1682	0	Literature
1780 – 1810	0	Literature
1845 – 1866	0	Literature

1872 – 1902	0	Literature
1930-1955		
1970 – 1998 – 2006		
2018 – present	10	Literature

5 Tertiary WWT

Calculation:

How to calculate

X = Percentage of population connected to tertiary sewage treatment.

Indicator 5 = X/10

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, color, etc.) (OECD, 2013).

Score:

The first WWTP was in 1921. The scores after that must be determined on the basis of interviews.

	Score	**Data**
1672 – 1682	0	Literature
1780 – 1810	0	Literature
1845 – 1866	0	Literature
1872 – 1902	0	Literature
1930-1955		
1970 – 1998 – 2006		
2018 – present	9.9	Literature

6 Groundwater quality

Calculation:

X = Number of samples of ‘good chemical status’

Y = Number of samples of ‘poor chemical status’

Indicator 6 = X / (X+Y) x 10

Score:

The scores were determined on the basis of the interviews. Tests have already been done around 1800, but the 'good' or 'bad' quality status has changed over time.

	Score	Data
1672 – 1682		
1780 – 1810		
1845 – 1866		
1872 – 1902		
1930-1955		
1970 – 1998 – 2006		
2018 – present	6.1	Literature

7 Nutrient recovery

Calculation:

A. Wastewater treated with nutrient recovering techniques at the wastewater treatment plants (Mm^3 $year^{-1}$)

B. Total volume of wastewater passing the wastewater treatment plants (Mm^3 $year^{-1}$)

Indicator 7 = $\frac{\boldsymbol{A}}{\boldsymbol{B}} * \frac{\%\ \textbf{secondary WWT coverage}}{100} * \mathbf{10}$

Score:

No data found in literature, therefore these scores must be determined by experts.

	Score	Data
1672 – 1682		
1780 – 1810		
1845 – 1866		
1872 – 1902		
1930-1955		
1970 – 1998 – 2006		
2018 – present	9.932	

8 Energy recovery

Calculation:

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).

Indicator 8 = $\frac{C}{D} * \frac{\%\ \text{secondary WWT coverage}}{100} * 10$

Score:

No data found in literature, therefore these scores must be determined by experts

	Score	Data
1672 – 1682		
1780 – 1810		
1845 – 1866		
1872 – 1902		
1930-1955		
1970 – 1998 – 2006		
2018 – present	9.932	

9 Sewage sludge recycling

Calculation:

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)

Indicator 9 = $\frac{C+D}{A} * \frac{\%\ \text{secondary WWT coverage}}{100} * 10$

Score:

No data found in literature, therefore these scores must be determined by experts.

	Score	Data
1672 – 1682		
1780 – 1810		
1845 – 1866		
1872 – 1902		
1930-1955		
1970 – 1998 – 2006		
2018 – present	9.932	

10 WWT energy efficiency

Calculation:

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	the topic is addressed in a chapter at the national and local level
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 plus subsidies are made available 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
10	as 9 and the activity is in place for = 3 years

Score:

First WWTP was build in 1921, therefore first four periods score 0. the next 2 periods must be consulted through interviews.

	Score	Data
1672 – 1682	0	Literature
1780 – 1810	0	Literature
1845 – 1866	0	Literature
1872 – 1902	0	Literature
1930-1955		Literature
1970 – 1998 – 2006		Literature
2018 – present	10	Literature

11 Stormwater separation

Berekening:

A. Total length of combined sewers managed by the utility (km)

B. Total length of stormwater sewers managed by the utility (km)

C. Total length of sanitary sewers managed by the utility (km)

Indicator 11 = $\frac{B+C}{A+B+C}$ x 10

Score:

In 1955 the idea of a separate sewerage system arose. Before that it was a completely mixed sewer system. That is why the indicator scores a 0 in the first 5 steps.

The number of meters of pipelines for the year 2006 is unknown, but we do know for the year 2007, so we calculate with the data from 2007 (assuming that not much has happened in a year).2007:

DWA	Gemengd	Totaal
720.8473	428.3309	1414.148

Score indicator= 6.27272

	Score	Data
1672 – 1682	0	Literature
1780 – 1810	0	Literature
1845 – 1866	0	Literature
1872 – 1902	0	Literature
1930-1955	0	Literature
1970 – 1998 – 2006	6.3	Literature
2018 – present	8.3	Literature

12 Average age sewer

Calculation:

X = Average age sewer

Indicator 12 = $\frac{60-X}{60-10}$ x 10

Score:

The modern type of sewerage was built in 1906. The system is replaced every 40 to 60 years. In addition, the system is cleaned every 5 years.
2006:
I assume that the sewerage system was eleven years younger in 2006 than in 2017, so 30-11 = 19 years. The score of the indicator is then: 8.2
2017: Indicator scores a 6, which means that the average age of the sewerage system is 30 years.

	Score	Data
1672 – 1682		
1780 – 1810		
1845 – 1866		
1872 – 1902	10	Interview
1930-1955	6	Interview
1970 – 1998 – 2006	9	Interview
2018 – present	6.4	Interview

13 Water system leakages

Calculation:

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.

X = Water system leakages (%)

Indicator 13 = $\frac{50-X}{50-0}$ x 10

Score:

Literature showed that since the construction of water pipes in Amsterdam, the city has suffered little from leaks. That is why the scores have been estimated to be high since the construction of the system.

	Score	Data
1672 – 1682		
1780 – 1810		
1845 – 1866	9	Literature
1872 – 1902	9	Literature
1930-1955	9	Literature
1970 – 1998 – 2006	9	Literature
2018 – present	9.3	Literature

14 Operation cost recovery

Calculation:

$$\text{Operating cost recovery (ratio)} = \frac{\text{Total annual operational revenues}}{\text{Total annual operating costs}}$$

X = Operating cost recovery (ratio)

$$\textbf{Score indicator 14} = \frac{\mathbf{X - 0.33}}{\mathbf{2.34 - 0.33}} \textbf{ x 10}$$

Calculation:

	Score	Data
1672 – 1682		
1780 – 1810		
1845 – 1866		

1872 – 1902		
1930-1955		
1970 – 1998 – 2006	5	Waternet
2018 – present	8.5	Waternet

15 MSW collected

Calculation:

X = kg/cap/year of collected solid waste. The min-max method is applied. Here the lowest and highest 10% produced solid waste of all countries that are available is taken. These are respectively 136.4 kg/cap/year and 689.2 kg/cap/year.

Indicator 15 = $\left[1 - \frac{X-136.4}{689.2-136.4} \right] * 10$

Score:

Waste is collected in all periods. However, there were many technical and organizational problems, which is why the scores were estimated to be low. In 2001, the city established six waste-collecting places where bulky household waste, hazardous waste, and electrical appliances are collected. The city scores now according to previous research a 3.13.

	Score	Data
1672 – 1682	1	
1780 – 1810	1	
1845 – 1866	1	
1872 – 1902	1	
1930-1955	1	
1970 – 1998 – 2006	2	Literature
2018 – present	3.13	Literature

16 MSW recycled

Calculation:

Indicator 16 = $\frac{\text{\% recycled or composted}}{100-\text{\% used for incineration with energy recovery}}$ x 10

Score:

Data are available for the years 2019 and 2006. No data are available for previous years.

	Score	Data
1672 – 1682		
1780 – 1810		
1845 – 1866		
1872 – 1902		
1930-1955		
1970 – 1998 – 2006	6	Literature
2018 – present	9.84	Literature

17 MSW energy recovered

Calculation:

Indicator 17 = $\frac{\%\ \text{incinerated with energy recovery}}{100 - \%\ \text{recycled or composted}}$ x 10

Score:

In 1918 a waste incinerator was built in which the generated energy was reused.

	Score	Data
1672 – 1682	0	Literature
1780 – 1810	0	Literature
1845 – 1866	0	Literature
1872 – 1902	0	Literature
1930-1955	1	Literature/Interview
1970 – 1998 – 2006	2	Literature/interview
2018 – present	9.744	Literature

18 Green space

Calculation:

Indicator 18 = $\frac{X-16}{48-16}$ x 10

where X = Share of blue and green area (%). All values of x < 16 will lead to an indicator score of 0 and all values > 48 will lead to an indicator score of 10.

Score:

Kaart 1 A t/m O Amsterdam 1000 -2000
Bron: Amsterdams Historisch Museum

Elk kaartje geeft weer hoe groot de stad is aan het eind van de periode.
Dus bijvoorbeeld kaartje B = situatie 1275

	Score	Data
1672 – 1682	5	Literature
1780 – 1810	6	Literature
1845 – 1866	5	Literature
1872 – 1902	4	Literature
1930-1955	7	Literature
1970 – 1998 – 2006	6	Literature
2018 – present	5.9	Literature

19 Climate adaptation

Calculation:

Indicator	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	the topic is addressed in a chapter at the national and local level
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 plus subsidies are made available 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

Score:

1672 – 2006

There is no data available during this time period, however Amsterdam was always prone to climate variables such as heavy rains and heavy rains. Looking in the history there were many alterations made to cope with climate threats. During this time the concept ‘climate adaptation’ did not exist yet which is why it was not documented.

2006:
In 2006 hebben de ministeries VROM, V&M,LNV en EZ het initiatief genomen om het Nationaal Programma Adaptatie Ruimte en Klimaat (ARK) op te zetten (Ministerie van Volkshuisvesting, Ministerie van Verkeer en Waterstaat, Ministerie van Landbouw, & Ministerie van Economische Zaken, 2006). Het doel van de ARK was om Nederland klimaatbestendig te maken. Op lange termijn wordt daarbij gestreefd naar verankering van adaptatie in bewustzijn, beleid en regelgeving, en op korte termijn naar het ontstaan van een impuls (Klimaat voor Ruimte, n.d.). . Het Rijk wil dit programma samen met alle relevante partijen verder vormgeven en wil zicht houden op de uitvoering ervan. De uitwerking en uitvoering van de programma-activiteiten zijn een gedeelde verantwoordelijkheid van alle partijen (overheden, bedrijfsleven, wetenschap, maatschappelijke organisaties) (Ministerie van Volkshuisvesting et al., 2006). Het klimaatbestendig maken van Nederland is een uitdaging die gezamenlijk wordt opgepakt. In 2006 scoort de indicator een 3 omdat het onderwerp wordt benoemd in nationale programma, maar nog niet in de organisatie van Waternet.
Present:
In 2007 heeft het kabinet de nationale adaptatiestrategie vastgesteld . Op 1 januari 2014 startte Waternet in samenwerking met de gemeente een programma: Amsterdam Rainproof. Het doel van het programma is een regenbestendige stad in 2050. Naast Rainproof hebben de gemeente en Waternet allerlei klimaatadaptatie projecten en houden ze bij fysieke veranderingen rekening met klimaatadaptatie.

	Score	Data
1672 – 1682	0	Literature
1780 – 1810	0	Literature
1845 – 1866	0	Literature
1872 – 1902	0	Literature
1930-1955	0	Literature
1970 – 1998 – 2006	3	Literature
2018 – present	10	Literature

20 Climate-robust buildings

Calculation:

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	the topic is addressed in a chapter at the national and local level
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 plus subsidies are made available 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

Score:

Klimaat bestendige gebouwen hoort bij de klimaatadaptatie projecten en plannen. Na het onderteken van het Kyoto protocol werd het meer belangrij. Voor 2006 werd het onderwerp wel benoemd in lokaal en nationaal beleid, maar er was nog geen speciaal beleid. Na 2006 heeft zowel Nederland als Amsterdam een beleid doorgevoerd voor klimaat en milieu waarin dit onderwerp is vastgelegd.

Januari 2017, nieuwprojecten moeten aan verschillende eisen voldoen.

2013: Start Rainproof. Focus op groene daken in het begin. Ze moesten particulieren mee krijgen omdat veel gebouwen en oppervlakten in handen zijn van particulieren.

	Score	Data
1672 – 1682	0	Literature
1780 – 1810	0	Literature
1845 – 1866	0	Literature
1872 – 1902	0	Literature
1930-1955	0	Literature
1970 – 1998 – 2006	2	Literature
2018 – present	9	Literature

21 Management & action plans

Calculation:

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	the topic is addressed in a chapter at the national and local level
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 plus subsidies are made available 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

Score:

IWRM is introduced in the Netherlands around 1980, first in the south east later in the whole country. The IWRM concept lays also a basis on some national frameworks. In 1989 integrated water management was used as a strategy for water policy in the fourth Memorandum on Water Housing (Verbeek, 1997). (integral water management between undisturbed control & undisturbed failure). In 2006, Waternet was established in Amsterdam, which ensures an IWRM approach, the company represent the whole water cycle. In 2006, the indicator scores approximately a 4, because it is being tackled but not yet fully implemented in local policy.

	Score	Data
1672 – 1682	0	Literature

1780 – 1810	0	Literature
1845 – 1866	0	Literature
1872 – 1902	0	Literature
1930-1955	0	Literature
1970 – 1998 – 2006	4	Literature
2018 – present	9	Literature

22 Water efficiency measures

Calculation:

Measure of the application of water efficiency measures by the range of water users across the city. A lower Indicator score is given where efficiency measures are more limited.

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	the topic is addressed in a chapter at the national and local level
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 plus subsidies are made available 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

Score:

	Score	Data
1672 – 1682		
1780 – 1810		
1845 – 1866		
1872 – 1902		
1930-1955		
1970 – 1998 – 2006	9	Policy documents Waternet
2018 – present	10	Policy documents Waternet

23 Drinking water consumption

Calculation:

X = m^3/person/year drinking water consumption

The volume is then normalized against maximum and minimum volumes for European cities. The minimum is for Rotterdam at 45.2 m3/person/yr. The maximum is for Kiev at 266 m3/person/year (European Green City Index).

Indicator 23 = [1 - $\frac{X-45.2}{266-45.2}$ **] * 10**

Score:

	Score	Data
1672 – 1682	10	
1780 – 1810	10	
1845 – 1866	10	(Biemand et al., 1983)
1872 – 1902	10	(Biemand et al., 1983)
1930-1955	9.8	
1970 – 1998 – 2006	9.57	
2018 – present	9.8	

24 Attractiveness

Calculation:

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	the topic is addressed in a chapter at the national and local level
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 plus subsidies are made available 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

Present score: 9

2006: Information has been communicated to the public about the goal of getting the Amsterdam canals on the UNESCO World Heritage List. In 2007 the documents were delivered to UNESCO and in 2010 the Amsterdam canals were accepted as world heritage. I therefore score the indicator a 7 during this period. Present score: 9.

In the previous periods, there are few documents available about the attractiveness of the Amsterdam canals during the periods, but the canal system has traditionally been very important for the city and a tourist attraction. For example, the Tsar of Russia was impressed by the canal belt through which the city of Saint Petersburg was built with Amsterdam as an example.

	Score	Data
1672 – 1682		
1780 – 1810		
1845 – 1866		

1872 – 1902		
1930-1955		
1970 – 1998 – 2006	7	Literature
2018 – present	9	Literature

Appendix II: Interview results

Tabel 2: TPF: Interview versus caculated scores

	1672 – 1682		1780 – 1810			1845 – 1866		1872 – 1902		1930-1955		1970 – 1998 – 2006		2018 – present		2030
	Calculated	Interviews	Calculated	Interviews	Corrected	Calculated	Interviews	Calculated	Interviews	Calculated	Interviews	Calculated	Interviews	Calculated	Interviews	Interviews
1. Urbanization rate	1.9	6.5	0	0.0		3	5.5	6.6	9.0	1.0	9.0	3.2	6.0	1.6	3.3	4.3
2. Burden of disease		7.3		4.0			5.7		4.7		3.5	2.0	2.4	2.0	2.0	2.3
3. Education rate	10	6.3	10	8.2		10	8.0	10	8.7	9.6	4.5	4.1	10.2	1.3	2.5	3.3
4. Female Participation		2.5		7.0			5.5	7.6	5.0	7.7	7.0	3.2	5.1	2.4	2.8	2.8
5. Urban drainage flood		2.3		2.0			4.0		4.3		1.5	3.6	3.0	4.0	3.6	3.2
6. River peak discharges	10	3.3	10	3.3		10	3.7	10	3.7	10.0	5.3	10.0	7.5	10.0	10.0	7.5
7. Sea level rise	10	8.3	10	8.3		10	8.3	10	6.2	10.0	9.0	10.0	10.0	10.0	10.0	10.0
8. Land subsidence	7.5	5.8	7.5	5.8		7.5	5.8	7.5	6.7	7.5	7.5	7.5	7.5	7.5	7.5	7.5
9. Freshwater scarcity		6.3		6.3			6.0		5.3		3.0	3.0	4.3	2.0	4.3	2.7
10. Groundwater scarcity		0.0		0.0			0.8		2.7		2.8		2.5	2.5	2.5	1.0
11. Sea water intrusion	10	10.0	10	10.0		10	10.0	7.5	8.7	7.5	7.5	7.5	7.5	7.5	7.5	9.0
12. Surface water quality		9.3		8.7			9.3		9.3		8.0		5.3	3.0	3.0	2.5
13. Biodiversity		9.3		9.3			9.3		9.7		9.5	10.0	9.7	10.0	9.0	8.3
14. Heat island		2.8		2.5			3.2		3.3		2.8	2.1	2.7	2.1	3.4	3.6
15. Air Quality		8.7		7.7			8.7		9.5		6.8	1.9	3.5	3.0	2.5	2.3
16. Economic pressure		3.3	10	8.0		10	6.3	10	6.3	9.9	5.0	2.7	2.2	1.5	2.0	2.3
17. Unemployment rate		3.3	0.8	6.2		1.9	4.8	1.2	4.0	0.0	4.0	2.1	3.7	1.1	3.0	3.3
18. Poverty rate		5.0		7.5			6.0		6.0		6.0	0.0	3.0	0.0	3.0	3.5
19. Invest freedom		2.3		9.0			4.3		4.7		5.0	1.0	2.3	1.0	2.0	3.3
20. Voice and accountability		6.3		8.3			7.2		7.3		4.0	1.9	1.6	1.8	2.0	2.3
21. Political Stability		5.3		8.3			4.0		4.7		6.5	3.2	3.1	3.3	3.0	3.5
22. Government effectiveness		3.3		7.0			4.7		3.7		3.5	1.4	1.9	1.3	1.3	2.0
23. Regulatory quality		3.3		3.7			4.3		4.3		3.0	1.6	1.4	1.0	1.0	2.0
24. Rule of law		2.3		2.7			3.0		3.3		1.0	1.4	1.3	1.4	1.0	1.5
25. Control of corruption		4.0		4.7			3.3		3.0		2.0	0.9	1.6	1.0	1.7	1.7

Appendix III: City Blueprint Paris

Trends and Pressures Framework (TPF)

Indicator	Value	Score	Degree of concern	Source
Urbanization rate	0.73	1.58	No concern	(CIA, 2020)
Burden of disease	19104.00	2.00	Little concern	(WHO, 2020)
Tertiary Education	66.13	3.40	Little concern	(The Worldbank, n.d.)
Female participation	68.40	3.16	Little concern	(EEA, 2012b)
Urban drainage flood	74.47	10.00	Great concern	(EEA, 2012b)
River peak discharges	4.20	0.00	No concern	(EEA, 2012b)
Sea level Rise	0.00	0.00	No concern	(EEA, 2012b)
Land subsidence	0.00	0.00	No concern	(Le Mouélic, Raucoules, Carnec, King, & Adragna, 2002; Sarti & Fruneau, 2000)
Fresh water scarcity	12.53	3.00	Little concern	(Aquastat, 2020)
Groundwater scarcity	6.00	2.50	Little concern	(IGRAC, n.d.)
Seawater intrusion / salinzation	0.00	0.00	No concern	EEA (2003)
Biodiversity	70-90	10.00	Great concern	(EEA, 2012a)
Heat risk	1,8 & 7,5	4.65	Medium concern	(Arcgis, 2015; EEA, 2012b)
Air quality	1.78	1.78	No concern	(World Health Organization, 2018)
Economic pressure	42400.00	3.12	Little concern	(The Worldbank, n.d.)
Unemployement rate	8.43	4.18	Medium concern	(The Worldbank, n.d.)
Poverty rate	0.00	0.00	No concern	(The Worldbank, n.d.)
Investment rate	75.00	2.50	Little concern	(The Heritage Foundation, 2020)
Voice and accountability	1.18	2.64	Little concern	(Worldbank, 2020)
Political stability	0.11	4.78	Medium concern	(Worldbank, 2020)
Government effectiveness	1.48	2.04	Little concern	(Worldbank, 2020)
Regulatory quality	1.17	2.65	Little concern	(Worldbank, 2020)
Rule of Law	1.44	2.12	Little concern	(Worldbank, 2020)
Control of Corruption	1.32	2.37	Little concern	(Worldbank, 2020)

TPI score= 2.85

City Blueprint Framework (CBF)

Indicator	Score	Data	Source
1 Access to drinking water	10.00	100%	(Eau de Paris, 2013; WHO & Unicef, 2013)
2 Access to sanitation	9.86	98.59%	(OECD, 2020)
3 Drinking water quality	10.00	100%	(Eau de Paris, 2013, 2020b)
4 Secondary WWT	7.90	11% in France	(OECD, 2020)
5 Tertiary WWT	6.80	68% in France	(OECD, 2020)
6 Groundwater quality	9.46	Good: 14073. Poor: 809. Unknown" 1046	(EEA, 2018)
7 Nutrient recovery	7.63		SIAAP (Contact by email)
8 Energy recovery	8.86		SIAAP (Contact by email)
9 Sewage sludge recycling	3.40		SIAAP (Contact by email)
10 WWT energy efficiency	10		SIAAP (Contact by email)
11 Stormwater separation	0.00		SIAAP (Contact by email)
12 Average age sewer	0.00	Sewer system is developed around end of the 19th and early 20th centuries, they try to rehabilitate 2-3% per year.	SIAAP (Contact by email) (Eau de Paris, 2020a)
13 Water system leakages	8.26	91.30%	(Eau de Paris, 2020b)
14 Operation cost recovery	2.04	Ratio: 0.739639518	(Eau de Paris, 2018; SIAAP, 2018)
15 MSW collected	3.61	489.4 (including bulky, road and market waste) 419.8 (household waste)	(European Commission, 2015)
16 MSW recycled	8.28	20,2 % 225 365 tonnes recyclées. 75,6 % 844 688 tonnes incinérées	(European Commission, 2015)
17 MSW energy recovered	9.47	20,2 % 225 365 tonnes recyclées. 75,6 % 844 688 tonnes incinérées	(European Commission, 2015)
18 Green space	2.47	23.9%	(EEA, 2012b)
19 Climate adaptation	10.00	Siaap, Eau de Paris and Ville de Paris have a climate action plan and its included in the annual reports. Subsidies for local innovations are available. Good communication to local communities by using museums, games, etc. Climate adaptation is in place for more than 3 years	(City of Paris, Green Parks, & Environment Urban Ecology Agency, 2018; Eau de Paris, 2015, 2020b) SIAAP (Contact by email)
20 Climate-robust buildings	10.00	In the reports they state that they want to design the buildings more circular and climate proof. Geothermal energy is widely used for the buildings.	(City of Paris et al., 2018; Eau de Paris, 2015, 2020b) SIAAP (Contact by email)
21 Management & action plans	10.00		SIAAP (Contact by email) (Eau de Paris, 2018)
22 Water efficiency measures	10.00	Water efficiency explained in national and local documents, mentioned as vision on website, citizens are involved through serious game.	(Eau de Paris, 2020b, 2020a)
23 Drinking water consumption	8.51	78 m3/inhab./year	(Tabuchi & Blatrix, n.d.)
24 Attractiveness	10.00	The connection between the inhabitants and water is mentioned in the annual reports and on the website. There are many plans to raise awareness and inform the population about the water system. There are guided tours through the sewage system and there is a water museum.	(Eau de Paris, 2013, 2020b)

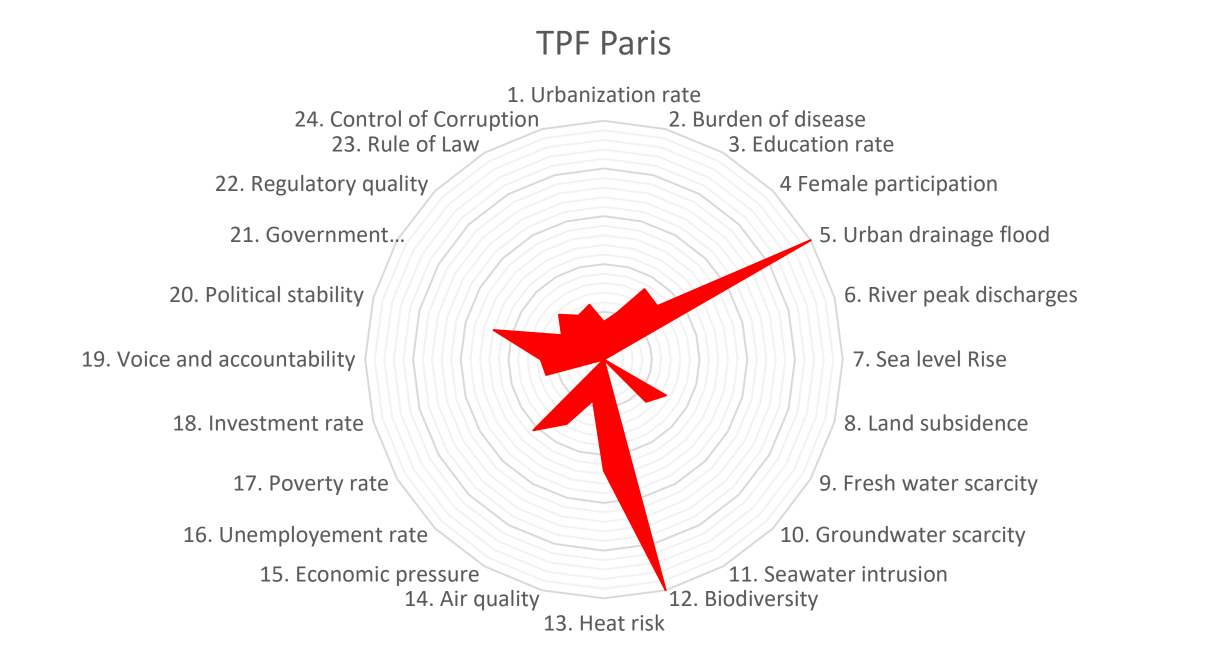

Figure 23: TPF Paris

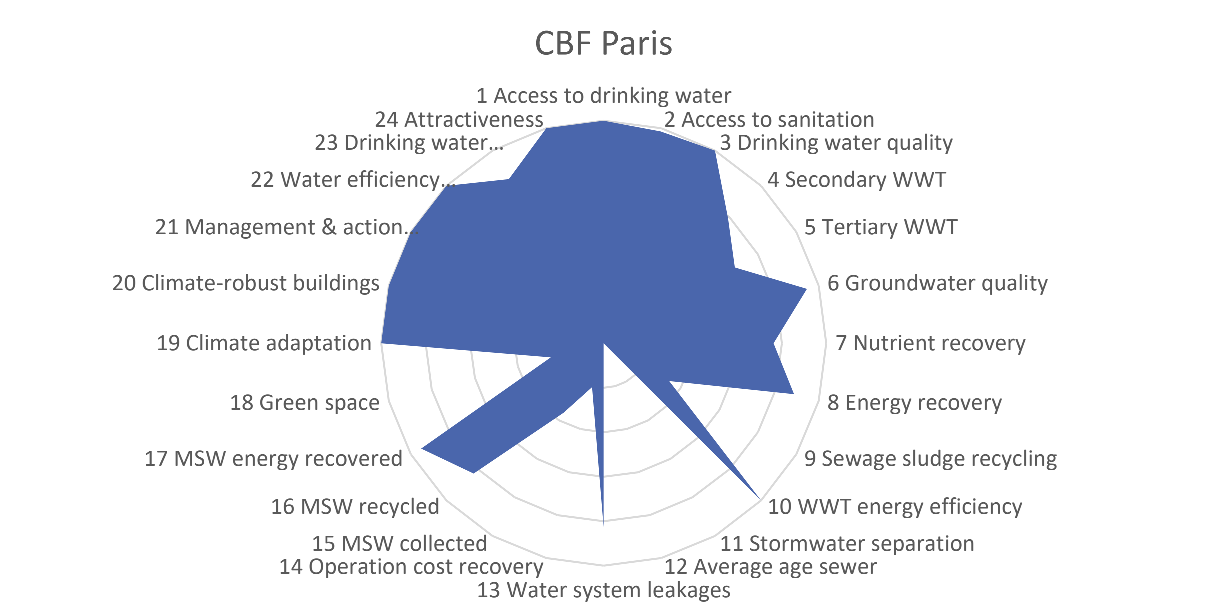

Figure 24:CBF Paris

Appendix IV: Survey

Retrospectief onderzoek watermanagement en beleid in Amsterdam

Beste collega's,

Allereerst hartelijk dank voor uw deelname aan het onderzoek.

Zoals u hebt kunnen lezen voer ik momenteel mijn afstudeeronderzoek uit voor de master Water Science & Management aan de Universiteit van Utrecht in samenwerking met Waternet en KWR.

Voor mijn afstudeeronderzoek doe ik onderzoek naar hoe watermanagement en beleid is veranderd in Amsterdam vanaf 1672 tot en met nu, welke toekomstige ontwikkelingen er zijn en wat steden hiervan kunnen leren om huidige en toekomstige uitdagingen op het gebied van water aan te gaan.

De vragenlijst zal minstens tien minuten van uw tijd in beslag nemen. De resultaten worden geheel anoniem verwerkt. Mocht u nog vragen, opmerkingen of aanbevelingen voor het onderzoek hebben, neem dan contact met mij op via 0616336495 of sannah.peters@waternet.nl

Nogmaals bedankt voor uw deelname.

Met vriendelijke groet,
Sannah Peters

Vragenlijst:

Vraag 1: Wat is uw expertise op het gebied van water? (Meerdere antwoorden mogelijk)

O Drinkwater	O Afvalwater	O Leidingwerken
O Oppervlakte water	O Grondwater	O Biodiversiteit
O Klimaat	O Beleid en Asset management	O Overig_______

Vraag 2: Heeft u expertise over de historische ontwikkeling van water management/governance in Amsterdam?

O Ja (Verder naar de volgende vraag) O Nee (Verder naar vraag 6)

Vraag 3: Wat zijn de belangrijkste historische ontwikkelingen (1672 -2020) in Amsterdam op het gebied van uw expertise/afdeling?

Vraag 4: Hoe belangrijk zijn onderstaande trends voor de ontwikkeling van watermanagement en beleid voor de stad Amsterdam?

	Zeer onbelangrijk	Onbelangrijk	Noch onbelangrijk, noch belangrijk	Belangrijk	Zeer belangrijk
Bevolkingsgroei					
Ziektelast					
Educatie niveau					
Vrouwen participatie					
Verdichting van stad					
Stijging van zeespiegel					
Rivierafvoer					
Bodemdaling					
Zoetwater beschikbaarheid					
Grondwater beschikbaarheid					
Zeewater intrusie					
Kwaliteit oppervlaktewater					
Biodiversiteit					
Klimaatverandering					
Lucht kwaliteit					
Economische druk					
Mogelijkheid om vrij te investeren					
Politieke stabiliteit					
Effectiviteit van bestuur en openbare dienst					
Vermogen van overheid om beleid en regelgeving te formuleren en uit te voeren					
Wetgeving					
Controle op corruptie					

Vraag 5: Welke les of lessen vanuit het verleden zijn belangrijk voor stadsontwikkelaars om mee te nemen bij het aanleggen van een nieuw systeem of het maken van een nieuw beleid met betrekking tot water?

Vraag 6: Onderzoek naar water in de stad heeft geleerd, dat beleid vaak reactief is en volgt op crisissituaties (ziekte, overlast, economische schade, etc.). Terugkijkend zou Amsterdam met de kennis van nu (opgedaan in de afgelopen vier eeuwen), er waarschijnlijk anders uitzien dan wanneer de hele stad nu zou worden gebouwd.

Wat zou u adviseren – wanneer Amsterdam nu zou moeten worden gebouwd- omtrent (vanuit uw expertisegebied):

a) Aanleg (water)infrastructuur?

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b) Water management (operationeel)?

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c) Waterbestuur/governance?

Vraag 7: Wat zijn de belangrijkste nieuwe uitdagingen en ontwikkelingen in uw vakgebied die u in de toekomst in Amsterdam verwacht?

Vraag 8: Hoe kan watermanagement en -beleid in Amsterdam verbeterd worden om toekomstige en huidige uitdagingen aan te gaan?
