MENA Megacities Approaching Day Zero: A Comparative Study Between Cairo and Istanbul

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Abstract

Megacities around the world are facing water scarcity, including two of the largest cities in the MENA region – each with different geography. Cairo is situated in an arid environment, relying mostly on one water resource: The River Nile. The city is becoming more vulnerable with population growth, modern urban sprawl, and political tension over the Nile. Infrastructure, governance and management of existing water systems are posing more stress. On the other hand, Istanbul is more water-rich, however is expanding beyond its watershed and drawing on water within a 200 km radius. Its water demand is expected to increase with the expected population growth, unsystematic urbanization and impacts of climate change on water security. This paper reviews the key challenges and issues that these countries face and outlines possible sustainable solutions such as decentralizing the governance framework, developing city-specific water security and climate change mitigation plans and restructuring the tiered water tariff system and deploying water-sensitive urban design. Within the context of Istanbul, for decades, considerable efforts and investments have been made by the governance to develop water resources. These measures should be further expanded to address the complex challenges towards achieving urban water security in these sprawling cities.

Keywords

Urban water security, sustainable cities, water scarcity, IWRM

I. Introduction

Urban water scarcity is a growing global dilemma faced by numerous megacities. Water security could be defined as “sustainable access, on a watershed basis, to adequate quantities of water, of acceptable quality, to ensure human and ecosystem health” (Bakker et al., 2010). To tackle the water security challenge in general, states have committed to developing functioning integrated water resources management (IWRM) systems at the basin level by 2030 as part of the Sustainable Development Goals (SDGs). IWRM is a holistic approach of water management based on the four key principles of the 1992 Dublin Statement on Water and

Sustainable Development: "(1) fresh water is a finite and vulnerable resource essential to sustain life, development and the environment; (2) water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels; (3) women play a central part in the provision, management and safeguarding of water; (4) water has an economic value in all its competing uses and should be recognized as an economic good" (White, 2013).

In assessing the likelihood of achieving urban water security, five factors should be considered in relation to IWRM: socio-demographic, economic, technological, environmental, and governance (SETEG).[1] Socio-demographic factors refer to satisfactory access to water and sanitation; economic factors refer to water demand and the allocation of budgets; technological factors refer to the adequacy of the water supply and sanitation (WSS) infrastructure; environmental factors refer to climate change, watershed uses and water pollution and contamination; and, finally, governance factors refer to institutional frameworks, plans or strategies and performance (Romero-Lankano & Gnatz, 2016).

Two megacities in the Middle East and North Africa region with different geographical characteristics – Cairo, Egypt and Istanbul, Turkey – are experiencing day zero type scenarios that pose a serious threat to the sustainable management of water resources. Water scarcity is a rapidly growing problem in both cities where the infrastructure and wastewater treatment facilities seem to be insufficient in the long-term perspective. Both cities continue to mobilize their resources within different organizational frameworks to address water scarcity, mainly caused by supply shortages, population growth, and climate change impacts. This paper provides an in-depth analysis of the cities while critically reflecting on the adequacy of the different approaches they adopt towards achieving water security.

The paper is organized as follows. Section 2 provides a review of the general situation in Cairo and Istanbul. It assesses their water resources, needs, infrastructure, governance and actors, and overall performance. Sections 3 and 4 describe, first Cairo's and, second, Istanbul's key challenges for achieving water security, current efforts towards sustainability and opportunities for moving away from 'day zero'. Section 5 analyzes the research by comparing both cities within the context of the SETEG factors for achieving water security. The final section, Section 6, presents our conclusions and recommendations.

II. Background

Cairo

Cairo, Egypt's sprawling capital, is situated in northern Egypt and has an arid, dry climate. It receives 24.7mm of rainfall annually, which is a 25-50% decrease caused by climate change (ECC, 2014). Cairo has a yearly average evaporation rate of 10.1 mm/year (El-Sayed, 2018). Cairo's main water resource is the Nile River and is situated downstream of more than 40 Egyptian and African cities and towns. Under the 1959 agreement, Egypt receives 55.5 billion cubic metres annually from the Nile (El-Sayed, 2008), part of which supplies 90% of

1 Adapted from Romero-Lankao & Gnatz (2016) SETEG domains of urban water security.

Cairo's water (Myllylä, 1995). This is expected to decrease by 25% in the years of filling the Grand Ethiopian Renaissance Dam (GERD) (Schlanger, 2019). Figure 1 provides a regional map of Cairo, the Aswan Dam, and the provisioned location of GERD. Cairo is also surrounded by groundwater aquifers which supply 4.6 billion cubic metres of water annually (El-Sayed, 2018). However, they are becoming increasingly contaminated from industry discharge.

Figure 1. Regional map of the Nile River
Note: *Reprinted from: "Ethiopia's Nile mega-dam nears completion" by K. Cook (2018).*

Cairo has 20.5 million inhabitants (Macrotrends, 2020a) who consume an average of 330 L/day/capita (MHUUC, 2012). Much of the unaccounted-for water is attributed to the informal settlements in the city as they install self-made pipe extensions to the formal water supply infrastructure (Khalil, 2019). The informal settlements account for approximately 60% of Cairo (Khalil, 2019). Currently, Cairo is working towards extending its WSS infrastructure – part of which is over a century old (Sada Elbalad, 2017) - to incorporate the expected population of 38 million by 2050 (GOPP, 2008).

Egypt's WSS institutional framework is centralized and operates at the national level (World Bank Group 2014). The Ministry of Housing, Utilities and Urban Communities (MHUUC) is the main actor responsible for decision-making and supervision. The Cairo and Alexandria Potable Water Organization (CAPWO) is responsible for the planning and implementing infrastructure investments in Cairo and Alexandria and reports to the MHUUC. The Holding Company for Water and Wastewater (HCWW) performs the operation and management of assets through its subsidiaries – the Water and Sanitation Companies (WSCs). The HCWW is responsible for developing master plans that are then implemented by the WSCs and monitors their performance. The Egyptian Water Regulatory Agency (EWRA) regulates the quality of WSS service delivery, monitors WSS tariffs and undertakes consumer protection responsibilities. It operates under the MHUUC. Table 1 provides a summary of the different actors and their roles, and Figure 2 illustrates the relationships among the stakeholders.

Organization	Main roles and responsibilities
Financing	
Ministry of Finance	Allocation of capital for WSS sector
Policy Making	
MHUUC	Established in 1996. Provides leadership for the WSS sector, sets policies and coordinates investment programs. Oversees agencies and companies including EWRA, HCWW, NOPWASD and CAPWO
MWRI	Sets standards for discharges into the Nile basin Development, distribution and management of water resources. Development of operations and maintenance. Assesses water quality of various water sources.
Ministry of Health	Monitors municipal water quality
Ministry of Environmental Affairs	Environmental planning, policy setting and legislation. Oversees environmental legislation enforcement
Infrastructure Delivery	
CAPWO	Investment planning, design and supervision of construction of WSS infrastructure in Greater Cairo and Alexandria
Service Delivery	
HCWW	Established in 2004. Public owned company. Helps to improve the performance of WSCs and improve their management practices
WSCs	Provides drinking water and wastewater services on the governorate level. Maintenance work and repairs.
Regulation	
EWRA	Established in 2004. Ensures sustainability and quality of services at reasonable prices.

Table 1. Main institutions in the WSS sector in Egypt
Note: *Adapted from "Status of Water Sector Regulation in the Middle East and North Africa", by World Bank Group (2014).*

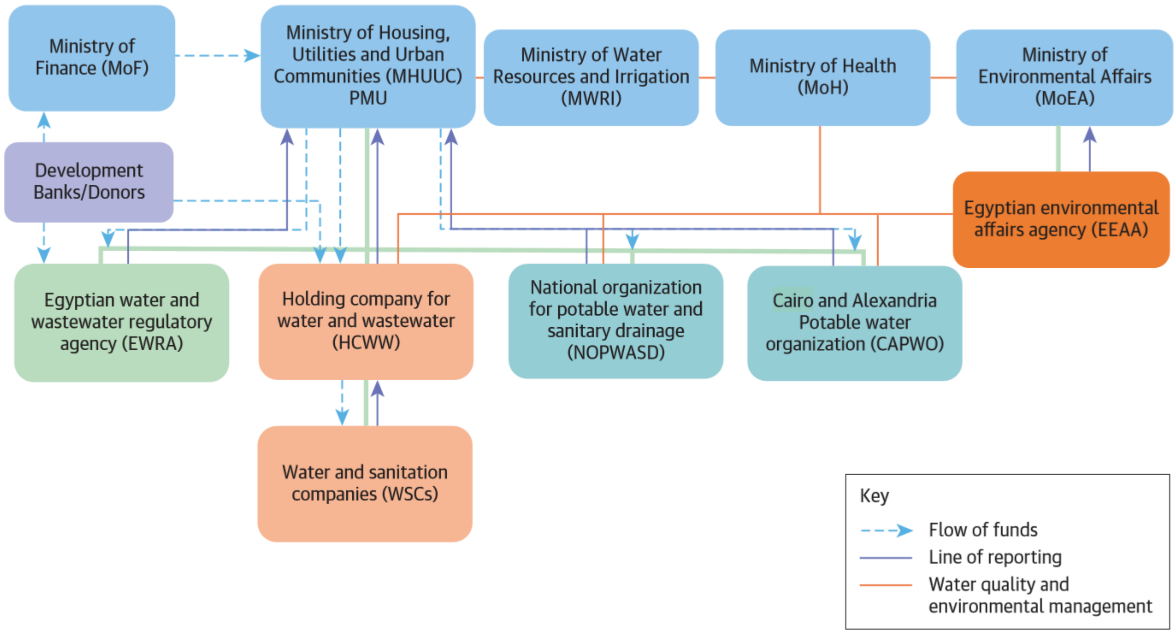


Figure 2. Egypt's water stakeholder map
Note: *Reprinted from "Status of Water Sector Regulation in the Middle East and North Africa", by World Bank Group (2014).*

Cairo is constantly expanding its water and wastewater infrastructure to accommodate its growing population. The current potable water capacity is 7,233,000 m^3/day and is expected to double by 2027 (MHUUC, 2012). Regarding its reuse of wastewater, Cairo has six wastewater treatment plants with a collective capacity of 4,290,000 m^3/day, which is also expected to double by 2027 (MHUUC, 2012). Cairo adopts a tiered pricing system (see Table 2). The cost of domestic water in Cairo ranges from 0.65 L.E. to 3.15 L.E. (Daif, 2018), and 3.00 L.E. to 10.00 L.E. for industrial use (Egypt Today, 2018).

There have been ongoing efforts to introduce effective water governance and management in Egypt and Cairo that are discussed at length in Section 3. Although there have been national efforts such as establishing a specific water sector regulator (the EWRA), establishing water laws, and incorporating IWRM into the National Water Resources Plan, there remain institutional challenges in overlapping responsibilities, poor law enforcement and outdated plans. Additionally, while the national and local governments acknowledge the risks of increased droughts due to climate change, there is no climate change mitigation strategy relevant to Cairo in place. Egypt is also a powerful member of the Nile Basin Initiative set to achieve sustainable strategies for the transboundary water source.

There are three relevant government plans. First, the National Vision 2030 addresses the national economy and sustainable development and encompasses 11 programs relevant to water, sanitation and sustainability. Second, the National Water Resources Plan 2037 focuses on developing new water supplies, strengthening demand management, enhancing water quality control, and ensuring sustainability (World Bank Group, 2014). Third, the Greater Cairo

Urban Development Strategy 2050 focuses on the economic development of Greater Cairo and expects the economic returns to trickle down to water and sanitation infrastructure – especially that of slums.

In 2019, Egypt in general, and Cairo by extension, have been 'moderately improving' their actions towards the sixth sustainable development goal (SDG 6): Clean Water and Sanitation (Bertelsmann Stiftung & SDSN, 2019). Particularly, Egypt has been on track for maintaining target 6.1 with 98.4% of the population (on record) using at least basic drinking water services (Bertelsmann Stiftung & SDSN, 2019). 93.8% of Egypt's population has access to basic sanitation services, which has been a stagnating effort. On the other hand, Egypt's performance for SDG target 6.4 is decreasing in the freshwater withdrawal but improving in groundwater depletion. Egypt withdraws 159.9% of freshwater as a percentage of total renewable water resources, but also maintains a small 2.8 m^3/year/capita of groundwater depletion (Bertelsmann Stiftung & SDSN, 2019). Egypt's degree of IWRM implementation is 40% in accordance with the National Water Resources Plan. The challenge with the above data is that they do not accurately reflect informal settlements, and therefore true performance may be poorer than the numbers shown above. Table 2 provides a summary of WSS in Cairo in comparison to Istanbul.

Istanbul

Istanbul is a transcontinental city of Turkey situated in Europe and Asia facing the Bosphorus Strait and Golden Horn, between the Black Sea to its North and the Sea of Marmara to its South (Figure 3). Because of its geography, the city has a transitional Mediterranean characteristic resulting in various types of microclimates in its different zones, such as humid subtropical and oceanic. Annual precipitation is 812.8mm (Weather Atlas, n.d.-b). Istanbul has a population of 15 million as of 2020 (World Population Review, n.d.) and is projected to reach 40 million by 2050 (Saatci, 2013). As one of the 38 megacities in the world, the city has experienced exponential population growth over the last century and sets a clear example of urban water scarcity. Istanbul is characterized by an unproportionate distribution of its water resources and population. Although only 30% of the population lives on the Asian side of Istanbul, it holds 77% of the water resources, creating challenges to maintain an uninterrupted water supply for the whole city (Cuceloglu et al., 2017).

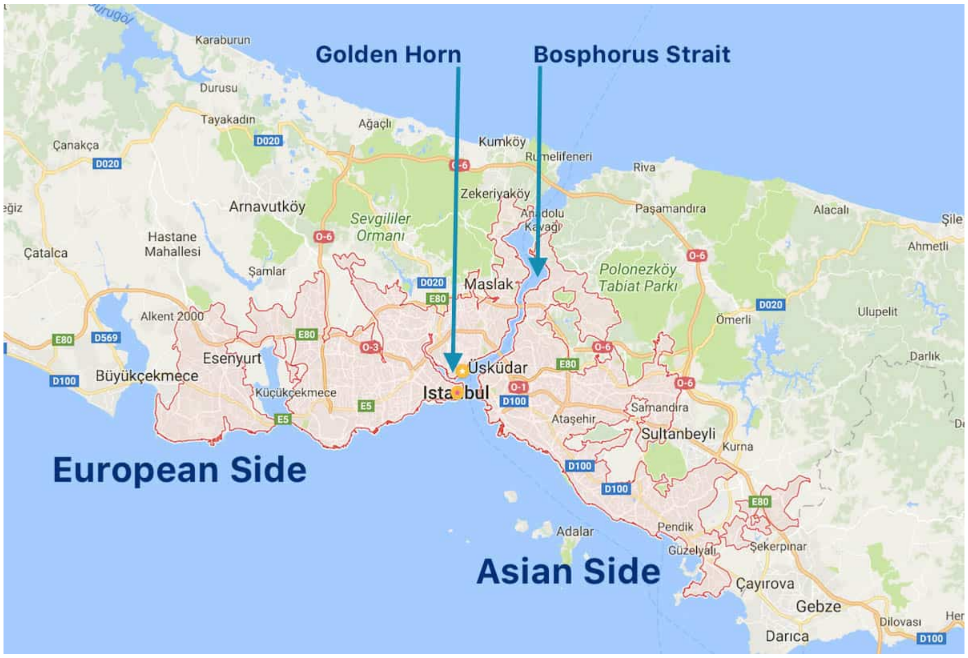


Figure 3. Istanbul City Geographical Map

The water systems of this megacity are composed of dams, reservoirs, water treatment plants and pipelines with a total length of 17,000 km. According to the most recent information provided by the Istanbul Water and Sewerage Administration (ISKI), the average water supply to the city was 2,733,388 m^3/day. 98% of the city's water resources is made up of surface water resources. Currently, a total of 18 surface water resources provide water supply to Istanbul in various capacities, including a natural lake, eight dams, eight regulators and embankments. Furthermore, groundwater resources – which amount to 161 water wells and spring water bodies - constitute 2% of the drinking water demand. Some of the drinking-water reservoirs, namely the Kazandere reservoir, Papucdere reservoir, Istranca River and the Melen system are in the neighbouring cities outside of Istanbul's watershed (Cuceloglu et al., 2017). However, most of the reservoirs (Terkos, Alibeykoy, Büyükçekmece, Sazlıdere) are situated on the European side and three (Ömerli, Darlık and Elmalı) on the Asian side of Istanbul. Figure 4 illustrates the reservoirs that are located within the boundaries of Istanbul. Among the mentioned water resources, the Ömerli Watershed is the major contributor, providing approximately 32% of the total freshwater supply. Regarding wastewater management, 88 wastewater treatment plants operate in Istanbul with a capacity of 5,815,910 m^3/ day (ISKI, n.d.-a).

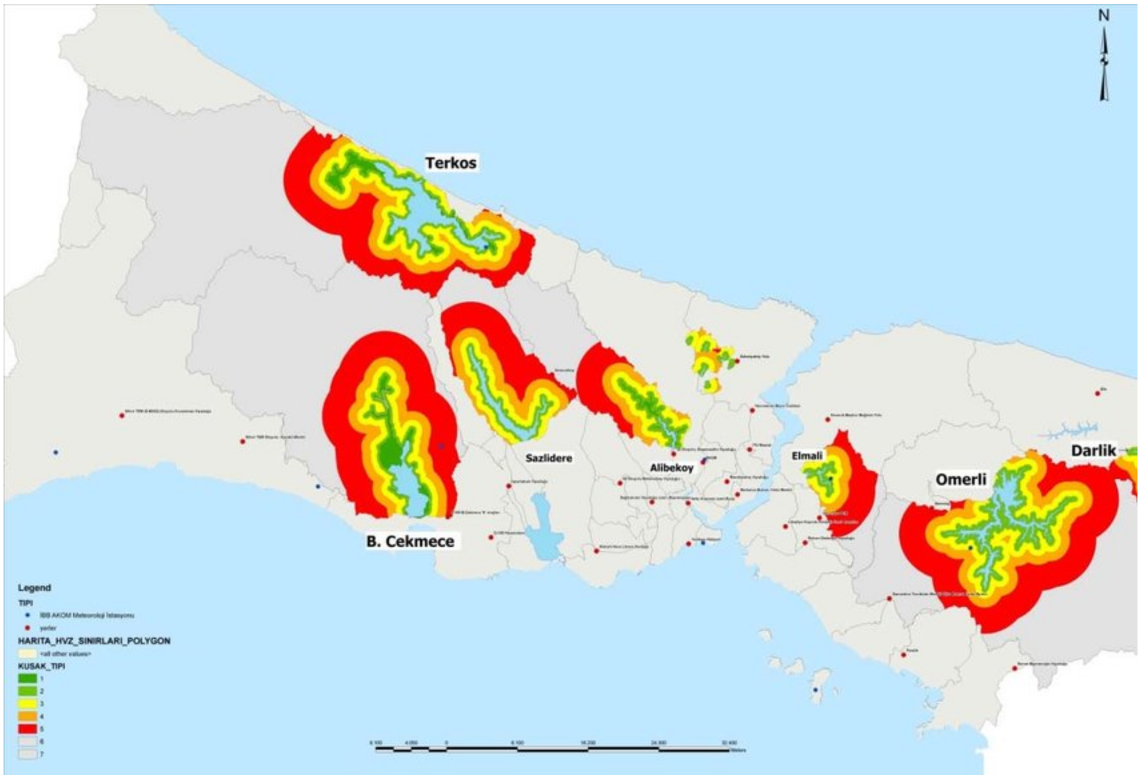


Figure 4. Istanbul reservoir map[2]
Note: *Reprinted from Final Report: 2007-2008 Precipitation Augmentation Program and Research on Istanbul Clouds and Aerosols (PAPRICA)", by S.M. Hunter (2008)*

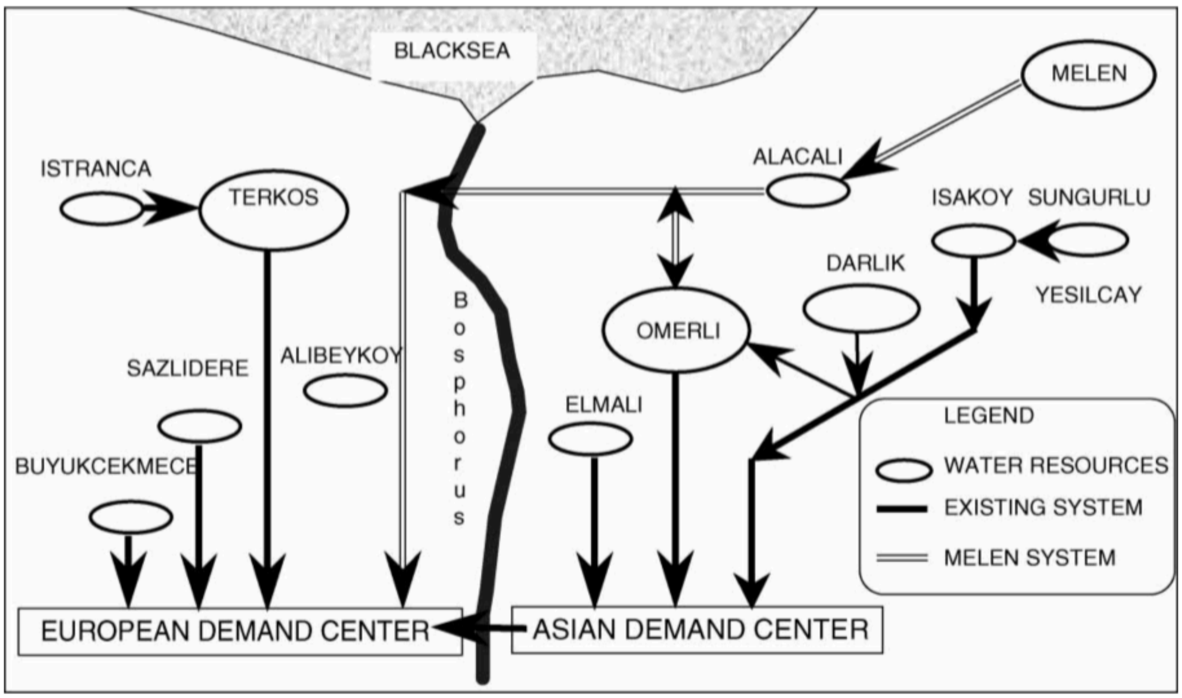
Water resources management in Turkey involves many stakeholders at the decision-making and executive levels. The Ministry of Forestry and Water Affairs (MoFWA) holds the key responsibility for water resources management, including surface and groundwater planning. Turkish Water Institute (SUEN), under the authority of MoFWA, is involved in developing long-term sustainable strategies and national policies for water management (World Bank, 2016). The water management system of Istanbul province, including WSS, lies under the responsibility of the Istanbul Water and Sewerage Administration (ISKI), which was established in 1981. Being a public utility of the Istanbul Metropolitan Municipality, ISKI performs its functions with an independent budget where most of its investments are made through the income generated from water sales (ISKI, 2019).

Historically, Istanbul has always faced water scarcity because of being located remotely from potable water resources. To address this crisis, big underground reservoirs were constructed to curb water scarcity and meet the water demand of its population. However, considering the unprecedented scale of urbanization at present, managing water is even more complex than ever (Easton, 2017). Istanbul has made significant efforts to provide sufficient drinking water and sanitation through water and wastewater treatment systems. However, the city's water resources are threatened in the long run by the impacts of climate change,

[2] The color key at the lower left shows travel time in hours for the water to flow into an adjacent reservoir. The red color (5 in key) approximates seeding targets. Watershed boundaries are delineated by thin gray lines and Istanbul emergency management (AKOM) surface meteorological stations by dots.

unplanned urbanization and uncontrolled settlements in watershed areas, causing water pollution, groundwater depletion and saltwater intrusion (Van Leeuwen & Sjerps, 2016). In this regard, Turkey has made considerable progress in its water policy framework by formulating various laws and regulations on water management and environmental protection (IU, 2015). Moreover, several projects have been initiated towards the long-term solution for water security in Istanbul. As shown in Figure 5, the implementation of the Greater Melen project on the Asian side which passes through the Bosphorus Strait via a pipeline of 189 km in length, is targeted to meet the water demands of the European side. This project is set to provide 1.18 billion m^3 year (3 million m^3 /day) until the year 2040 (Altinbilek, 2006).

Figure 5. Schematic of water supply projects for Istanbul



Note: *Reprinted from "Water Management in Istanbul" by D. Altinbilek, 2006*

In response to the sustainability challenges that the city is experiencing in terms of water security, the City Blueprint approach was applied to gain in-depth insight into the IWRM in Istanbul (Van Leeuwen & Sjerps, 2016). As shown in Figure 6, the city's performance in IWRM has been measured based on the three main frameworks and contributed significantly to the SDG 6.5 target assessment (EIP Water Action Group of the European Commission, n.d). In 2019, Turkey, in general, and Istanbul, by extension has been "moderately improving" the actions towards SDG 6 (Bertelsmann Stiftung & SDSN, 2019). The achievement of SDG 6.1 has been on track, with 98.9% of the population using at least basic drinking water services in Turkey, followed by the SDG 6.2 with 96.4% of the population using at least basic sanitation services. However, Turkey has been moderately improving SDG 6.3, where it withdraws 27.5 % of total water resources. The country also imports only 6.5 m^3/year/capita of groundwater depletion within SDG 6.4. The treatment of anthropogenic wastewater is moderately satisfactory at 48.8 % (Bertelsmann Stiftung & SDSN, 2019). According to the 2018 report by the United Nations Environment Programme (UNEP) for SDG 6.5, Turkey's score of IWRM implementation was 70%, which was ranked as medium-high performance (2018). In order to improve Istanbul's performance for SDG target 6.5, the efficiency and effectiveness of IWRM should be reinforced by enforcing laws and consistently reviewing and achieving periodic objectives that address outstanding challenges.

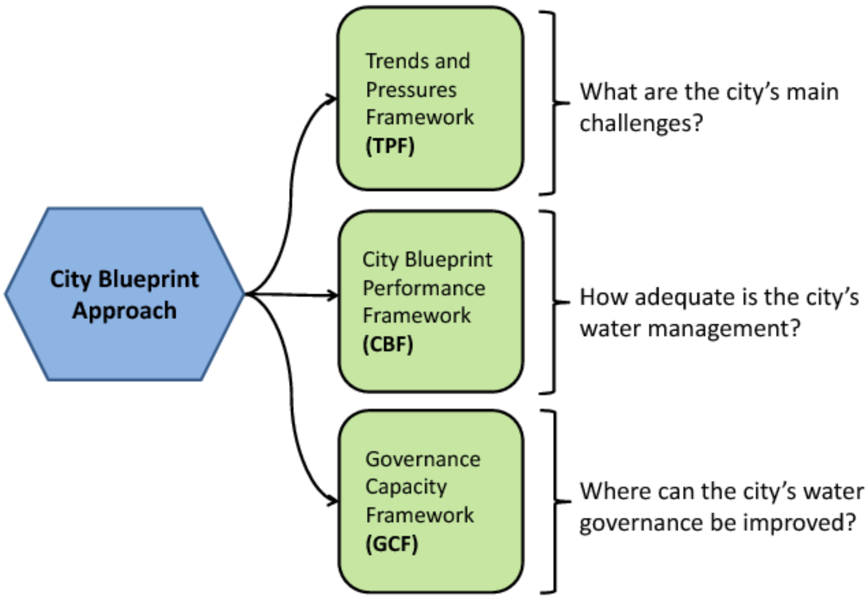


Figure 6. The City Blueprint Approach
Note: *Reprinted from "The City Blueprint Approach: Improving implementation capacities of cities and regions by sharing best practices on urban water cycle services" by EIP Water Action Group of the EU, n.d.*

	Cairo	Istanbul
Needs	• The current population of 20.5 million (Macrotrends, 2020a). • Expected to grow to 38 million by 2050 (GOPP, 2008). • Meet the water demand of 330 litres/capita/day • Improve supply to informal settlements. 60% of Cairo's areas are classified as informal (Khalil, 2019) • Reduce heavy wastewater discharges and drainage to River Nile and its aquifers (Abd-Elaty et al., 2019) • The yearly average evaporation rate attains 10.1 mm/year (El-Sayed,2018)	• The current population is 15 million (World Population Review, n.d.) • Expected to grow to up to 40 million by 2050 (Saatci, 2013) • Average daily water supply to Istanbul: 2,733,288 m³/day • Improve water supply to informal settlements. Approximately 70% of the housing stock in Istanbul are classified as informal (Uzun et al., 2010) • Annual precipitation is 812.8mm throughout the year (Weather Atlas) • Gross water demand in the city is estimated to be 175L/ capita, and this figure is expected to reach 225 L/ capita by 2050 including industrial usage (Cuceloglu et al., 2017) • More demand in European side (leading to the transfer of water from Asian to European side)

Actors	• International: USAID for funding, EU for technical assistance • Regional: Nile basin countries through the Nile Basin Initiative • National: Ministry of Housing, Utilities & Urban Communities; Ministry of Water Resources and Irrigation; Ministry of Agriculture and Land Reclamation; Ministry of Water Supply and Sanitation Facilities; Egyptian Water and Wastewater Regulatory Agency; Holding Company for Water and Wastewater • Municipal: Cairo and Alexandria Potable Water Organization (CAPWO). Water Sanitation Company (WSC). • Local: residents, informal settlers, industry	• International: EU IPA Regional development programmes • National: Ministry of Forestry and Water Affairs (MoFWA); Turkish Water Institute (SUEN) • Municipal: Istanbul Water and Sewerage Administration (ISKI) • Local: residents, informal settlers, industry
Resources	**The River Nile** • The assigned amount of Nile water to Egypt is about 55.5 billion cubic metres a year **Groundwater Aquifers** • Cairo: the withdrawal quantity of groundwater from the aquifer system is 4.6 BCM a year (El-Sayed, 2018) • 78.9% of the groundwater is safe for human consumption (El-Sayed,2018) **Rainfall** • There are 14.7 days of rain in Cairo, amounting to 24.7mm accumulated precipitation (Weather Atlas, 2020)	• Surface water collected in reservoirs of Asian and European side: Bosphorus, Eastern Thrace, Istranca stream, Black Sea basin • 98 % of water resources in İstanbul are surface water resources, and 2% from groundwater (ISKI, n.d.-a) • 18 surface water resources in İstanbul: one natural lake, eight dams, eight regulators and embankments (ISKI, n.d.-a) • 18 drinking water reservoirs operate to meet the demand for potable water in Istanbul European side resources: • Terkos, Alibeykoy, Büyükçekmece, Sazlıdere Asian side resources: • Ömerli, Darlık and Elmalı Resources in neighbouring cities (i.e. outside Istanbul's watershed): • Kazandere, Papucdere reservoirs; Istranca River; Melen system (Cuceloglu et al., 2017) • The total annual yield of drinking water resources: 1,660,000 m³/year (ISKI, n.d.-a)
Infrastructure	• Drinking water capacity: 7,233,000 m3/day (MHUUC, 2012) • Wastewater capacity: 4,290,000 m3/day (MHUUC, 2012) • 6 wastewater treatment plants • Cost of water for domestic use in Cairo: 0-10 cubic metres: 0.65 L.E. 11-20 cubic metres: 1.60 L.E. 21-30 cubic metres: 2.25 L.E. 0-40 cubic metres: 2.75 L.E. >40 cubic metres: 3.15 L.E. • Range of cost of water for industrial use: 3.00 - 10.00 L.E.	• Greater Melen project, providing 1.18 billion m³ water per year (3 million m³/d) until the year 2040 (Altinbilek, 2006) • Average water delivered to the city: 2,733,388 m³ / day (ISKI, n.d.-a) • 21 Drinking Water Treatment Plants Capacity: 4,428,860 m³ / day (ISKI, n.d.-a) • 88 Wastewater Treatment Plants Capacity: 5,815,910 m³ / day (ISKI, n.d.-a) • 150 Water Storage Tanks Volume: 1 million 727 thousand 080 m³ (ISKI, n.d.-a)

Outside Issues	• Arid, desert climate with minimal rainfall. Rainfall has further decreased by 25-50% due to climate change • Discharge of waste from the 43 towns between the Aswan Dam and Cairo, as well as other upstream African cities and towns • Contamination from industry • Grand Ethiopian Renaissance Dam: provisioned to decreased Egypt's water supply from the Nile by 25%	• Water availability and annual precipitation is predicted to diminish by 2050 due to climate change • Surface water pollution is mainly caused by factories & plants in Istanbul (ISKI, 2019) • Existing water reservoirs are polluted due to illegal settlements on watershed zones (Van Leeuwen & Sjerps, 2016)

Effective Water Governance and Management	• Nationally:
	  o IWRM incorporated in the MWRI plan
	  o Establishing a special regulatory agency: EWRA
	  o MWRI agreement with the EU to use modern irrigation and water treatment systems
	• Regionally: participation in the Nile Basin Initiative for peaceful transboundary water agreements
		• Nationally
		  o Water Framework Directive (WFD) adopted in 2000 with a new, combined approach into EU water policy
		  o WFD incorporated the whole aspects of IWRM in its Article 3
		  o SCADA (Supervisory Control and Data Acquisition) technology was provided by ISKI for potable water distribution to reduce water losses and monitor water quality

Relevant Government Plans	• National Vision 2030 • National Water Resource Plan 2037 • Greater Cairo Urban Development Strategy 2050	• Turkey's National Climate Change Adaptation Strategy and Action Plan (2011-2023) • Environmental Law (1983) • Water Pollution Control Regulation (1988) • Environmental Impact Assessment (EIA) in Environmental Law (1993) • Regulation on Water Pollution Control (2004) • Legislation related to Protection of watershed and preparation of watershed management plans (2012) • Legislation related to surface water quality for drinking water and water pollution control (2012) • Legislation related to the protection of groundwater resources (2012) (IU, 2015) • Melen Project from Melen River Basin to Istanbul

SDG 6 Country Performance	• Overall Performance: Moderately Improving • Target 6.1: On track for maintaining the target. 98.4% of the population using at least basic drinking water services • Target 6.2: Stagnating efforts. 93.2% of the population using at least basic sanitation services • Target 6.3: (no data on improvement status). 28.4% of anthropogenic wastewater receives treatment • Target 6.4: (no data on improvement status). 159.9% freshwater withdrawal of total renewable water resources, causing water stress. 2.8 m3/year/capita of groundwater depletion • Target 6.5: 40% implementation of IWRM, which is incorporated in national plans. There is no data on its implementation on all levels • Target 6.6: no data.	• Overall Performance: Moderately Improving • Target 6.1: On track for maintaining the target. 98.9% of the population using at least basic drinking water services • Target 6.2: On track for maintaining the target. 96.4% of the population using at least basic sanitation services • Target 6.3: Moderately improving. 48.8% of anthropogenic wastewater receives treatment • Target 6.4: (no data on improvement status). 27.5% freshwater withdrawal of total renewable water resources, causing water stress. 6.5 m^3/year/capita of groundwater depletion • Target 6.5: 70% implementation of IWRM, which was ranked as medium-high performance by the UNEP report for SDG 6.5 • Target 6.6: no data.

Table 2. Water systems in Cairo and Istanbul

III. Cairo

Key Challenges in Achieving Water Security

Cairo's geography, economy, and institutional structure create a myriad of challenges in ensuring water security. Cairo is faced with the mismanagement of water resources and an increase in water crowding. Additionally, its trend in water governance raises some issues. These challenges can be broadly divided into demand-side and supply-side challenges.

Demand-side Challenges

To begin with, Cairo faces an overwhelmingly increasing demand for water. Cairo's population is projected to almost double by 2050, reaching 38 million inhabitants (GOPP, 2008). This is compounded by the fact that Cairenes have one of the highest urban water consumption rates worldwide: 330 L/capita/day (MHUUC, 2012). This exacerbates Cairo's vulnerability because 90% of Cairo's drinking water is drawn from the Nile (Myllylä, 1995) - an amount expected to decrease due to GERD and climate change. GERD is expected to reduce Egypt's water intake by 25% (Schlanger, 2019). Therefore, urban growth will further increase water stress. Furthermore, Cairo has excessively exceeded its watershed – a phenomenon common to urban areas (Hoekstra et al., 2018), and its decision-makers fail to adopt a watershed perspective.

The second challenge that Cairo faces is its urban-scape. In an interview on Maspero Memory (2016), vernacular architect Hasan Fathy explains that the modern planning and architecture of Cairo imitate Europe's and are incompatible with Cairo's climate. As opposed to the traditional structures of Old Cairo, modern Cairo creates the heat island effect, which increases heat and evaporation and decreases water absorption. Additionally, Cairo's per capita share of green spaces is only 3 m^2 (Figure 1) (MHUUC, 2012). These factors ultimately increase the water demand of nature, man and the built environment. Cairo's modern urban-scape also causes flooding from rainfall every winter, drowning the city and requiring the deployment of hundreds of trucks to drain the rainwater (Almal News, 2020).

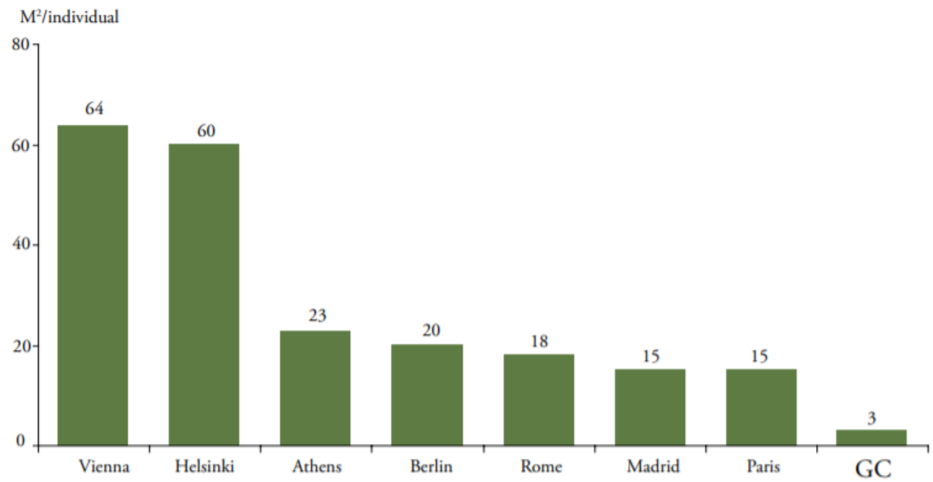


Figure 7. Per capita share of green spaces
Note: Reprinted from "Greater Cairo Urban Development Strategy" by MHUUC, 2012.

Supply-side Challenges

Fundamentally, the overarching supply-side challenge is that water security is not a priority of Cairo's government, despite it being water resource-poor. The Greater Cairo Urban Development Strategy's primary focus is economic development (MHUUC, 2012). This could be because the National Water Resources Plan mainly addresses large water – i.e. agriculture – and does not prioritize urban WSS. Nonetheless, this lack of prioritization creates challenges in governance and water management.

There is disjointed coordination between governance actors (Myllylä, 1995) that is evident in the lack of alignment across the various national and municipal development plans. This results in competing demands and, at times, unfinished efforts. There is also a gap between policymaking and implementation (Myllylä, 1995; Khalil, 2019), and between government plans and day-to-day affairs (Khalil, 2019). Another common underlying challenge is the inequitable delivery of water supply in informal settlements. A great portion of Cairo's population resides in informal settlements (GOPP, 2008) and rely on illegal, self-installed pipe extensions (Khalil, 2019). Although the national government has been extending the formal water and wastewater infrastructure post-Arab Spring to include informal settlements, the services' inconsistency, poor water quality, unreliable accountability of charged fees and the cost of water still exclude many informal settlers (Khalil, 2019).

In terms of management, although the government is striving to meet the city's rising demands, the fact remains that Cairo relies almost entirely on a transboundary resource: The Nile River. Although Egypt has regional negotiation powers over the Nile and the timeframe of filling the GERD, Egypt (and Cairo by extension) are vulnerable. Another entrenched management challenge is the poor infrastructure system, which has not been upgraded for 100 years (Sada Elbalad, 2017). Although water is purified to global standards in the treatment plants, the neglected pipe system leads to unaccounted for water and increased health risks (CGTN Africa, 2018). Upgrading the piping system is a challenging and costly undertaking as it lies underneath the subway system (Sada Elbalad, 2017).

Efforts Toward Sustainability

The government has made significant strides in monitoring water pollution on the Nile river. There has been an advancement in the mode of monitoring from the conventional traditional approaches to the new advanced technological solutions. Twenty-one stations were built to track both the quality of the Nile River and the quality of direct industrial wastewater discharged into the river, and by 2030 the number of monitoring stations is projected to be 95. In addition, there has been a substantial decrease in the number of facilities that discharge their waste into the Nile River from twenty-seven to only nine facilities (MPMAR, 2018). Several programs and projects have been carried out by the MWRI to ensure the optimal use of the water resources and water management for sustainable development that have taken place as per the National Water Policy till the year 2017 (Alnaggar, 2003; Bedawy, 2014). Regarding the water quality status, there are preventative measures taken through the regular assessment of the status of water quality and suitability for its various uses as well as regulations set to protect the water resource against pollution. Furthermore, the MWRI has developed and operates a National Water Quality Monitoring System in the Nile, canals, and drains and lake Nasser (Alnaggar, 2003; Bedawy, 2014). The Regional Center for Training and Water Studies (RCTWS) program was developed to support capacity building, training, education, and public awareness, and applied studies focused on IWRM. The Water Communication Unit was established to strengthen the ministry's capacity for raising public awareness to prompt water saving and protection measures. The program was launched to inform citizens of the importance of the role of water resources in development plans and to invite consumers to participate in the decision-making process (Alnaggar, 2003; Bedawy, 2014).

The MWRI has signed an agreement with the European Union (EU) for cooperation under the National Plan for Water Irrigation until 2037 as well as projects such as modern irrigation and water treatment in drainage systems (Takouleu, 2018). The government relies on water reuse techniques, particularly for irrigation, to overcome water scarcity. The agricultural drainage water is reclaimed at 10% of irrigation capacity, and the amount of reused wastewater amounted to 2 BCM in 2017 (Alnaggar, 2003). The treated wastewater from Cairo is used to cultivate mainly timber trees and industrial non-food crops (Khalifa, 2017). The government plans to upgrade the existing secondary wastewater treatment plants to save a total of 11.67 BCM water through tertiary wastewater treatment and reuse. The Government has committed to extending the use of natural methods such as wetland and soil aquifer treatment techniques that are known to be highly efficient and cost-effective (Helmecke et al., 2020). Rapid population growth and urban sprawl have created immense pressure on the existing WSS services in cities. The government, therefore, planned to build the New Cairo wastewater treatment plant to meet current and future demand. The Cairo wastewater treatment plant has a capacity of 500,000 m^3/day, providing the city and the surrounding area with a cost-effective and environmentally sound wastewater treatment plant to meet the current water demand and demand of the projected population growth (Water Technology, n.d.). Furthermore, there are ongoing attempts to transform the irrigation system into a drip system. These efforts are matched on the private sector side, where companies like Sekem have pioneered organic farming, sustainable irrigation methods as well as the processing of wastewater. This has ensured the efficient use of water resources due to the lower water requirement for organic cultivation (40% less) and the use of sprinkler and drip irrigation methods. Moreover, all the wastewater produced is reused after treatment (MPMAR, 2018).

Key Opportunities in Achieving Water Security

Demand-side Opportunities

Opportunities for Cairo include maximizing the natural circumstances and enhancing manmade infrastructures. Although Cairo receives less rainfall than Egypt's other urban cities (Gado & El-Agha, 2019), recent studies prove that rainwater harvesting is suitable (Elsaeed, 2019). Since this rainfall is concentrated over few days and results in flooding, the Cairo governorate could adapt the existing flash flood guidelines of other Egyptian governorates such as Sinai, Aswan, and Qena (UNECE, n.d.) and effectively plan to reuse this water. In addressing manmade infrastructure, Cairo should be keen to minimize evaporation demands throughout its ongoing real estate development. It could also add shading to the treatment of plant water pools (Figure 8) to decrease evaporation.

Figure 8. New Cairo Wastewater treatment plant

Supply-side Opportunities

Cairo in specific, and Egypt, in general, should work towards collective transboundary efforts to ensure water security for, and responsible use by all Nile-basin territories. Another key opportunity is effective coordination among local decision-makers. By coordinating different projects and priorities across ministries, water security could be practically addressed within the urban agenda. With effective laws and policies in place about water use and protection - some of which are aligned with IWRM principles – the government could also mobilize actors to enforce the laws would be effective. To bridge the gap between government planning and day-to-day affairs, the government could work towards formalizing the existing extensive expertise of the informal sector. Instead of building the formal infrastructure alongside the informal ones – as is currently occurring – the Cairo and Alexandria Water Organization (CAPWO) could examine the existing informal infrastructure, incorporate needs and challenges faced by inhabitants, and rectify the existing infrastructure, and expand it to meet growing demands.

IV. Istanbul

Istanbul is threatened by a water crisis due to its distant location to drinking water resources, both geologically and geographically. Many reservoirs operate under an integrated system to meet the water demand of the European and Asian parts of the city. As mentioned in the background, the City Blueprint approach with 24 indicators (Table 3 and Figure 9) has been applied to Istanbul to provide a long-term framing of the city's performance in managing its water resources. The indicators are scored on a scale between 0 (very poor performance) to 10 (excellent performance) based on three frameworks, namely; Trends and Pressures Framework (TPF) indicating the city’s challenges on main social, environmental and financial aspects, City Blueprint Performance Framework (CBF) indicating the IWRM performance and its bottlenecks in Istanbul and the city’s adequacy to water management, and Governance Capacity Framework (GCF) indicating the capacity in the improvement of city’s water governance. Based on this preliminary assessment, the indicators for drinking water sufficiency, consumption and quality, and safe sanitation in Istanbul are scored on a noticeably higher scale due to large-scale engineering projects. However, complex challenges in surface and groundwater quality and climate adaptation commitments have been recognized to avoid the anticipated water shortage in the long-term (Van Leeuwen & Sjerps, 2016).

No.	Indicator	Score	No.	Indicator	Score
1	Water footprint	6.3	13	Energy efficiency	5.0
2	Water scarcity	5.2	14	Energy recovery	1.0
3	Water self-sufficiency	7.9	15	Nutrient recovery	0.0
4	Surface water quality	5.8	16	Average age sewer system	5.0
5	Groundwater quality	4.0	17	Infrastructure separation	7.0
6	Sufficient to drink	10.0	18	Climate commitments	4.0
7	Water system leakages	7.6	19	Adaptation strategies	4.0
8	Water efficiency	5.0	20	Climate-robust buildings	3.0
9	Drinking water consumption	8.9	21	Biodiversity	6.3
10	Drinking water quality	9.0	22	Attractiveness	7.0
11	Safe sanitation	9.5	23	Management and action plans	5.0
12	Sewage sludge recycling	0.0	24	Public participation	0.5

Table 3. City Blueprint scores of the city of Istanbul
Note: *Reprinted from "Istanbul: the challenges of integrated water resources management in Europe's megacity" by K. Van Leeuwen and R. Sjerps, 2016*

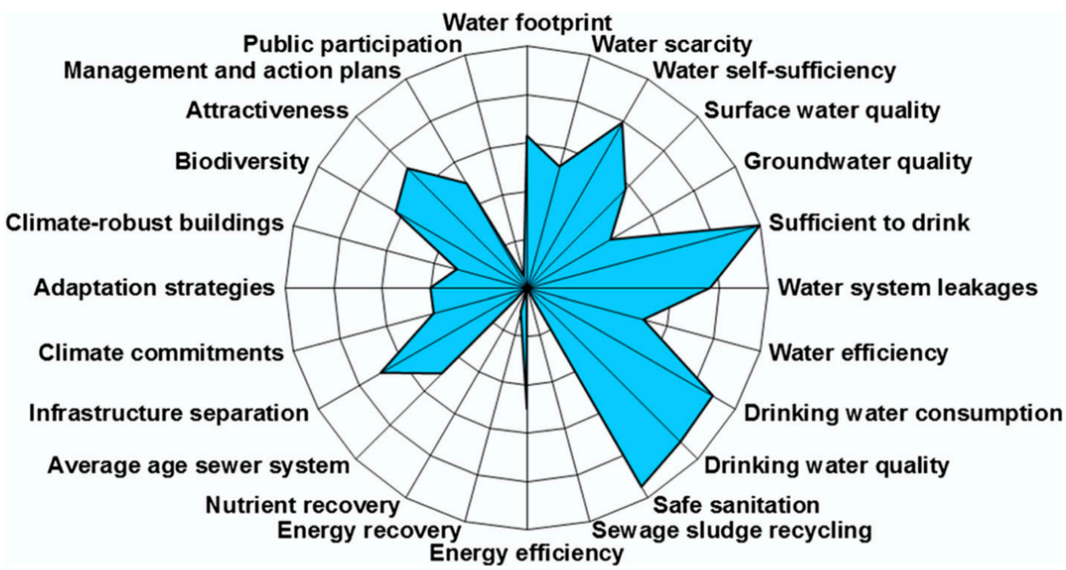


Figure 9. City Blueprint of Istanbul[3]. The BCI (Blue City Index) is 5.3
Note: *Reprinted from "Istanbul: the challenges of integrated water resources management in Europe's megacity" by K. Van Leeuwen and R. Sjerps, 2016*

[3] The performance-oriented set of indicators provides a snapshot of the current WRM performances. The indicator scores of the city are shown in a spider diagram

Key Challenges in Achieving Water Security

Demand-side Challenges

Istanbul has implemented large-scale projects to provide the increasing population with safe drinking water. However, a major challenge jeopardizing the existing water supply infrastructure is the pollution of Ömerli and other reservoirs due to illegal settlements on watershed zones. Population growth in Istanbul is around twice the overall rate for Turkey because of massive in-migration. From the 1950s, rapid and chaotic urbanization has led to an increase in the number of unauthorized and uncontrolled settlements in coastal areas without adequate sanitation. The enforcement of the regulations enacted in 1949 and 1966 to demolish slums and prohibit the construction of new ones closer to the reservoirs in Istanbul has been neglected due to social, economic and political reasons that posed a serious threat to water resources (Van Leeuwen & Sjerps, 2016).

As the economic centre of Turkey, around 40% of the Turkish industry is based in Istanbul. Manufacturing plants, industries and widespread use of chemical products contaminate the city's water resources (ISKI, 2019). Surface water pollution is mainly caused by the effluent that is disposed of by factories into the rivers. In response to preventing water quality deterioration by industrial activities, every factory is required by law to have a purification unit to prevent the disposal of contaminated water. However, this is often ignored due to high infrastructure and operational costs (Albut et al., 2007).

Supply-side Challenges

Climate change and its main impacts are expected to pose severe threats to water security and deteriorate the quality and quantity of surface water. Because of its latitude, Istanbul feels the effects of climate variability more significantly. Despite the high annual precipitation rates in Istanbul, the city experienced a drought from 2006 to 2008, recording the lowest rainfall in 50 years, which has since increased concerns over urban water supply among water management stakeholders (Easton, 2017). Water availability (m^3/year/capita) in Turkey is predicted to diminish from 3070 in 1990 to 1910 by 2050 due to droughts, floods, and decreases in annual precipitation that may lead to the loss of economic, social and natural resources (Aktash, 2014). This would mean that in the next 50-years, changes in precipitation are likely to diminish the water supply of dams and exacerbate water losses through evaporation (Turoglu, 2013).

Efforts Toward Sustainability

Istanbul poses an asymmetric situation regarding its water supplies and a non-homogeneous distribution of the population between the European and Asian sides. The Asian side accounts for 77% of the water resources, including Greater Melen, while only 35% of the population resides (Van Leeuwen & Sjerps, 2016). To accommodate for the water deficit of the European side, the Melen system in the Water Supply Master Plan was developed by ISKI. Water resources of Istanbul are mainly surface waters that are beyond the provincial boundaries. Following the 1994 severe drought, the emphasis has been made on the development of water resources and the total capacity has been increased from 590 mm^3/year in 1994 to 2100 Mm^3/year in 2014 (Öztürk & Altay, 2015). The Istanbul Master Plan Consortium (IMC) was assigned by ISKI to prepare a master plan for water supplies, stormwater and wastewater investments in the Istanbul Metropolitan Area (Altinbilek, 2006). Additional water resources are to be developed for the periods after 2040 to meet the future water demand and their annual water supply, as proposed in the masterplan (Öztürk & Altay, 2015).

The inadequate supply of water resources within the provincial borders prompted the protection of water catchment basins that have been acknowledged to ensure sustainable water supply in the future. The national framework legislation of the Water Pollution Control Regulation was implemented to protect the watershed against pollution. The first 300 metres of the boundary line of the reservoir (maximum water level) have been expropriated by the ISKI and designated as an absolute protection zone where settlement within this zone is prohibited. ISKI has expropriated and forested 65% of absolute protected areas in all associated watersheds, except for the Greater Melen (Öztürk & Altay, 2015). While between the border of the protection zone and the dividing line of water, industrial activities where manufacturing is directly involved with water are prohibited, and only low density and regulated settlements are permitted. A 10-metre-wide strip has been expropriated on both sides of the river where wastewater and stormwater channels and service roads are being contoured (Altinbilek, 2006; Öztürk & Altay, 2015). Furthermore, in attempts to protect the Melen resource, the ISKI has taken over the construction and operation of wastewater treatment plants in Duzce Province that encompasses most of the watershed (Öztürk & Altay, 2015).

There are currently 12 potable water treatment plants in Istanbul with a total capacity of nearly 4.4 million m^3/day (ISKI, 2020). The treated water quality is monitored regularly by the Istanbul Metropolitan Municipality and Provincial Directorate of the Ministry of Health. The urban drinking water has increased significantly through the improvements in water treatment plants and the renewal of pipes in the water distribution network (Öztürk & Altay, 2015). The ISKI operates the water transmission and distribution system in Istanbul. The length of the water distribution had reached over 18,000 km in 2014, and 98% of the network consisted of ductile iron pipes, as proposed by the ISKI's distribution system rehabilitation program, the remaining cast-iron pipes will be changed in the short term. Effective water pressure control and renewal of the pipes in the water network have decreased the ratio of unaccounted water to 24% in 2014 (Öztürk & Altay, 2015).

Key Opportunities in Achieving Water Security

Supply-side Solutions

With the ongoing water crisis caused by climate change, rapid industrialization and urban sprawl observed in Istanbul, supply-demand management appears to be an urgent necessity task for sustainable water resources management. The potential vulnerability of the city to global climate change requires examining hydrological processes and causes of water deficiency, as well as having long-term planning of water resources. Climate adaptation and mitigation strategies including water management policy were adopted within the "Turkey's National Climate Change Adaptation Strategy and Action Plan" for 2011-2023 that targets at developing an urban infrastructure master plan and financing strategy, private sector engagement in water investments with new finance methods and use of the most appropriate technologies for water and wastewater facilities (MoEU, 2011). In this context, the Greater Melen project, as illustrated in Figure 10, is expected to significantly increase the total water resources capacity of Istanbul on a long-term basis within the Bosphorus Undersea Water Supply Tunnel (Van Leeuwen & Sjerps, 2016). However, climate risk analysis still needs to be carried out on the supply-side by identifying droughts and effectively coordinating the city's water distribution systems as part of drought preparedness.

The ISKI has initiated the purification of wastewater through treatment units that may then be used for agriculture, parks or any other purpose that does not need high-quality water (Albut et al., 2007). The introduction of Supervisory Control and Data Acquisition (SCADA) technology for potable water distribution by ISKI has significantly reduced water losses and monitors water quality in dams and pumping stations. SCADA has also been an effective system to measure the water increase level due to weather conditions (ISKI, n.d.-b). To control the pollution of reservoirs, a new model of upgrading illegal settlements in Istanbul and other urban areas was developed by the Turkish Housing Development Administration (TOKI) in 2003. Due to the fact that around 70% of the housing stock in Istanbul has been informal settlements since the 1950s, water management stakeholders will have to be highly committed and coordinated including private sector participation to see the considerable progress of this model and its impact on watersheds of reservoirs (Uzun et al., 2010).

Demand-side Solutions

According to City Blueprint Approach, demand-side solutions for complex water security challenges in Istanbul, including efficient wastewater management, reducing water losses and public awareness campaigns will only be achieved through strong collaboration among national and local governments, private sector, civil society and other stakeholders (Van Leeuwen & Sjerps, 2016). Under the pressures of urban sprawl and climate change, the effective implementation of water supply, sanitation, and wastewater treatment necessitates a major transition to sustainable IWRM through Public-Private-Participation (PPP) initiatives. In this context, the implementation of the build-operate-transfer (BOT) model within urban wastewater treatment plants is promoted to carry out water management plans until 2050 in collaboration with the private sector. In the last few years, public outreach campaigns have been extensively carried out by ISKI in educational institutions and public places, but their scale should be further extended to make the community develop awareness on water and environment (ISKI, 2019).

In conclusion, to achieve urban water security in Istanbul through contemporary water use and management, and inclusive system of good governance should be the primary goal by coordinating the roles of legislative, financial and political authorities. Problems emerged by the delays in the implementation of regulations, such as informal settlements, could be compensated by the massive water transfer Melen project, technology transfer and other engineering solutions (Saatci, 2013).

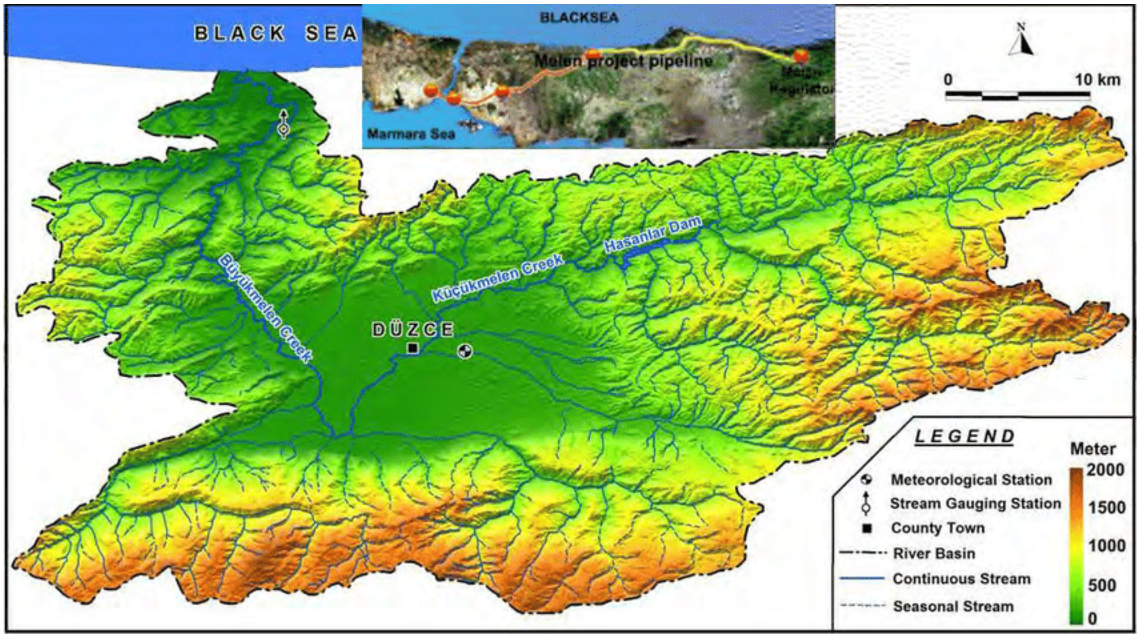


Figure 10. Melen River Basin and Melen Project pipeline
Note: *Reprinted from "Climatic Assessment of Sustainable Water Management in Melen River Basin" by H. Turoglu, 2016*

V. Discussion

Having analyzed the current situation, outstanding challenges and efforts from both cities, it becomes clear that there is no one-size-fits-all solution for Cairo and Istanbul in achieving urban water security considering their differences and very few similarities in many aspects given below. In researching urban water security in these cities, we have found the fundamental challenges to be in socio-demographic, economic, technological, environmental and governance factors. Therefore, we analyze these cities' statuses in urban water security through them.

Although both megacities are near the Mediterranean Sea, they have various geographical features in terms of landforms and ecosystems. Cairo is downstream of its largest water resource which is a transboundary river that begins in another country. On the other hand, Istanbul sits on, and is close to, water bodies through the Bosphorus strait connecting the Black Sea to the Mediterranean by way of the Sea of Marmara. Istanbul's water resources lie within Turkey. This difference gives rise to different outside issues. Cairo's vulnerability lies in not only climate change, but also in reduced water supply due to its transboundary basin. Turkey's greatest vulnerability lies in climate change, which resulted in water shortage due to extreme weather events (droughts) over the last decades. Moreover, the city's water reservoirs are at high risk of contamination due to unauthorized settlements on watershed zones. All these facts have increased the concerns over urban water supply among water management stakeholders in both cities.

Cairo receives considerably less amount of rainfall and has a high evaporative demand compared to Istanbul due to its arid climate that poses a threat to water security in the context of rapid urbanization demands. On the contrary, Istanbul experiences high precipitation annually in the humid subtropical Mediterranean zone. However, due to global warming, the city has experienced below-average rainfall annually over the last decades that has amplified the risk of water shortage. Both cities have undergone climate-related events that resulted in water shortage over the last decades. In this respect, effective water resources management in both cities requires incorporating climate variability factors in the long-term WRM strategies.

Water resources in Cairo are limited to the Nile River, together with minor amounts of rainfall and flash floods. The Aswan High Dam provides storage and guarantees regulated water supplies for municipal, industrial and agricultural uses. Three water supply projects have also been implemented, namely the Bahr El-Ghazal development, Jongile Canal and River Sobat- Machar Marshes in the upper Nile. Another source of water supply is the groundwater in the Nile valley and delta; however, the ground water potential greatly depends on subsurface drainage. In Istanbul, The Melen regulators and Sakarya pipeline projects, dams and underground reservoirs are the main water supply sources. In the past, dams were the main source of water supply to the city; however, there has been an increasing share of water obtained from the pipeline projects. Nevertheless, both Cairo and Istanbul rely on waste treatment plants. The treated wastewater is mainly used for agriculture in Cairo, while Istanbul has 21 potable water treatment plants to meet the demands of residential use. Both cities are faced with vulnerability of water resources and water supply systems due to significant changes in rates of flow and reduction of water potential due to climate change. Istanbul has taken the initiative to decrease the impacts and increase resilience against climate change by adopting the Climate Change Adaptation Strategy and Action Plan in 2012. Although aware of the impacts of climate change, Cairo has yet to develop a climate change adaptation and mitigation plan. Furthermore, the inadequate supply of water resources within the borders of Istanbul has prompted regulators such as Sakarya to import water from neighbouring cities. Meanwhile, Cairo's withdrawal rate from the Nile is greater than the rate of return.

Cairo and Istanbul have many similarities in terms of water supply needs. First, both cities need to meet the water demands of a large, dense population. Secondly, they should mitigate the risks of climate change on water resources. Finally, growing informal settlements are a big threat to urban water security that both Cairo and Istanbul are struggling right now. Within a comparative perspective, Cairo needs to fill the existing gaps in the implementation of water management policies and plans due to the lack of coordination between different governance actors. Regarding Istanbul, the city administration still makes efforts to collaborate with the industrial sector to reduce surface water contamination from manufacturing.

The closed water system of Cairo makes it more vulnerable to quality deterioration. As the population has been growing, and the expansion of urban areas continues, there has been an increase in water pollution. The pollution of surface and groundwater is due to agricultural, industrial and domestic waste. Although a water quality monitoring system of the Nile is in place, the development of other mechanisms including governance, policies, institutions, infrastructure for monitoring, laboratories and skilled human resources, are needed. On the other hand, surface water pollution in Istanbul is due to the overflow of the sewer system during intense precipitation. Remediation projects have taken place regarding the streams within residential areas, mainly focused on densely populated areas. The sewer network system will consist of two separate systems of stormwater and wastewater channels.

In assessing the socio-demographic factor and as illustrated in Section 2 of this paper, both Cairo and Istanbul have successfully provided improved piped WSS. Cairo's government is also working towards improving the water infrastructure in informal settlements, albeit not a priority. Similarly, a new model for upgrading illegal settlements in Istanbul was developed in 2003 by the Turkish Housing Development Administration which plans to demolish unplanned slums from watershed zones and construct new residential areas in the long term. Although the implementation of this model might require more time due to rapid urbanization in Istanbul, it is likely to significantly reduce the scale of water pollution in reservoirs if implemented systemically.

With regard to governance, Cairo's institutional framework is centralized, with overlapping responsibilities and weak enforcement. This results in national water strategies, plans and reforms which address agriculture and have minimal focus on urban water security. Istanbul's main water actors are decentralized. Although many institutions are engaged in water resources management at the primary and secondary levels, the functioning of the financially independent and centralized administration in Istanbul makes it more capable of taking effective and tailored action. The consequences are also reflected in data collection and availability. It is tremendously challenging to find specific data on Cairo's water, such as its withdrawal from the Nile and the percentage of improved WSS. Data was relatively easier to collect for Istanbul due to the decentralized decision-making and urban-focused institutions. On the other hand, both cities suffer from weak water pollution law enforcement, resulting in water contamination. The performance of both cities toward SDG 6 is ranked as "moderately improving". Both cities have made accomplishments on SDG 6.1 and 6.2 by providing basic drinking water services and sanitation services to more than 90% of the population. However, the actions on other targets are still not satisfactory and need to be improved to sustain high performance.

Both cities allocate budgets for their water infrastructure plans. However, it is noteworthy that for Cairo, the priority is to expand the infrastructure and supply to meet the urban sprawl, whereas meeting current demands of poor pipe quality and lack of infrastructure in informal settlements is a lower priority. In fact, it is planned to be tended to through trickle-down: after urban economic development, it will be possible to allocate considerable budgets for that purpose. The funding for water infrastructure comes from the Ministry of Finance, and decision-making is still very centralized. Compared to Egypt, water management plans in Turkey have been formulated for all urban settlements until 2050, with particular attention to Istanbul. The government encourages the public-private partnership through the build-operate-transfer (BOT) model in many infrastructure projects, including urban water management. Due to the large-scale projects to be finalized for Istanbul water supply and treatment, ISKI and associated government agencies encounter difficulties in handling the financial cost of these projects. Upgrading unplanned settlements to prevent the pollution of the reservoirs in this sprawling city requires huge investment and strong commitment from all stakeholders. Therefore, the cooperation between the private sector and the city administration is essential to facilitate the implementation of present and proposed initiatives.

VI. Conclusions and Recommendations

In this final section, we present our conclusions and recommendations. They are set out and discussed in terms of descending scales or domains of action, i.e. national and municipal. As shown, in Table 4, each city faces continuing challenges, but there are also many opportunities for improved urban water security.

	Cairo	**Istanbul**
National	• Allow for a decentralized governance system • Include a budget for sustainable urban water among the national water efficiency and treatment projects • Include Cairo in the climate change action project • Collaborate with Nile basin countries for protection and sustainable consumption of the Nile River	• Facilitate the implementation of the illegal settlements upgrading program. • Provide slum owners with housing units with adequate water supply • Achieve an inclusive system of governance by encouraging private sector participation in the decision-making and water supply projects. • Apply a multidisciplinary approach to mitigate the impacts of climate change on Istanbul water resources
Municipal	• Prioritize extending the WSS infrastructure to informal settlements • Apply a more effective water pricing strategy to facilitate equitable access to low-income households and discourage excessive use and water waste • Include a climate change mitigation and adaptation plan in the urban development strategy that is aligned with the general national strategies • Maintain and upgrade the WSS infrastructure • Develop governance, policies, institutions, and infrastructure to monitor water quality • Reduce evaporation demand of the water system and urban-scape	• Apply a more effective water pricing strategy to stimulate the efficient use of water and discourage its waste • Expand the scope of water use awareness measures to reach to more target audience • Incorporate environmental impacts of water scarcity in the public outreach campaign programs • Achieve better payment of water tariffs through enforcing municipal laws to increase financial resources of ISKI • Extend the use of up-to-date technologies for better operation and protection of water systems.

Table 4. Recommendations to achieve water security in Cairo and Istanbul

Cairo

Cairo's socio-demographic performance is improving, its governance is adequate, but its economic, technological and environmental performances are weak. Therefore, Cairo is less likely to sustainably achieve urban water security if 'business-as-usual' practices persist. Below are some recommendations to address water scarcity.

On a national level, the centralized institutional framework in Cairo presents considerable challenges. In contrast, Istanbul has instituted a decentralized governance system which, as shown throughout this paper, provides better outcomes in terms of city-specific sustainable water supply plans, water protection laws, climate change adaptation efforts and data collection and compilation. Therefore, a decentralized governance framework, with a water authority of Cairo with the power of decision- and policymaking, would allow for not only more efficient performance but, in fact, more tailored solutions and projects, as well as better allocation of resources. It would also facilitate better water accountability, which would, in turn, allow for more effective plans and efforts. Also, Cairo could improve its water law enforcement by increasing the authority of the EWRA. Additionally, Egypt's national budget for water efficiency and treatment projects is sizeable; however, it is mostly directed towards agriculture in rural Egypt. The Ministry of Finance can increase the municipal water budget to help mitigate water scarcity.

As the Nile River Egypt’s main water resource, it is imperative that efforts should be made towards ensuring sustainable use of the source. Therefore, it is recommended that Egypt continues to collaborate and also share its existing efforts of sustainable consumption and protection of the Nile River with the other Nile Basin countries. Furthermore, the Nile is vulnerable to the impacts of climate change. Since the national government signed a climate change adaptation plan with UNDP that focuses on coastal cities (Maged, 2019), it should also incorporate Cairo. The municipal government should further detail and execute the plan within the urban development efforts.

On a municipal level, ensuring equitable access to water, as a basic human right, is a significant step toward achieving urban water security. Egypt has done well in increasing water supply in urban areas. However, the lack of prioritization for extending infrastructure to informal settlements and unaffordable domestic rates for the poor has led to inequitable access to water. Therefore, increased efforts and resources should be directed towards increasing access to water in informal settlements and incorporating them into the formal water system. Additionally, the government should ensure fair pricing so that the system is maintained and extended. The current system is divided into four tiers reaching to 40 L. Since the average daily consumption in Cairo is 330 L, the tiers could be divided more evenly, to allow for more equitable low consumption rates, and to discourage higher consumption rates. Moving the tiers apart would ensure that a fair price is paid for water and discourage wasting water, as the MHUUC (2012) predicts that affordability for those with access to formal, in-house water supply is the main driver of the high urban water consumption rates in Cairo.

Another challenge faced is the poor quality of the WSS infrastructure in Cairo, which is causing pipe leakage and the flow of impurities into the water supply, posing health risks. Therefore, it is important for Cairo to not only upgrade, but also ensure the regular maintenance of the infrastructure to eliminate pipe leakage and water contamination. Even though a water quality monitoring system of the Nile is in place, the development of other mechanisms, including governance, policies, institutions, infrastructure for monitoring, laboratories and skilled human resources, are needed. Development in these areas can also improve the quality of treated wastewater, increasing the resource supply for food crops and potable water. Moreover, reducing the evaporation demand for water treatment plants, water infrastructure, and general urban design would effectively reduce water demand.

Istanbul

In comparison to Cairo, Istanbul has made more significant efforts towards achieving water security. Several initiatives have been introduced by the city’s policymakers for the protection of water resources and adaptation to climate change. Taking into account the complexity of the water resources management in this sprawling city, further recommendations are provided below.

Considering the fact that the proportion of the informal residential settlements is increasing in Istanbul in the context of urban sprawl, the implementation of the illegal settlements upgrading program within the new model by TOKI should be facilitated. Within this program, it is planned to provide the slum owners with compensation for their slums that will allow them to live in new housing units with adequate water supply (Uzun et al., 2010). However, this complex task requires a high level of commitment and strong collaboration among government agencies in the long term. Significant investment to ameliorate the contamination of water bodies must be a part of the slum upgrading effort.

On a national level, where water is formally provided, underpricing results in the underestimation of real value of water by the industrial sector and households. Therefore, a water pricing strategy that can stimulate the efficient use of water and discourage its waste must be put in place. This can also allow ISKI to get involved in future investments with a sufficient budget. Since 2017, within the framework of social responsibility, ISKI has promoted water use awareness by organizing seminars, training programs for young generations at approximately 400 educational institutions, and setting up booths in public spaces (ISKI, 2019). However, the scope of these measures must be expanded to incorporate environmental impacts of water scarcity by various means, particularly mass media and the internet to reach a greater target audience, including households and private businesses.

According to UNEP, the implementation of IWRM in Turkey is moderately improving with medium-high performance as of 2018. This was achieved due to progress in laws and policies and long-term management instruments in place for sustainable water use (2018). At the national level, the country reports the existence of the coordination in water resources management between inter-ministerial committees and institutions supporting the sustainable strategy to overcome water shortage. However, Turkey has failed to achieve an inclusive system of governance since the role of the private sector as a stakeholder in the decision structures and as a contractor in water supply projects is at the basic level (UNEP, 2018). Therefore, in order to reach a 'very high' classification of IWRM performance during the next phase, the private sector participation should not be limited to the operation of water and wastewater treatment plants. They should also be actively involved and make a financial contribution to water management (Istanbul International Water Forum, 2011).

Regarding the financial aspects for IWRM implementation, Turkey is ranked by the UNEP among the small percentage of countries that have sufficient funds disbursed for all work. As a growing megacity, Istanbul has been defined among the priority areas for the planning of water supply infrastructure projects, such as the Melen project, which is the largest drinking water project investment in the country's history. Furthermore, Turkey has received financial support from the international development programmes, such as the EU Regional Development Programmes in the area of water management cycle (EC, n.d). On a local level, domestic, commercial and industrial water consumption is regulated by different tariff rates in Istanbul. However, industries and public institutions show poor payment records in terms of water and sewerage tariffs. So, ISKI should enforce municipal laws to achieve the better payment of water tariffs in order to cover its operation and maintenance expenses and create financial resources for future investments (Altinbilek, 2006).

Water security has also been included in the Climate Change Action Plan of Istanbul. The Golden Horn Environment Protection Project is a great example of environmental rehabilitation efforts initiated by the city (Altinbilek, 2006). In addition to that, the scale of environmental awareness measures should be increased for the conservation of the watersheds of water reservoirs with the support of the Ministry of Environment and Forestry. Additionally, to mitigate the impacts of climate change on water resources, a multidisciplinary approach should be applied, including technical and administrative precautionary measures to prevent the pollution of watersheds in water supply reservoirs.

On a municipal level, Istanbul has made substantial progress towards the technological advancement in water resources management. The introduction of SCADA – the central command system for Istanbul - is one of the biggest achievements by ISKI that transfers all data on water resources, rainfall and water lines to a centralized data system (ISKI, n.d.-b). Another important initiative is ISKABIS (İSKİ Infrastructure Data System) – a GIS project enabling spatial inquiries on potable water supply and wastewater infrastructure plants. This technology has been an efficient response to climate variability with its application in Disaster Management Data System in Istanbul (ISKI, n.d.-c). Thus, use up-to-date technologies such as remote sensing and GIS should be further extended for the better operation and protection of water systems in Istanbul.

All in all, urban water scarcity is a challenge faced by several megacities, and there is no single blueprint for achieving water security. Cities vary in climate, resources, governance, and challenges as witnessed by the case studies of Cairo and Istanbul. In our view, operating within a general framework provides direction for tailored efforts in achieving urban water security.

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