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# Towards reduced policy implementation barriers applicable to smart water resources management: a qualitative analysis

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Ethical approval reference number: 220453

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Word count:12,000
Presented: 30.06.2022

**Abstract**

Smart solutions are an essential element to strive with the upcoming water scarcity and extreme rainfall events. Scientific literature demonstrates that the technologies to enhance water management are developed already, but cities are facing challenges during the implementation process of Smart Water Resource Management (SWRM) tools. These challenges include increased managemental complexity, risk-aversion and weak cooperation of the involved stakeholders, lack of supporting regulatory frameworks, financial resources, and efficient market conditions, and ethical challenges including data privacy and cyber-security concerns. Barcelona is a pioneer in sustainable and smart development in water management and shows high ambitions to deal with these challenges. This research is expected to support local governments and companies to implement SWRM tools sustainably and thereby contribute to SDG 6 and 11. To answer the research question, a qualitative research design was conducted on this case study. The qualitative data to answer the research question were collected via semi-structured interviews with nine experts working in the water sector in Barcelona (including technical experts, managers, scientists, and NGOs). The findings of the research specifically highlight the significance of the motivation of the involved stakeholders and citizen involvement as the main promoter for the implementation.

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**List of Abbreviations**

SWRM: Smart Water Resource Management

UN: United Nations

SDGs: Sustainable Development Goals

SSCs: Sustainable Smart Cities

ICT: Information Communication Technology

CE: Circular Economy

NBS: Nature-based solutions

IUWM: Integrated Urban Water Management

GDPR: European General Data Protection Regulation

UWA2030: Urban Water Agenda 2030

RESCCUE: RESilience to cope with climate change in urban areas

SMEs: Small and medium enterprises

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## 1. Introduction

Emerging water scarcity and jeopardized water quality have led to the circumstance that water has become a significant topic in cities worldwide (Sgroi et al., 2018). These challenges are caused by a constantly growing urban population, aggravated weather conditions, as well as a lack of adequate infrastructure (IWRA, 2021). In Europe, 83% of the population is expected to live in cities by 2050 (EC, 2010). By 2050, the UN forecast that nearly 50% of the urban population will live in regions challenged by water sacristy (UN, 2019). In contradiction, cities are key contributors to climate change by being the most significant contributors to $CO^2$ emissions (IWRA, 2021). Cities occupy only 3% of the world´s land surface but are estimated to be responsible for approximately 75% of global $CO^2$ emissions (IWRA, 2021). Therefore, it is essential to design water management in a more innovative and energy-efficient way. The United Nations (UN) declared 2018-2028 as the International Decade for "Water for Sustainable Development" (UN, 2022). Goal 6 and Goal 11 of the SDGs (Sustainable Development Goals) focus on 'ensuring the availability and sustainable management of water and sanitation for all while making cities inclusive, safe, resilient, and sustainable, by aiming to reduce the impact of disasters, and reduce the environmental impact of cities' (UN, 2022). Due to the strong interlinkage of water supply and climate change, the issue of sustainability is indispensable in urban water management. Appropriate water management can be a driving force to overcome these challenges by providing crucial functions for urban areas, such as meeting public needs, connecting other sectors with water, and supporting them to meet their economic, social, and ecological goals (Grigg, 2022; Nika et al., 2020). Digital technologies to cope with the challenges associated with SWRM flourished in the last couple of years. The Internet of Things, Artificial Intelligence, and Big Data are considered the most relevant innovations to provide accurate real-time predictions and precise information for the water sector (Bhardwaj et al., 2022). SWRM offers a wide potential for solutions to ensure the reliability of water supply and water quality, improve leak detection, reduce flooding, decrease energy consumption, lower operational costs, and adjust to consumer needs (Gemma et al., 2014). Although a ready-to-use technology is provided, cities are struggling with the implementation process (Cipolletta et al., 2021).

The qualitative case study was applied to Barcelona because previous studies have shown that water scarcity triggered by a severe rainfall shortage will be a main concern for the next century (Forero-Ortiz et al., 2020). Barcelona has outstanding ambitions in SWRM, is part of several European projects concerning SWRM, and successfully implemented several SWRM tools. Experts recommend that the greatest benefits may be in the implementation of SWRM tools in small and medium-sized cities, as is Barcelona, because it is less complex compared to big or mega cities (GWP, 2000).

Next to the social relevance of the study, it shows important academic relevance for several reasons. Public and scientific interest in SWRM has increased rapidly over the past decade, but the

implementation of SWRM tools has been significantly slower compared to other sectors (e.g. energy and transport). Several implementation barriers such as managemental, financial, legislative, and ethical barriers were detected in smart cities worldwide. However, the literature is lacking reports of concrete studies that show the overall picture of implementation barriers and possible solutions (Janurova et al., 2020; Razmjoo et al., 2021). Research illustrates that weak governance significantly hinders innovation in water management and limits the capacity of the water sector to adequately focus on many of the current challenges (Cosgrove & Loucks, 2015). Most literature concerning barriers in SWRM is technology-focused, and case studies are primarily applied to cities in developing or economically weaker countries (Enkhtsetseg, 2017; Ho-Young & Dong Won, 2020; ITU-T, 2014). It is lacking reports that focus on political and public admirative barriers and recommendations for the implementation of smart technology in a sustainable way. Cipolletta et al. (2021) and Waylen et al. (2019) raised awareness to the research gap that that further empirical data on implementation barriers in SWRM in Europe is needed to provide decision-makers with research on the benefits of SWRM and how to support successful implementations appropriately. Even though current literature sees sustainability as a crucial element of smart city management, previous studies did not consider the aspect of sustainability in their recommendations (Yigitcanlar et al., 2019). This study should fill the gap and serve as an orientation for other cities that are facing problems during the implementation. Therefore, this thesis aims to answer the following research question:

- "*How can implementation barriers applicable to Smart Water Resource Management in sustainable smart cities be reduced? Demonstrated by a case study in Barcelona?* "

To answer this research question, semi-structured interviews with nine experts in SWRM from Barcelona were conducted. This thesis is organized in seven chapters. After the introduction, the theoretical framework is presented in section 2 to acknowledge the role of sustainability and SWRM in smart cities on which the following results are based on. This section also analyses implementation barriers that have been detected by previous research, as well as recommendations from previous research to show what has been detected already and what is missing in particular that form the basis for the interview questions. Section 3 shows the applied methods, how this research has been conducted, and the case description. Afterwards, in section 4, the results of the interviews are presented. Followed by section 5, which first answers sub-question 1:

- "*What makes Barcelona a sustainable smart city in the context of water management?* "

Followed by presenting the implementation barriers that have been overserved through the interviews and finally answers sub-question 2:

- "*What can we learn from Barcelona´s experience to reduce implementation barriers in SWRM?* "

Section 6 highlights this paper´s limitations, and section 7 ultimately answers the research question and concludes the most important finding and implications for future research.

## 2. Theoretical framework and concepts

### 2.1. Sustainable smart city

Cities worldwide are often described as hubs of innovation and creativity (IWRA, 2021). The challenges in cities totally differ from the challenges in rural areas (IWRA, 2021). Not only the income level in cities is 21% higher than the national average, but cities have to deal with complex challenges that come with being the center of economic growth, communication, and logistics (IWRA, 2021). Smart solutions can significantly help to cope with these challenges. The concept of smart cities has evolved during the last 30 years (Yigitcanlar et al., 2019). The definitions of smart cities are manifold. According to Yigitcanlar et al. (2019, p.350), a smart city can be defined as "*a city in which an investment in human and social capital is performed, by encouraging the use of Information and Communication Technology (ICT) as an enabler of sustainable economic growth, providing improvements in the quality of life of consumers, and consequently, allowing better management of water resources and energy* ". Yigitcanlar et al. (2019) explored five main objectives sustainability, governance, accessibility, livability, and wellbeing. Smart innovations are designed to fulfill the needs of the citizens, to be involved in everyday urban life fit to the environment, and to be long-lasting for future generations (IWRA, 2021; Yigitcanlar, 2016). Most recently, the focus in research lies on sustainable smart cities. Yigitcanlar et al. (2019, p.360) concluded that 'cities cannot be truly smart without being sustainable'. Sustainable smart cities (SSCs) go beyond employing technology for citizens they are interconnected systems that converge with the industry, the natural environment, and the society (Arup et al., 2018; IWA, 2016). Sustainability is often still considered through a green environmental lens. Further characteristics are required in smart urban development, such as social and economic sustainability. Sugandha (2022) describes social sustainability as an integral component of urban development. Additionally, the focus on technology and the lacking attention on citizen empowerment is criticized as a technology-utopian neoliberal approach (Viitanen & Kingston, 2014). Smart technology that enables citizen participation should be therefore prioritized (Martin et al., 2018).

### 2.2. Smart Water Resource Management

Reduced water availability results in higher operation and maintenance costs for the industry and the energy sector, which can limit the economic growth of a city by 12% (Spinoni et al., 2018; Zaveri et al., 2021). Technological tools such as wireless monitoring, satellite mapping, other data sharing tools, and grid-dominated infrastructure tools, such as sensors, and smart controls, aim to provide benefits through digitalization, including real-time solutions (Hoffmann et al., 2020). By

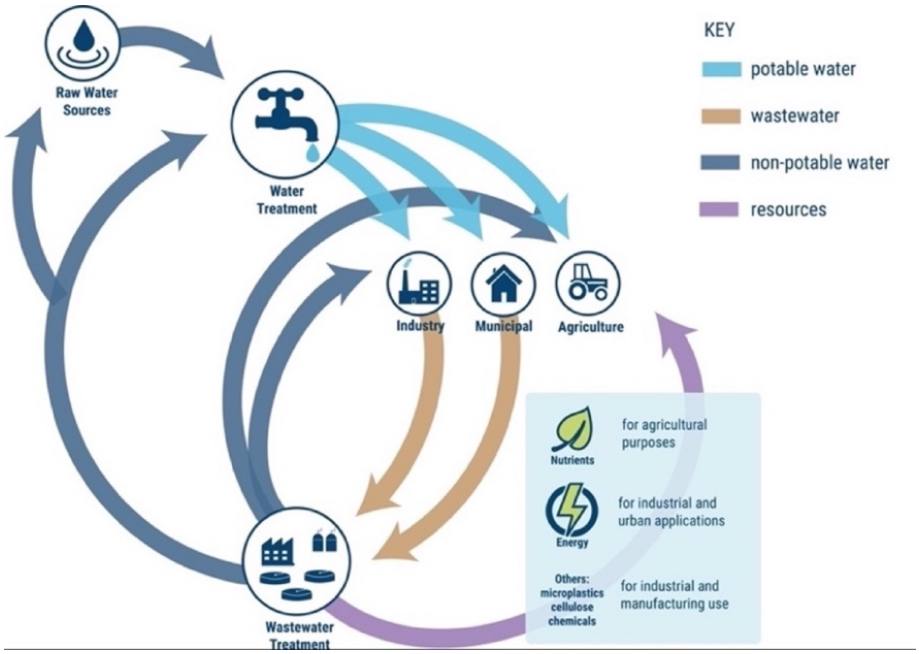
introducing these smart solutions, decision-making in water management services will become more efficient, reliable, and inclusive (Gemma et al., 2014). It should be noted that SWRM consists of various types of water, including drinking water concerns, urban water restoration and waterfront usage (IWRA, 2021).

As well as the smart city concept, the concept of smart water resource management (SWRM) has been around for a long time but is still evolving (Sanne et al., 2021). The development of SWRM is a response to the water crisis that is constantly becoming more complex due to the ICT development that aims to complement and improve existing infrastructure in urban water management (Sanne et al., 2021). Studies have emphasized that SWRM can play a key role in the transformation of cities into sustainable smart cities (Cosgrove & Loucks, 2015). There is a strong concern among producers, governments, and researchers about abandoning the linear model that is still applied in many cities and adopting a circular model (Figure 2). "*[CE is] an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes."* (Kirchherr et al, 2017, p.224). The notion that is used in policymaking focuses mainly on the last stage of the linear process in water management (waste management, recycling, and reuse) and promotes the development of novel technologies and encourage the transition to SWRM (Cipolletta et al., 2021; Hoffmann et al., 2020; Nika et al., 2020). Scientists have detected that water supply and reuse through non-conventional water resources can significantly reduce the stress on natural water resources and can increase revenue in utilities and reduces operational costs (Cipolletta et al., 2021). Smart cities are trying to become more sustainable and therefore aim to introduce a circular model in the water sector. The circular economy (CE) paradigm in water systems is based on three advantages: First, it regenerates natural capital, second, it keeps resources in use, and third, it designs out waste externalities (Arup et al., 2018). The concepts of CE and nature-based-solutions (NBS), aim to connect human-managed to nature-managed systems, and has been strongly promoted at European Union (EU) level in the last years (EC, 2015).

During the last years, the technology in water management has advanced immensely and has also become more relevant for private users. Smartphones are used in control and data acquisition functions, accurate smart meters and improved process controls were developed, which can improve system management tasks such as leak detection (Grigg, 2022). In the following years, the technology will focus on further automatization, and cyber-security will be extremely relevant (Grigg, 2022). Moreover, user information is expected to be further advanced (Grigg, 2022).

**Figure 2**

*Water in the circular economy*. Source: Water Reuse Europe, 2020.




### 2.3. Implementation barriers derived from literature

The implementation of smart technologies in urban water management is recognized as a complex socio-technical challenge (Cipolletta et al., 2021). Barriers that hinder the implementation of ready-to-use technology will be further elaborated in the following (Cipolletta et al., 2021). The implementation barriers are categorized into four main categories: Managemental, legal, financial, and ethical barriers.

A. Management

One of the main challenges during the implementation of SWRM tools identified by scientific literature is the managemental complexity, whereby different interests of public, private, and civil stakeholders collide (Gemma et al., 2014; Vannevel & Goethals, 2021). These complex dynamics can hinder efforts in upscaling and can lead to institutional and personal biases meaning that different individual interests influence the judgment of the stakeholders, which could hinder the implementation of the most suitable solutions (Kiparsky et al., 2013). Waylen et al. (2019) consider cooperation within and between different stakeholders as multi-level and nested.

A further identified barrier is weak cooperation between parties responsible for implementation, including overlapping responsibilities that can cause a lack of efficiency (Kiparsky et al., 2013). Currently, cities tend to work isolated, and communication is often only provided through individual relationships. Inefficiency in water management is often a result of fragmented systems that consist of

several isolated sub-systems (Gemma et al., 2014; Ramírez-Agudelo et al., 2021; Sanne et al., 2021). At present, different types of water, such as rainwater, groundwater, greywater, and stormwater, are predominately managed separately (EC, 2019). Consequently, solutions are less transferable to other cities, with slightly different conditions (Grigg, 2022).Therefore, pilot studies are not easily transferable to other projects and lose their significance (Grigg, 2022). A lack of transparency from the designers on future technologies hinders the implementation further (Mukheibir & Howe, 2014).

An additional challenge can be the attitude to change, including a lack of motivation or political change of the stakeholders involved (Sanne et al., 2021). The adoption of smart technology is constantly developing in the water sector in European cities. However, in a slower pace than other sectors such as the energy, transport, and agriculture sector (IWRA, 2021). Grigg (2022) confirms that SWRM in public institutions is compared to private businesses, slower and less agile. Risk-aversion and resistance to change in conventional water management are identified to be anchored at the individual and the organizational level (Tanner et al., 2018). Public authorities play a key role in water management, and the public sector is considered to have a comparatively low innovative organizational culture (Sanne et al., 2021). Decisions concerning smart technology combine high risks and uncertainty of costs, combined with low data of performance which can prove success probabilities (Kiparsly et al., 2013). As well as the public sector, the water sector is generally considered to be conservative and risk-averse, resulting in inflexibility to changing circumstances (Wehn & Montalvo, 2018). Water systems are mostly constructed to match fixed capacities, resulting in immense problems if these capacities are exceeded (Mukheibir & Howe, 2014). The lack of flexibility can lead to dysfunctionality when water infrastructures are confronted with increasing climate variability (Mukheibir & Howe, 2014). Often the motivation to change is present but especially in the public sector, employees that perform traditional, although now outdated, functions limit innovation. However, to reduce these positions can be difficult because of long-term working contracts (Grigg, 2022). Additionally, other stakeholders, including joint agencies and water utility companies, need to have enough capacity to support the transition to SWRM (Grigg, 2022).

B. Regulatory frameworks

Innovative strategies of state/ regional/ local governments and private companies in water management highly depend on regulatory frameworks (Mukheibir & Howe, 2014). The EU is currently pushing the topic of sustainable water management, but it has not been extensively studied regarding regulatory frameworks for the implementation of smart tools. Nika et al. (2020) detected that in some cases current regulations, which are designed for a linear model can have negative effects on the implementation process of SWRM tools, which are designed based on CE. Cipolletta et al. (2021) confirmed that current EU regulatory frameworks limit the development of a CE and the implementation of further SWRM tools. On the one hand, regulatory frameworks are not in line with

managemental developments in SWRM. On the other hand, it is criticized that they are rapidly changing (Stewart et al., 2016). A further discovered barrier is the missing uniformity of the regulatory frameworks in the water environment (Adler, 2009). Sometimes regulatory frameworks are overlapping with private, local, state, regional, federal, and sometimes even international law (Adler, 2009). Gemma et al. (2014) confirmed that inconsistency and overlap caused jurisdictional conflicts that led to fragile implementation processes. Stewart et al. (2016) raised awareness that some regulatory frameworks are too complex and thus hinder innovation.

C. Financial

A further challenge is that 'higher-than-expected costs and lower revenues than needed' often occur during the implementation process of SWRM tools (Grigg, 2022). The strategic approach to urban water management mostly focuses on solving acute problems, and thus is often designed for short-term solutions (Mukheibir & Howe, 2014). That can result in less financial sustainability and fewer costs in the short-term but higher costs in the long term (Grigg, 2022). However, performance improvements are usually only getting visible in the long term, making the implementation of smart water tools less attractive (Mukheibir & Howe, 2014). Kiparsky (2013) detected a lack of funding and effective market incentives in urban water management. One example of the lack of financial support for the implementation is too little financial means for demonstration and training and inaccurate prices that do not reflect the true costs of the development, supply, and maintenance of the systems (Grigg, 2022). Another aspect is that privatization of water utilities during the last decades has led to mixed results and opens the question to what extent market efficiency can take effect without disproportionate risks for consumers (Kiparsky et al., 2013).

D. Ethical

Cyber-security and privacy issues are caused by the continuous digitalization, which includes monitoring personal water consumption through water metering (Razmjoo et al., 2021). Water consumption measured at the household level reveals user-specific behavior, and time series on a minute scale provide especially detailed insights about personal lifestyles (Boyle et al., 2013; Cominola et al., 2021). That leads to possible misuse of private information and fear of consumers. However, appropriate quality drinking water service, reliable wastewater management, and drainage of properties can only be provided if sufficient users' informations are available (Grigg, 2022). Oberascher et al. (2022) concluded that the vulnerability to these new risks requires further research.

**Table 1**

*Implementation barriers derived from literature*

| Category | Barrier | Source |
|---|---|---|
| **Management** | Increased Management complexity (Institutional and personal biases, nested system) | Gemma et al. (2014); Kiparsky et al. (2013); Vannevel & Goethals (2021); Waylen et al. (2019) |
| | Weak cooperation of different stakeholders (Overlapping responsibilities, fragmentation, isolated sub-systems, lack of transparency) | Gemma et al. (2014); Grigg (2022); Kiparsky et al. (2013); Mukheibir & Howe (2014); Ramírez-Agudelo et al. (2021); Razmjoo et al. (2021); Sanne et al. (2021); Wehn & Montalvo (2018) |
| | Attitude to change (Lack of motivation and political will, risk-aversion of local governments, resistance to change, low innovative culture, lack of flexibility) | Grigg (2022); Kiparsky et al. (2013); Mukheibir & Howe (2014); Sanne et al. (2021); Tanner et al. (2018); Wehn & Montalvo (2018) |
| **Regulatory Frameworks** | Missing uniformity, overlapping, not in line with managemental developments, rapidly changing | Adler (2009); Cipolletta et al. (2021); Gemma et al. (2014); Mukheibir & Howe (2014); Nika et al. (2020); Stewart et al. (2016) |
| **Financial** | Lack of adequate financial resources and efficient market conditions, short-term planning | Gemma et al. (2014); Grigg (2022); Kiparsky (2013); Mukheibir & Howe (2014) |
| **Ethical** | Privacy issues, Cyber-security | Oberrascher et al. (2021); Razmjoo et al. (2021) |

### 2.4. Recommendations derived from literature

Several barriers to successful implement SWRM tools are presented in the literature. In contrast, the recommendations on how to solve these challenges are more limited. The authors focused only on solutions for specific barriers and specific recommendations. This section summarizes the main recommendations that can be found in the state-of-the-art literature.

A. Management

SWRM involves various stakeholders that need to effectively collaborate to develop innovative and sustainable solutions (Razmjoo et al., 2021). Transdisciplinary partnerships among academics, policymakers, water providers, and other stakeholders in SWRM are necessary (Waylen et al., 2019). A successful cross-sectoral collaboration requires all stakeholders involved in water management to be aware of their responsibilities, participate, setting priorities, and taking-action (GWP, 2000). Nearly all processes are to varying extents multi-level, thus the cooperation could be even more powerful if extensive networks cooperate to optimize their operations and knowledge to reduce current challenges in water management and finally achieve their common goals (Grigg, 2022). Stakeholder engagement that complies with all different interests is significant for the transformation toward smart cities (Shin & Jin Park, 2017). The implementation of SWRM tools requires a supportive institutional setting, including business models, such as public-private partnerships (GWP, 2000).

Enhanced cooperation of public and private stakeholders brings additional viewpoints and generates more long-lasting solutions (Kiparsky et al., 2013). Standardization of SWRM tools would improve the compatibility and increase transparency regarding upcoming technologies to ensure that investments are not made in soon-to-be upgraded technologies (Oberascher, 2022). Successful cooperation is also indispensable to overcome fragmentation. Experts claim for an integrated approach that comprises all aspects of water management, including environmental, technical, economic, political, and social aspects (UN, 2015). The concept of IUWM recognizes that different kinds of water can be used for different purposes: Freshwater sources (surface water, groundwater, rainwater) and desalinated water may supply domestic use, and wastewater can be used to comply with the demands of agriculture, industry, and the environment. As well as sustainable smart cities, integrated urban water management (IUWM) promotes an alignment of these systems (GWP, 2000).

Extended stakeholder engagement of city leaders with citizens, including education and training, can drive change and cause innovation by developing creative solutions (Fernandez & Rainey, 2006). Planas (2017) describes citizen participation as an 'anchor of a new water management model'. Several scientific authors see significant advantages in public participation, such as the creation of transparency and accountability, which results in democratic deepening (Garfí et al., 2017). These technologies can push the implementation of SWRM tools and can help to achieve social equity (Martin et al., 2018). Civil commitment may be expensive, complex, and time-consuming but results in more efficiency and sustainability because long-term acceptance is more likely to be achieved (Collentine & Futter, 2018; EC, 2022). Behavioral changes of citizens, including enhanced reliance on tap water as drinking water and increased reuse and conservation of water, can be encouraged as citizens learn more about their local water systems (Grigg, 2022). That could be a further promoter for the implementation of SWRM tools (Grigg, 2022). Derkzen et al. (2017) raise awareness that the positive effects of SWRM on the environment are mostly unknown to citizens and recommend raising awareness to promote digitalization. Garfi et al. (2017) suggest defining a clear action plan responding to local challenges to build citizen trust. He anticipates that if citizens are involved in the planning process, they will be more likely to accept the new approach (Garfi et al., 2017). This could be accomplished by establishing cross-sector representatives, working groups, and organizations that reflect the targets.

Garfi et al. (2017) further suggest defining a long-term vision that will help to implement tools in SWRM. IWRA (2021) confirmed that long-term planning and a comprehensive, inclusive, and resilient approach are necessary because water governance policies are closely linked to other sectors (IWRA, 2021). However, these sectors have completely different goals and interests, which are often in conflict (Enkhtesetseg, 2017). To establish smart tools in the water sector in smart cities, it is important to set long-term goals that can potentially be implemented through an incremental approach (IWRA, 2021). Changing deeply rooted institutional practices in large cities can be difficult. The

authors further suggest that it might be easier to implement on a higher level, such as in national policies, than on an operational level (Gemma et al., 2014). It is also recommended to integrate environmental concerns, such as water management, into a more powerful policy domain such as transport or energy (IWRA, 2021).

B. Regulatory Frameworks

Cipolletta et al.(2021) concluded that social, economic, and environmental progress should be achieved by adopting innovative regulatory frameworks suitable to current developments in the water sector. Future regulatory frameworks can support the implementation process of SWRM tools by addressing topics such as the lack of standardization and transparency, that several projects currently face because they are not yet regulated (Mukheibir & Howe, 2014). Therefore, it is important that regulations in SWRM are introduced in areas where further drivers are needed (Oberrascher, 2021). Mukheibir & Howe (2014) suggest goal-oriented, collaborative regulations that could be implemented through an incremental approach, which is helpful to improve the coordination of several different components of the legislation that applies to urban water management.

C. Financial

SWRM has become a priority for governments and has greatly facilitated the adoption of successful SWRM tools, as strong political support often includes significant funding for research and the development of smart solutions. Short-term costs may be rewarded by long-term efficiency savings, such as reductions in imported water, cost-savings from lowering pumping costs, reductions in the carbon intensity of water systems, and other benefits that might accrue to water providers in response to conservation but may be difficult to measure (Waylen et al., 2019). From a financial point of view, public bodies need to transform to become flexible, open, and capable of self-restructuration to create market conditions that promote innovation (Varela et al., 2020). Oberascher et al. (2022) confirm that the development of new business models would promote the implementation process further and suggest combining public and private resources to ensure long-term sustainability. For example, individual large-scale risk-taking is not necessary. Increasing collective risk-taking of the water industry could promote innovation (Potts, 2009). Financial incentives could be rebates, subsidized retrofits, water audits, seasonal pricing, and zonal pricing. On the opposite side, polluter-pay schemed can be used (GWP, 2000). They can serve as incentives for agricultural, commercial, municipal, and industrial users to reduce surface or groundwater consumption and promote gray water usage (GWP, 2000).

D. Ethical

No specific ethical recommendations regarding cyber security and privacy could be observed.

**Table 2**

*Recommendations derived from literature*

| Category | Recommendations | Source |
|---|---|---|
| **Management** | Enhance Collaboration (Cross-sectoral collaboration, transdisciplinary partnerships, public-private partnerships, standardization of technologies, IUWM) | Grigg (2022); GWP (2000); Razmjoo et al. (2021); Shin & Jin Park (2017); Waylen et al. (2019); Kiparsky et al. (2013); Oberascher et al. (2022) |
| | Citizen involvement, behavioral changes of citizens | Collentine & Futter (2018); Derkzen et al. (2017); EC (2022); Fernandez & Rainey (2006); Garfi et al. (2017); Gemma et al. (2014); Grigg (2022); Martin et al. (2018); Planas (2017); Waylen et al. (2019) |
| | Long-term vision implemented through an incremental approach | Enkhtesetseg (2017); Garfi et al. (2017); Gemma et al. (2014); IWRA (2021); Oberrascher et al. (2021) |
| | Implement on a higher level rather than on the operational levels | Gemma et al. (2019) |
| | Integration into a more powerful policy domain | Waylen et al. (2019) |
| **Regulatory framework** | Adjust legislation to current developments, incremental approach | Cipolletta et al. (2021); Mukheibir & Howe (2014); Oberrascher (2021) |
| **Financial** | Create market conditions, public-private investments, collective risk-taking, financial incentives, polluter-pay schemes | GWP (2000); Oberascher et al. (2022); Potts (2009); Waylen et al. (2019); Varela et al. (2020) |

## 3. Methodology

A qualitative research design was conducted on this case study to answer the research question. In this chapter the focus lies on the case study, the reflection of the research method, and how the data has been analyzed.

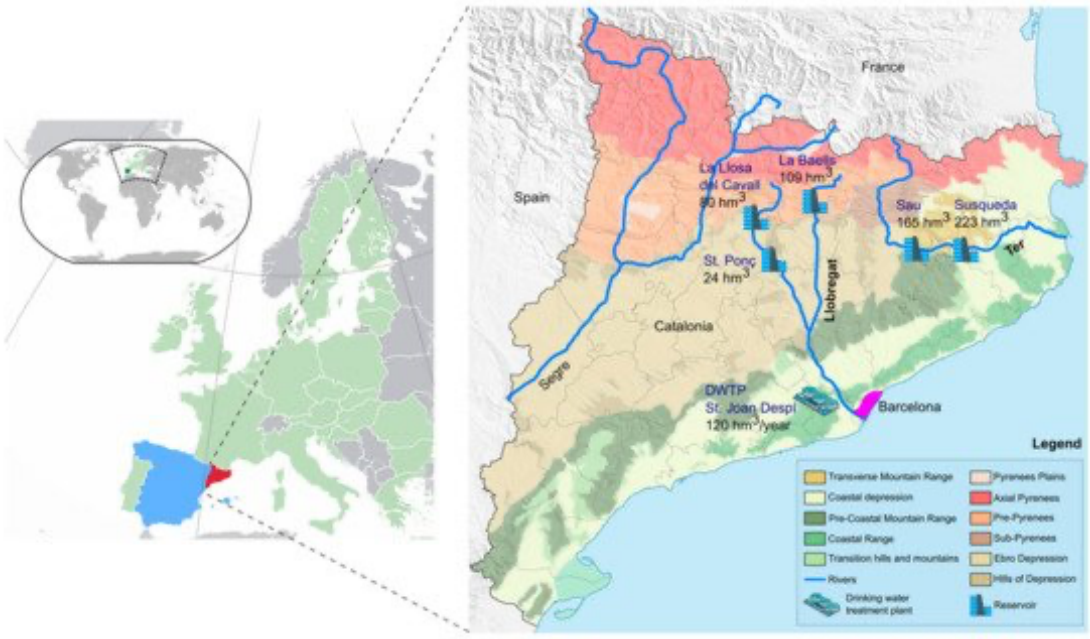
### 3.1. Case study: Barcelona

Barcelona is located on the northeast coast of the Iberian Peninsula on the Mediterranean Sea and is the capital city of the autonomous community of Catalonia, Spain (González et al., 2020). The city is surrounded by the mountain range of Collserola and has a strong dependence on the Llobregat river in the southwest and the Besòs river in the north (Figure 2) (Forero-Ortiz et al., 2020; González et al., 2020). The limited living space by the mountains and the sea results in one of the highest population densities in Europe (González et al., 2020). The permanent population amounts to 1.619.337 inhabitants is the city with the second-largest population in Spain and the sixth-most populous city in the EU (González et al., 2020). One of the main challenges Barcelona faces is vulnerability to environmental threats such as coastal and pluvial flooding, droughts, sea-level rise,

and heatwaves. These threats pose a risk to Barcelona's resilience and are expected to be aggravated by climate change (Pagani et al., 2018 & Monjo et al., 2019). Floodings can cause broken pipes that can lead to subsidence and sinkholes on public roads, significant accidents, and damage to property (Locatelli et al., 2021). The last heatwave event occurred simultaneously with an extreme rainfall event in 2018 (González et al., 2020). Understanding the complexity is essential to protect Barcelona´s population and mitigate the negative effects of climate change. Barcelona has a proactive approach and fighting against climate change has become a strategic priority (González et al., 2020).

**Figure 2**

*Location of the involved reservoirs, rivers, and morphology of the study area. Source: Forero-Ortiz et al., 2020.*




The current structure demand shows that 61% of the water is used for domestic consumption, 23% for industrial activities, and 16% for agriculture (BFSC, 2022). Water management in Barcelona is carried out by various companies (public, semi-public and private). The water sector consists of three different systems. Distributed in the water supply system, the sewer system, and the wastewater treatment system. The water supply system is managed by two private companies (Aigues de Barcelona and Suez Spain). Currently, BCASA (Barcelona Cicle de l'Aigua) monitors the sewerage systems and developed the new 'Alternative Water Resources Master Plan', which aims to strengthen the water resources and detect further water resources to increase Barcelona's resilience (EC, 2022).

Barcelona is internationally seen as one of the pioneers in the smart city movement (Urban Hub, 2018). The city started working through a cyclic and integrated approach to ensure strong support to foster innovation continuously (Ferrer, 2017). Jupiter research ranked Barcelona third in intelligent smart city planning 2021, after Shanghai and Seoul (Jupiter Research, 2022). One of Barcelona´s

innovative strategies in SWRM is described in the ‘Master Plan’. Barcelona´s City Council concluded that one of the main future challenges is to implement these strategies according to the plan (González et al., 2020). The plan identified the existing water resources and their potential in the current demand and designed a capable infrastructure according to the needs of Barcelona. The two most outstanding smart city projects that Barcelona is part of are the EU project ‘UWA2030’ (Urban Water Agenda 2030) and the ‘RESCCUE’ (RESilience to cope with climate change in urban areas) project. The UWA 2030 project encourages local governments and their water utilities to take voluntary action to complement Member States' efforts to meet EU water regulations (EC, 2022). According to Eloi Badia Casas, Councilor of Presidency Water and Energy of Barcelona, ‘Barcelona’s participation in the Urban Water Agenda 2030 will open further collaborations in strategical planning of water cycle management’ (EC, 2022). The RESCCUE project, including the resilience action plan (RAP), which complements the Climate Plan and Barcelona’s smart IT strategy, aims to improve growth for the next decade and create a more sustainable, smart, and inclusive path (Ferrer, 2017).

### 3.2. Research Design

The explanatory case study, which followed a mixture of an inductive and deductive approach, was applied to the city of Barcelona, Spain. A case study, as defined by Yin (2018), allows an intensive study of a unit and intends to describe the selected issue in its real-world context. This method was chosen considering the nature of the problem. The present state of knowledge on the implementation process in SWRM is comparatively limited. Case studies offer the opportunity to increase knowledge about social or political phenomena. In this case, implementation barriers and suitable recommendations in SWRM have been identified and the significance of sustainability have been demonstrated.

The data were collected by revising secondary data and conducting interviews. The secondary data was revised to identify barriers and recommendations in SWRM and to design the interview questions (Table 3). The differences Barcelona faces as a city with very high ambitions in SWRM were analyzed. It was showed what other cities can learn from Barcelona´s experience to reduce implementation barriers in SWRM. Previous research on water management with a similar aim found interviews a useful method to answer their research question (Enkhtesetseg, 2017; Janurova et al., 2020). Interviews are a reliable method and are chosen as the most suitable method to conduct information to answer the research question. The interactive nature opens the ability to achieve depth, and data is captured in its natural form (Legard, 2003). Qualitative semi-structured interviews were conducted to test whether implementation barriers and recommendations identified from the literature apply to the case study and to observe additional barriers and recommendations the interviewees

suggested. In total, nine interviews were conducted via Google Meet[1] and Microsoft Teams[2] between April and June 2022, with experts in SWRM from Barcelona. A purposeful selection of the sample was executed to include different expertise and specializations (Table 4). First, the interviewees were asked if specific implementation barriers identified by previous research are relevant for Barcelona. To not influence the interviewees, they were first asked if they had recommendations on how to reduce these barriers. To receive more information, in the following it was asked for their opinion of three possible recommendations identified in the literature (Table 3). Furthermore, the questions were slightly adjusted to the specific interviewee's occupation and their expertise, as several authors recommend, including Enkhtesetseg (2017) and Janurova et al. (2020), to gain as much information as possible to answer the research question. An extended document of all interview questions can be found in the annex. Interviews lasted between 30 and 60 minutes. Follow-up questions were asked as Legard (2003) recommends gaining a deeper and fuller understanding of the participant's responses meanings.

**Table 3**

Most significant interview questions

| **Category** | **Question** |
|---|---|
| Questions relating Sub-Question 1 | "*What makes Barcelona a sustainable smart city in the context of water management?* " |
| **Sustainability** | - Would you say that smart solutions in water management could lead to more sustainability?<br>- How sustainable is urban water management in Barcelona in your opinion? |
| **SWRM** | - Do you generally see an advantage in the use of smart technology in water resource management? (If yes, what kind of?)<br>- How smart is water management in Barcelona in your opinion? |
| Questions relating Sub-Question 2 | "*What can we learn from Barcelona´s experience to reduce implementation barriers in SWRM?* " |
| **Implementation barriers** | |
| Collaboration | - Have you encountered any difficulties during the cooperation? |
| Attitude to change | - The water sector and the public sector are known for their resistance to changes. Do you agree with the statement?<br>- Have you observed an institutional or personal bias? |
| Personnel | - How capable is the staff in SWRM in Barcelona for the implementation of innovative technologies? |
| Regulatory Framework | - Do you see the European and Spanish regulatory frameworks as a barrier or promoter to the implementation progress? |
| Financial Resources | - Are the financial resources sufficient to effectively implement smart tools? |
| Data security | - Do you see any issues in data security of citizens in SWRM? |
| Further barriers | - Have you detected further policy implementation barriers in SWRM? |
| **Recommendations** | |

[1] https://meet.google.com/
[2] https://www.microsoft.com/de-de/microsoft-teams/

| | | |
|---|---|---|
| General | - | Do you have any recommendations how the barriers we talked about could be reduced? |
| Citizen involvement | - | Is the involvement of citizens in SWRM important in your opinion? |
| Incremental shift | - | Do you see incremental shifts as a useful method to implement SWRM tools? |
| Short-term/Long-term solutions | - | Do you think that SWRM is designed for short-term solutions or long-term solutions? What is the better approach in your opinion? |
| Implement in more powerful domains | - | Do you think it could be helpful to implement SWRM tools into a more powerful policy domain e.g. energy, transport? |
| Level of implementation | - | Is it better to implement smart tools at the national level or local level? |

**Table 4**

Sample breakdown of semi-structured interviews (n=9)

| | **Gender** | | **Age** | **Organization** | | | | | | **Position** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | F | | Water supplier (public/ private) | Water supplier (public) | Environ mental Service | University | NGO | Barcelona City Council | Project Manager/ Head of the organization | Research | Water Engineer |
| N | 3 | 7 | 25-56 | 2 | 2 | 2 | 1 | 1 | 1 | 6 | 1 | 2 |

### 3.3. Data Analysis

All interviews were recorded with the permission of the interviewees and consent to use the data in research was taken in writing using consent forms. The recordings were transcribed with the software Amberscript[3] and afterwards manually adjusted if it was absolutely necessary. Atlas.ti[4] software was used to apply thematic coding that aims to identify patterns and to interpret qualitative data (Maguire & Delahunt, 2017). Transcribing interviews is described as an interpretive process that requires sensitivity, and the decontextualized nature of texts should be kept in mind during the processes of analysis (Given, 2008). Thematic coding was applied, and the codes were designed with the aim to answer the research question, including the sub-questions. Therefore, the main themes were sustainability, SWRM, and implementation barriers and recommendations identified from the literature. The analysis evaluated which of the barriers and recommendations apply to Barcelona. New themes have been created inductively. An extended version of the themes relevant to the analysis can be found in the following table (Table 5).

[3] https://www.amberscript.com/de

[4] https://atlasti.com/de

**Table 5**

*Coding Themes*

| Category | Themes |
|---|---|
| Questions relating Sub-Question 1 | "*What makes Barcelona a sustainable smart city in the context of water management?* " |
| **Sustainability** | S.1. Sustainability of Water Management in Barcelona |
| | S.2. Sustainability of SWRM tools |
| **SWRM** | SW.1. SWRM in Barcelona |
| | SW.2. Advantages of SWRM |
| Questions relating Sub-Question 2 | "*What can we learn from Barcelona´s experience to reduce implementation barriers in SWRM?* " |
| **Implementation barriers** | |
| Managemental | M.1. Weak cooperation of different stakeholders (Institutional and personal biases, overlapping cooperation, lack of coordination between parties responsible for implementation)<br>M.2. Attitude to change (Motivation political will, Risk-aversion, resistance to change, fragmented system (Water sector, public sector, citizens) |
| Regulatory Framework | R.1. EU Regulations, National, local regulations |
| Resources | Re.1. Financial Resources |
| Ethical | E.1. Privacy issue, Cyber-security |
| **Recommendations** | |
| Managemental | R.M.1. Improved Collaboration |
| | R.M.2. Citizen involvement/ Public participation/ Behavioral changes of citizens |
| | R.M.3. Incremental approach |
| | R.M.4. Short-term solutions/ Long-term solutions |
| | R.M.5. Implement at a higher level |
| | R.M.6. Integration of SWRM into a more powerful policy domain e.g. Energy, transport |
| Regulatory Framework | R.RF.1. Regulatory Framework |
| Resources | R.RE.2. Financial |
| **Categories added during the analysis** | |
| | M.3. Managemental complexity |
| | M.4. Citizens |
| | R.M.7. Flexibility |
| | R.M.8. Transformations in institutional cultures (Behavioral change) |
| | R.M.9. Holistic approach |
| | R.M.10. Experimentation |

**Table 6**

*Main themes with related qualifiers*

| Themes | Sample of qualifiers |
|---|---|
| Questions relating Sub-Question 1 | "*What makes Barcelona a sustainable smart city in the context of water management?* " |
| Sustainable orientation | • 'Water consumption per person significantly decreased' (I9)<br>• 'These solutions that are being implemented now will not be for forever, but the stakeholders and city managers are aligned and convinced the solution will last for a long time' (I1). |
| Smart orientation | • '20 years ago, Barcelona was on the top five world-leading cities in water management' (I7)<br>• 'Barcelona remains one of the most innovative cities' (I7) |
| Questions relating Sub-Question 2 | "*What can we learn from Barcelona´s experience to reduce implementation barriers in SWRM?* " |

| | |
|---|---|
| Barriers | • ‘Difficult to explain to consumers that millions of dollars have to be invested now in order to save millions of structural damage costs because of climate change in a few years’ (I3)<br>• (SWRM) ‘cannot be seen as one large system because it would be impossible to analyze’ (I1) |
| Recommendations | • ‘Almost 50% of the decision relies on the citizenship’’ (I5).<br>• ‘One to five percent of the annual financial water management budget would be enough to transform water management in any municipality in Spain’ (I7) |

## 4. Results

### 4.1. “What makes Barcelona a sustainable smart city in the context of water management?’’

The interviewees raised attention that Barcelona is in ‘a water war’ (I5) but that the city shows great efforts trying to cope with the challenge. Results illustrate that the mentality of involved stakeholders has already changed and that they recognized that adjustments are required due to the severe risks Barcelona is facing because of climate change. It was pointed out that ‘20 years ago Barcelona was on the top five world-leading cities in water management’ (I7) and that in recent years, water management has improved worldwide, but because of its long experience, ‘Barcelona remains one of the most innovative cities’ (I7) in SWRM. Master plans are very recently published by the local government and water utility companies. Furthermore, it was indicated that Barcelona is very open to research on smart and sustainable solutions and participates in several European projects that aim to advance SWRM further such as the ECHORD + project.

The findings show that compared to other European cities, Barcelona’s water systems are relatively young, especially the ‘water treatment system has been primarily constructed in the past 20 years’ (I4). However, pipes are sometimes hundreds of years old. Therefore, the risk of leakage is acute. Smart leak detection is one of the instruments Barcelona focuses on to save large quantities of water. It is very time-consuming to revise these immense amounts of data stored by the smart leak detection tool, which illustrates the massive efforts Barcelona is investing in a more sustainable water management approach. Another important topic on which Barcelona has extensive know-how and is currently working on is the use of gray water and the protection of biodiversity. It was highlighted that water management as a whole concept has a genuinely sustainable approach in Barcelona and that smart tools are designed accordingly. Since 2015, especially the water supply companies are strongly committed to reduce their carbon footprint and therefore introduced local supply chains. Data communications software, urban modeling software, simulation models, advanced control systems, and innovative sensors for real-time monitoring are indicated as the most important tools that allow more efficient use of water resources and minimize the risk of flooding. These smart systems have advanced immensely with a focus on sustainability and resilience in recent years. It was argued that

for this reason, water managers have better information for crisis operations, improve water infrastructure planning, and decide on the most cost-effective solutions.

Furthermore, it was explained that regarding sustainable development, the whole model on which water management was based on has changed. The linear model, which many cities still apply, was called a 'model of default' (I1) in the interviews. 'Barcelona applied the linear model and then realized that resources are not unlimited' and that 'crucial water resources have been wasted' (I1). Consequently, the model had to be changed. Now there is a different awareness that next to other resources, specifically water resources can no longer be squandered. A cyclic approach allows more efficient use of resources and ensures sustainability by saving water, energy, and money. Another issue related to sustainability is coping with cigarette dumping into the sea, which was detected as a giant environmental problem at the beaches and the sea surrounding Barcelona. The city arranged campaigns but has experienced that it is 'really hard to convince the population to avoid this kind of behavior' (I5). Water utility companies and governments made an extensive effort to sensitize people of their water consumption. In consequence, the 'water consumption per person significantly decreased' (I9).

The interviews demonstrated that Barcelona has not only a sustainable approach regarding environmental issues but as well concerning financial sustainability. The companies involved in water management and the city council are investing a lot in new infrastructure and projects on digitalization. Barcelona SWRM systems were described to be 'well-integrated' (I4), including 'well-connected' (I4) companies that are trying to make investments that are viable in the long-term even though it is a very fast-changing sector and uncertain times. It was concluded that 'these solutions that are being implemented now will not be for forever, but the stakeholders and city managers are aligned and convinced the solution will last for a long time' (I1). The interviewees emphasize that it is 'now time to slowly implement the new smart tools further' (I7) which is declared as one of the 'biggest upcoming challenges in water management in Barcelona' (I7).

### 4.2. Implementation barriers in SWRM in Barcelona

66,7% of the interviewees confirmed challenges during the cooperation that limited the implementation of SWRM tools in Barcelona. The interviewees described the internal cooperation within the organizations as efficient, but it was raised attention to challenges in external cooperation with other stakeholders. Enumerated reasons were conflicting interests of private and public companies, limited exchange of information, and a lack of political will of public administrations. The interviews showed that challenges during the cooperation are often connected with managemental complexity.

Secondly, 55,6% of the interviewees indicated managemental complexity as an implementation barrier. The main reason that was emphasized is the manifoldness in SWRM. In addition, the interviewees pointed out that water resource management is too fragmented. On the one hand, SWRM 'cannot be seen as one large system because it would be impossible to analyze' (I1). But on the other hand, it is important to keep in mind that 'all systems are highly interconnected' (I5), and decision-making in one system affects other sub-systems. A further reason which results in managemental complexity is that a continuous flow of data is involved in SWRM. Additionally, different communities in Barcelona have different interests, which are difficult to balance. Some communities are more interested in ecology and sustainability, and for other communities industrial aspects are more important.

Regarding the third barrier, attitude to change, the interviewees were asked about the motivation and political will to implement SWRM tools and if a risk-aversion and resistance to change exists in the water and public sector in Barcelona.

100% of the interviewees did not confirm a lack of motivation and political will in Barcelona. The motivation is described as very strong. They stressed out that Barcelona started very early to change its water system, which 'was really avantgarde at this time' (I1). Barcelona's openness to research city allowed scientists to show the effects of climate change concerning the water sector relatively early. Therefore, water management had to fundamentally change and adjust to the new circumstances. It was emphasized that Barcelona took part in several European projects during the change from a traditional to a smart water system to improve smart tools and methodologies to adapt them properly. The behavioral change is especially visible through the large investments in digitalization. The government has made available new generation funds that are in line with the recovery plans, which pushed for an update of the water sector. In addition, approximately '94% of the Catalan water sector are SMEs' (I4). Especially these companies strive for their cutting-edge technology to be implemented fast to cope with droughts which result in water shortages and other related issues. Some of the employees responsible for the implementation work in the sector for a long time and are not familiar with smart technology. It was expressed that although the attitude to change is high, especially in the public sector, changing the personnel to have the most qualified persons is difficult. Private companies have more flexibility to change their workers and the best-qualified person for the position.

77,8% of the interviews confirmed that a risk-aversion generally exists in the water-/ and public sector in Barcelona. On the contrary, most of the interviewees do not see it as a negative attribute. Arguments that were stated are that it is difficult for the public sector to change fast because

the system is very connected and complex. If wrong decisions are made, it has severe consequences for many people, that is why slow steps are taken. The ‘water sector is part of the critical infrastructure, and it has to be made sure that water services are provided 24 hours per day’ (I7). Consequently, the SWRM tools have to guarantee to be reliable and long-lasting at the point they are implemented. A further reason is that the city council is responsible for public funds and thus has to wisely distribute it and be sure that it will be a successful investment. Even though resistance to change in the public and private sector has not been seen negatively, resistance to change of citizens was declared as a challenge that mitigates the implementation of SWRM tools immensely. Many citizens are skeptical about reusing water (gray water). Gray water can be used to have proper wastewater treatment plants and to reintroduce water into the water supply system. From a technical point of view, it is possible to implement gray water for instance, it is implemented in the Netherlands already. But it is difficult to receive acceptance of the citizens. In contrary, the interviews showed that citizens are very open to participate in SWRM pilot projects.

The fourth issue, the regulatory framework sets the standard for the industry and the agriculture in water management, but 55,6% of the interviewees confirmed that the EU, Spanish and local regulations lack sufficient guidelines for a sustainable and smart approach. In addition, it has been pointed out that the fitness check of the Urban Wastewater Directive in 2019 evidenced that there are still major drawbacks in its implementation. It was criticized that the legislation on water reuse is not specific enough because it only considers reclaimed wastewater. It does not consider, for example, urban runoff, and rainwater harvesting. The other issue is that the legislation lacked for a long time for sufficient regulations for public health, including micro-pollutants. The Drinking Water Directive was implemented in 2021, shows the slow adjustments of the relevant regulatory frameworks. If water reuse on a small-size level is not sufficiently regulated, it hinders innovation. Hotels, for example, cannot reuse the water and therefore, the water cycle cannot be closed.

The fifth barrier is limited financial resources which 88,9 % of the interviewees. It was argued that the taxes and costs for drinking water are not sufficient to handle the current and upcoming challenges. Nevertheless, it was expressed that it is ‘difficult to explain to consumers that millions of dollars have to be invested now in order to save millions of structural damage costs because of climate change in a few years’ (I3). This change of mind towards financial investment seems to be difficult because of the Spanish and Catalan mentality, but it is an ongoing process that is slowly changing. Additionally, obligations of water companies are constantly rising, especially regarding developing European regulations. Consequently, an increase in water taxes will be necessary. On the contrary, the ‘Spanish government is investing more money at the moment in the water sector than they ever did before’ (I4). However, water is regarded as an essential service in Spain, and especially Barcelona´s local government does not want to raise taxes on water.

Lastly, ethical barriers, including privacy and cyber-security could only be confirmed relating to fear of citizens. 44% of the interviewees brought up that citizens tend to believe that private information and data collected by smart tools in water management are misused and not be anonymized, even though the interviewees expressed that the private water companies and the local government invest a lot in privacy and data security. Furthermore, it was pointed out that much time is spent anonymizing personal information. However, it is difficult to convince the citizens that the data is only used for machine learning and to advance smart tools. As a result, citizens are less open providing their data to the water companies, which mitigates the potential to implement smart tools. Additionally, it was revealed that water utility companies suffer from fraud. It happens regularly that people illegally receive water from the pipes. Consequently, companies lose money that could otherwise be invested in implementing smart tools. In addition, the cyber-attack risk raises immensely by implementing smart tools because a large amount of data is stored on servers and in clouds. Neither public nor private companies in Barcelona have experienced attacks so far, 'but they are prepared to cope with possible attacks' (I5).

### 4.3. Recommendations on how to reduce implementation barriers in SWRM in Barcelona

77,8% of the interviewees confirmed enhanced collaboration as a possible solution to implement SWRM tools more successfully. It was argued that 'in urban planning, everything is interconnected therefore, it requires an open transdisciplinary approach that integrates all systems' (I1). What has changed during the last years is that not only different technical experts have to cooperate in a project. Because of climate change, it is indispensable that also ecological, financial, and legal experts are included in the process develop and implement more efficient and sustainable projects. Furthermore, it was highlighted that different types of knowledge are required. Especially research developers and academia need to be included to translate the scientific outcomes to the government and the public. It is suggested that enhanced collaboration could be based on better communication, information exchange, and experimentation. During that processes, all parties need to be open to failure to achieve the best result. Referring to Barcelona´s experience it helps to 'improve decision-making for the purpose of strategy implementation' (I1). An example that illustrates the interconnectivity in the water sector is that usually, the city council has the responsibility for the sewer network. Nevertheless, in the case of Barcelona, a private company oversees the sewer network but is not in charge of the treatment plants controlled by the metropolitan area. Thus, both institutions need to coordinate and be closed in decision-making because the private company is transporting the wastewater to this treatment plant. Another example which reveals that not only stakeholders, who are directly concerned with water management have to cooperate, but also different city departments are

indirectly concerned. For example, if a street needs to be renewed, it also needs much time in the sewer system. Actions need to be coordinated because if errors are made during the modification challenges arise in the sewer system, which can result in immense costs. That shows that water management cannot be seen as an isolated and single system. It should be recognized in connection with other systems. It was also recommended to participate in European projects to exchange knowledge and experience with other member states to improve methodologies for an enhanced adaptation to the water sector.

The second recommendation confirmed by 100% of the interviewees is enhanced citizen involvement. According to the interviewees, citizen involvement is substantial to avoid resistance and consequently successful sustainably implement SMRM tools. Barcelona already involves citizens in the process of SWRM, but referring to the interviewees, it is an ongoing process that could be even further improved. Because the communities hold power, it is suggested to better inform the public about what, how, and why it is being done. Education programs for schools and universities reach ‘more than 600 people every year’ (I9). It is very helpful for water utility companies and local governments to have more educated and informed citizens. Subsequently, the public can be involved in the decisions to be taken. Flexibility means that the way of doing things is not only top-down, but it could be with the community who wants to be involved. A platform where the city council explains all projects and accepts the proposal from the citizens is provided. If pilot projects are executed before the implementation tools can be adjusted to the needs of specific communities. The example was given that during the development of a mathematical and hydrological model, to know when to replace the pipelines ‘‘almost 50% of the decision relies on the citizenship’’ (I5). Because even if water quality tests show excellent results, the feedback of citizens is required because if they do not agree with the taste of the water, projects are going to fail in the long run. In many cases, citizens are the direct consumers of smart tools. Centralized units at the household level are owners of SWRM tools. Therefore, they have to know how to use these tools and systems correctly and know how to improve consumption patterns. A further reason to involve citizens is to minimize the fear that robotics might take their jobs, which leads to resistance to change. Drones, for example, can help optimize processes in SWRM and reduce the health risk of workers in dangerous jobs.

Third, the interviewees who gave a recommendation regarding short-term and long-term solutions recommended a mixture of short-term and long-term solutions to successfully implement SWRM tools. It was described that the democratic structure, which generally includes election periods of four years, limits long-term planning of the public sector. It was explained that it is therefore difficult to create long-term solutions, not only in Barcelona. However, if private companies develop long-term visions, public institutions are more likely to adjust.

Fourth, the interviewees did not confirm to implement first at the national level. 44,4% recommended to implement some SWRM tools at a local level and others at the national level. It was explained that sometimes it is better to implement at the local level because the tools can be designed more individually to the needs of specific communities. Local implementation is very time-consuming because Barcelona consists of many districts. Thus, a regional approach is sometimes more efficient. It depends on the type of solutions, but now, where the technology has advanced, it is easier to implement them on a larger scale. In other cases, localized solutions work better. The challenge is to find the balance to have the most successful approach. First, implement at the local level first starting with pilot projects and then expand it.

The fifth recommendation to apply an incremental approach was confirmed as a suitable solution by 55,6%. Starting with a pilot project and according to the accomplishment of the goals, expand its implementation. It is a useful way to implement smart technology in the water sector. It is argued that it will not be radical, especially because water systems need to be adopted to large infrastructures. It was expected that the implementation cannot take place evenly, and within the incremental approach, a modular and decentralized strategy is recommended. It is also recommended to adjust employees in public administration if absolutely necessary step-by-step.

Sixth, 33,3% confirmed that it could be very helpful to implement in a more powerful domain for instance, in the energy or transport sector. That was shown by the example of the transport sector. It was explained that clear throughfares are needed to let the ambulances drive to hospitals if pipelines fail because of higher pressure, and they will block the streets.

Seventh, the legislation is slowly changing, and the topic of sustainable and smart water management is slowly incorporated into the legislation, but it will still need time to have sufficient regulations which push these topics further. It was explained that if it is improved, it would be way easier to implement innovative tools concerning these challenges. Furthermore, it was highlighted that both national and EU legislation is important in SWRM. EU regulations are required because they will harmonize practices among member states. In total, the interviewees state that the EU legislation could be even more advanced but, in general promotes progress. The Spanish regulatory framework is commonly behind and is pushed by EU regulations. It was suggested to adjust national regulatory frameworks to set the environmental and health standards higher on the national level. For instance, it was raised attention of a lacking common framework regarding contaminants and micro-pollutants. Another recommendation is to establish a holistic regulatory framework considering several types of water.

Lastly, additional financial resources are suggested by 88,9 % of the interviewees to have the possibility to implement further SWRM tools. It was mentioned that some parts of Barcelona need

rehabilitation. Further investment is needed to cope with the effects of climate change, especially damages will increase. Thus, it was recommended to design credit applications based on the ESG (Economic, social, and governance) criteria to have a more sustainable approach. If water management tools are updated, they are more resistant to damages, and in case of droughts, SWRM tools can help to save water and open additional sources of water. The implementation is related to economic benefits in the long run. It was explained that only 'one to five percent of the annual financial water management budget would be enough to transform water management in any municipality in Spain' (I7) and that proper risk management could avoid future costs. It was pointed out that there are financial resource challenges, especially in urban drainage, where these resources have limited short-term impact. Nonetheless, it should be recognized that water management needs a lot of financial resources, and implementing smart tools is relatively affordable. In addition, the cost-benefits method is recommended, which was the basis for convincing water stakeholders about smart and sustainable solutions. That entails massive savings in economic terms, as well as on the environmental level. Smart monetization and slightly raising the yearly taxes for water, and introducing environmental taxonomy are described as key solutions. It was explained that only '50 euros of additional taxes per person per year would be sufficient to make a big difference' (I6).

# 5. Discussion

## 5.1. Learnings from Barcelona´s experience to reduce implementation barriers in SWRM

The purpose of this study was to show how to reduce implementation barriers in SWRM in a sustainable manner and therefore, contribute to deal with the challenges that have occurred due to the ever-increasing population density in cities and the severe effects of climate change on water. It was raised awareness that management strategies and scientific concepts in water management need to adjust to current developments. It has been shown that water management challenges are multifaceted and intertwined, particularly when conceiving water management broadly (Wehn & Montalvo, 2018). The observed findings complement the previous findings, which are more suitable for developing and economically weaker countries and lack a sustainable orientation. Therefore, this thesis should serve as a starting point to develop a full picture of barriers and drivers for the implementation of SWRM tools in SSCs. The presented findings of the case study are discussed in the following to answer the second sub-question of the thesis: "What can we learn from Barcelona´s experience to reduce implementation barriers in SWRM?''.

The main barriers in Barcelona confirmed through the interviews were challenges during external cooperation, managemental complexity, risk-aversion of citizens, fear of data security, and a lack of supportive regulatory frameworks and adequate financial resources. Unexpectedly from what Kiparsky et al. (2013) detected, weak collaboration is only partly seen as an implementation barrier by the

interviewees. Only challenges during the external cooperation were expressed. In addition, the attitude to change of the local government and private companies is not even seen as an implementation barrier in SWRM in Barcelona, which contrasts with the observations of Sanne et al. (2021) and Wehn & Montalvo (2018). The attitude to change of the local government and private companies is described as very motivated, and it was highlighted that Barcelona started a long time ago as a pioneer to adjust the water management system to be smart and sustainable. However, results confirm Grigg´s (2022) findings that it is more difficult in the public sector than in the private sector to change employees to have the best suiting person capable of implementing innovative technologies. A further surprising finding is that the results showed that risk-aversion by local governments, as identified by Grigg (2022); Sanne et al. (2021); Tanner et al. (2018), is seen as a positive attribute in Barcelona. The main reasons stated are that decisions in SWRM have severe consequences and should therefore be taken carefully, as water systems must function properly at any time, and local governments and water utility companies are responsible for public money. However, risk-aversion and resistance to change of citizens were identified as one of the strongest barriers by the interviewees, which is further explained in the results section. Furthermore, data privacy and cyber-security issues have been identified as implementation barriers by Oberrascher et al. (2021) and Razmjoo et al. (2021). Even though Barcelona´s local government and water companies are very aware, it is one of the biggest fears of Barcelona´s citizens. The interviewees identified fraud as a further ethical barrier to the implementation of additional SWRM tools that have not been identified by previous research, and it limits the financial resources of the water providers.

Barcelona has a long experience in the implementation of smart tools, and the main solutions confirmed by the interviewees are first to enhance collaboration. Enumerated recommendations are better communication, enhanced information exchange, experimentation, and participation in European projects to exchange knowledge and experience with other member states. Second, Barcelona´s solution to resistance to change of citizens is to enhance citizen involvement, as also recommended by Fernandez & Rainey (2006) and Planas (2017). Although Barcelona already promotes citizen involvement and considers it a useful tool to increase acceptance of SWRM, further potential for improvement was perceived. The involvement in decision-making can minimize the fear of the citizens toward smart technology. To achieve more acceptance, a flexible bottom-up management is suggested. In addition, it was emphasized that the feedback of citizens is essential to adjust smart tools to perform in the best possible way. Third, in contrast to a long-term strategy recommended by Garfi et al. (2017) and IWRA (2021), the interviewees recommended to develop a mixture of a short-term and long-term vision. Fourth, Barcelona´s experts did not recommend implementation at a higher (e.g.) national level, as IWRA (2021) suggests, but balance between national and local strategies. Fifth, it was confirmed to implement SWRM tools through an incremental approach, as IWRA (2021) recommends. Therefore, establishing pilot projects has been confirmed as a useful method to promote the implementation process. Sixth, results showed that it is

necessary to adjust the regulatory framework to current developments in water management. It was confirmed that legislation needs to be updated, and EU and national regulations should be harmonized to further promote the implantation of SWRM tools. What has not been considered in previous research is the recommendation to develop a holistic regulatory framework that considers several types of water management, which were identified as a major recommendation in the interviews. Lastly, the results verified that additional financial resources would immensely support the implementation of SWRM tools. It has been confirmed through the interviews that it is essential to create market-conditions, apply smart monetarization, and raise taxes slightly. What has not been considered in previous research is to design credit applications according to the ESG (Economic, social, and governance) criteria for a more sustainable approach. Moreover, it was recommended to implement a cost-benefit approach to convince all stakeholders for future investments.

Even though this study has been conducted in a different environment than previous research, some barriers faced by Barcelona are in line with previous research, others were not confirmed, and additional barriers were identified. The strongest difference to the other environments is that Barcelona had a very early awareness of the upcoming challenges in water management and has more financial means to adapt to these challenges. Consequently, other recommendations were derived from the interviews. However, some of the recommendations from previous research have proved to be also suitable for Barcelona. This could be because these recommendations have more universal validity, regardless of the economic and cultural background.

### 5.2. Limitations

This study proposes recommendations that allow local governments and companies in the water sector to detect their implementation barriers and apply suitable recommendations to successful implement SWRM in a sustainable manner. However, it should be noted that the outcomes of this qualitative case study have several limitations. The first limitation is that this study only focuses on a single city due to the scoping requirements. The in-depth analysis of the implementation barriers and suitable recommendations in SWRM in Barcelona cannot be generalized but can function as an inspiration for other cities, especially in Europe, to adjust their water management strategies to the upcoming challenges. If a sustainable and smart orientation is already applied, the recommendations to reduce the identified implementation barriers might be suitable. However, the recommendations can also help cities to become more sustainable by introducing smart tools. Secondly, due to the limited feasibility of this research, the method to conduct interviews was selected as the most suitable one to answer the research question. The expert interviews were limited to nine due to the prescribed time and language barrier. Some of the experts in that field of SWRM in Barcelona did not speak English fluently or were skeptical to give an interview because the research question concerns a very specific topic. That was also why only limited recommendations regarding cyber-security and regulatory

frameworks could have been observed. The researcher trusts the honesty of the interviewees but keeps the possibility of biases in mind, e.g. loyalty or unconscious influence of the company the interviewees are working for.

## 6. Conclusion

The core question of this thesis was ‘‘How to reduce implementation barriers in SWRM in sustainable smart cities? Demonstrated by a case study in Barcelona?’’. The theory and the interviews have shown the indispensability of sustainability in smart city strategies. The results showed that a smart and sustainable approach in water management, based on the circular economy model, significantly helps to cope with the challenges that occur through climate change and to reduce $CO^2$ emissions.

The most relevant recommendations derived from the literature and confirmed through the case study from a managemental viewpoint are to improve collaboration through transdisciplinary partnerships, public-private partnerships, standardization of technologies, participation in multilateral projects, and to use an integrated approach. Another major recommendation is to increase citizen involvement through pilot projects, education programs, and participation in the decision-making processes. From a legal perspective, the regulatory framework should be adapted to current developments, legislation should be harmonized, and a holistic legal framework should be developed that takes into account multiple types of water management in line with the concept of IUWM. From a financial viewpoint, the interviews confirmed that it is essential to create market-conditions, apply smart monetarization and raise taxes slightly. In addition, it has been recommended to design credit applications based on the ESG (Economic, social, and governance) and to consistently apply a cost-benefit approach. The case study added specific recommendations to the broader ones identified in previous research. Recommendations that have not been fully confirmed by the case study are long-term planning, implementation at the national level, and the integration of SWRM tools into a more powerful policy domain.

In conclusion, it should be noted that SWRM is a crucial topic today and in the future. It can help to address challenges in constantly growing cities and can significantly contribute to SDG 6 and 11. The recommendations can help the water sector to catch up with faster developing sectors. The most outstanding finding are, first, that if all involved stakeholders in water management are particularly aware of the upcoming challenges and are open to change, as is Barcelona, it significantly promotes the implementation of SWRM tools. The literature showed that even though sustainability is substantial in the smart city concept, social sustainability is often still disregarded. However, to

implement SWRM tools in a sustainable manner, the most emphasized recommendation that has been highlighted in the literature as well as in the interviews is that the involvement of citizens is crucial for several reasons, including improvement of user needs, creation of transparency and accountability, minimize the fear of robotics, gain long-lasting acceptance and to raise public awareness of the topic to be able to leverage financial support.

Future research might consider the ethical barriers, which are in direct connection to social sustainability, that have been detected, such as cyber-security and data privacy, in-depth and focus on possible solutions. The protection of citizens is particularly crucial given the immense amount of data processed in SWRM, which is expected to increase in the next years. Developing uniform recommendations that apply to all cities will not be possible, but to develop more generalized solutions, further research is required to involve cities with different characteristics (e.g. economic, political, cultural).

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