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Making Urban Water Management Tangible for the Public by Means of Digital Solutions

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Abstract: Digital solutions are increasingly deployed in water management to support decision-making and to realize the automatization of processes. These solutions have a high potential to foster the sustainability of water management and related fields and thus to contribute to achieving the United Nations (UN) Sustainable Development Goals (SDGs). At the same time, more and more digital solutions aim to increase public awareness of specific urban water management aspects. To date, however, evidence is limited on the relevance and effectiveness of such digital solutions and on the effect of the governance settings on the potential of such solutions to raise awareness about the underlying water management issues. This paper aims to provide insights into the findings of two case studies, in Paris and Berlin, investigating the potential of digital solutions to make urban water management visible to the public and thus increase awareness about specific water management issues.

Keywords: sustainable water infrastructure; digitalization; urban water management; public awareness; water governance

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1. Introduction

Megatrends such as urban expansion and population growth as well as more frequent and severe extreme weather events due to climate change present major challenges to the management and governance of urban water systems in cities around the world [1]. To ensure sustainable urban water management [2–4] under complex governance settings, there is a need to critically reflect upon whether current water management approaches take public awareness aspects sufficiently into account.

Infrastructures in urban water systems and the services they provide are conceived to be so normalized in the daily lives of city dwellers that they become 'invisible' most of the time, and only perceivable when they fail or break down [5,6]. Their functioning is generally unknown to the public. Yet, such 'blackboxing' prevents citizens from understanding the sustainability challenges that these infrastructures and associated water resources may face in the future. This is reinforced by an observed reluctance and lack of resources among policy-makers to introduce measures to raise public awareness [7]. Increased awareness and knowledge of the public about water-related sustainability issues has been identified as an important factor influencing individual water consumption [8]. Yet, little is known about the potential influence of increased awareness and knowledge on public discourses evolving around the sustainability of urban water systems.

Digital solutions are increasingly deployed in urban water management. Generally referred to as "smart water management" [9,10], these solutions have a high potential to foster the sustainability of water management and related fields and thus to contribute to the United Nations (UN) Sustainable Development Goals (SDGs). Many of these digital solutions in the water sector are aimed at helping managers make decisions—for instance

on water loss control or water treatment optimization—to increase the efficiency of urban water management [11]. Apart from that, digital solutions are increasingly being developed that aim to foster public participation and knowledge on urban water management [12,13]. These new solutions are assumed to have the potential to contribute directly or indirectly to resource-efficient and sustainable water management (see Figure 1). They can open up the 'black box' and make water infrastructure visible to the general public. Since behavioral changes are key for improving consumption patterns, making infrastructure and data more visible has the potential to render urban water management more sustainable in the long run.

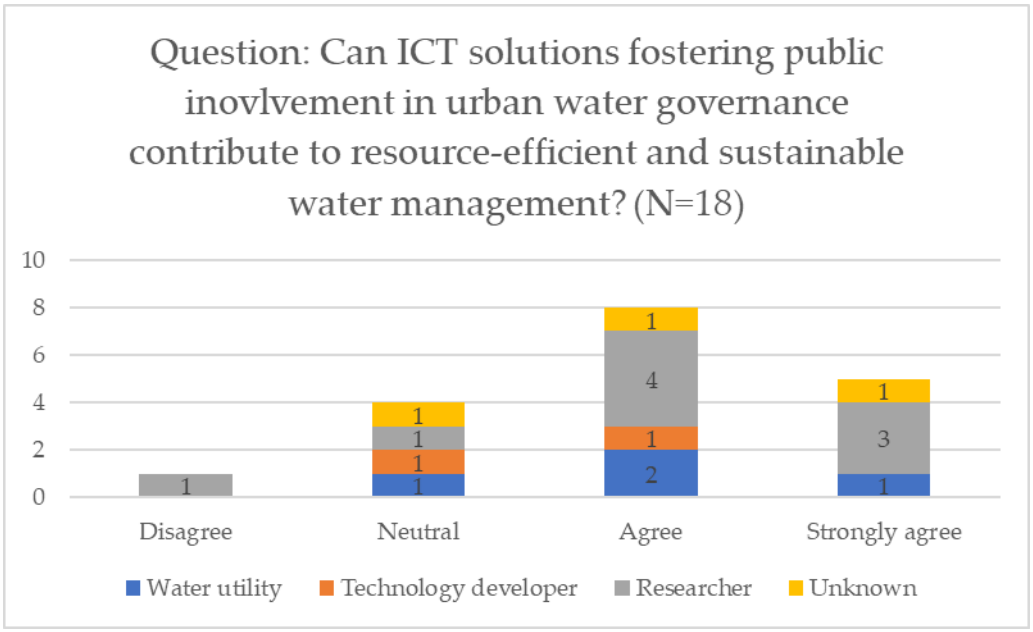

Figure 1. Online survey on assumed contribution of information and communications technology (ICT) solutions fostering public involvement in urban water governance on resource-efficient und sustainable water management across different actor groups conducted within the digital-water city project consortium.

In this paper, we build on two case studies from Berlin, Germany and Paris, France. The two applications in question are (1) an augmented reality (AR) application visualizing groundwater streams in Berlin, and (2) an online application to provide information on the quality of open-water bathing sites on the Seine and Marne rivers in Paris. Through the analysis of these two applications using digital technologies developed within the digital-water city research project, this paper explores the extent to which these solutions can contribute to making two distinct aspects of urban water management—groundwater flows and bathing water quality—visible, and what effects the resulting increased visibility can have on urban water governance and the public discourse around these two issues. Given the limited research in this field, we apply a grounded theory methodology [14] that aims to develop a hypothesis based on empirical observations to be explored in future research.

This paper is thus based on an inductive methodological approach. After providing a review of the relevant literature, we present the methodological framework as well as the co-creational processes that led to the development of the digital applications. We will then apply the methodological framework in the Berlin and Paris case studies and critically discuss the contributions of the digital solutions in making the underlying water management aspects visible and hypothesize in which way the applications may exert influence on the public discourse. The paper concludes by illustrating evidence from the two pilot case studies and giving an outlook on future fields of research.

2. Theoretical Background

An infrastructure is a technical system expanding further than a single site [6]. Its effective functioning for the user tends to mask all the work necessary to maintain it [15]. Technical water infrastructure, in particular, is hidden underground and provides services to end-users without their involvement at any stage of the provision process. Scholars in Science and Technology Studies (STS) have demonstrated the link between the invisibility of infrastructure and the lack of public debate about its development and functioning [16]. An infrastructure only becomes visible "upon breakdown" [6]. Yet, specific programs and "mediating technologies" can foster "the active consciousness whereby users are purposefully engaged in the performance of the network" [16]. Based on these observations, we consider urban water infrastructures as socio-technical infrastructures which comprise not only technical elements but also social interactions such as information exchange [17].

Advances in data-driven urban water management [18] and in digital solutions that can be used independent of time and location can increase the visibility of issues related to urban water infrastructure. Furlong [16] has documented the aspiration of many infrastructure managers towards more visibility. She considers that this could help municipalities to engage in the shaping of the system to better meet population needs. Such an engagement in the shaping of infrastructure requires not only top-down information about the system, but also bottom-up feedback from the population. Are digital solutions "mediating technologies" that can foster such dialogue? Or are they the vehicle for mere top-down information reducing public participation to the lowest degree of citizen participation—that of being informed [19]? Wilcox [20] has argued that the information-giving stance is essentially a 'take it or leave it' approach. Consultation, on the other hand, would include both information-giving and feedback. Making a joint decision would be a subsequent level in which people accept the ideas of their peers, and then choose from the options developed together. We assume that openness to public feedback is not an intrinsic characteristic of digital solutions but depends on their design.

Stein et al. [21] suggest that the effectiveness of digital solutions strongly depends on trust between the different actors involved. In this context, public awareness aims first to increase understanding and acceptance of digital solutions and second to improve the legitimacy and transparency of decision-making. To effectively communicate the benefits of digital solutions, they must be explained to the user in comprehensive clarity and depth. Complex data must be translated into a language that piques the public's interest and motivates laypeople, staff from public administration, and other societal actors to engage in dialogue with scientists and water managers. So far, there is only little knowledge on the effect of the governance settings on the environmental, economic, and societal impacts of such tools [21]. While initial research suggests raised awareness among citizens as a key benefit, others have pointed towards societal and environmental challenges, as well as to effectiveness issues of tools to enhance participation [22]. Scholars documenting participation in planning processes warn against a disproportionate influence of elite and special interest groups in public meetings [23,24]. This tends to distort and hinder attempts to democratize and open up inclusion in decision-making processes, especially in combination with unequally distributed knowledge on specific topics, time availability, and accessibility to meeting sites.

3. Methodological Framework

Applying a mixed-methods approach, we analyze and compare two urban case studies: (1) an augmented reality (AR) mobile application to visualize and raise awareness of groundwater flows in Berlin and (2) a public online application that provides information on bathing water quality in Paris (see Table 1 for a description of the digital solution developed in each case study). We conduct a relational comparison of two case studies in which digital solutions were developed to make these two different water management aspects visible. The comparison is relational [25] as the two case studies have influenced

each other through frequent exchanges between the respective water management and developer communities throughout the creation of the applications.

Table 1. Characteristics of the digital solutions in the two case studies (modified from Bouleau et al. [26]).

Features of the Digital Solutions	Berlin	Paris
Background	The tool was developed to make the invisible drinking water exploration infrastructure in Berlin visible	The tool was developed in order to initiate public bathing in the river Seine for the 2024 Olympic Summer Games in Paris
Description of the ICT solution	An augmented reality (AR) app visualizing geology and groundwater and highlighting their relevance as drinking water resources	(1) A smartphone or web application informing the public on the status of the bathing site (2) A web platform informing bathing site managers of water quality
Technology used	OBJ 3D models from MODFLOW dataMODFLOW simulations of scenes	Statistical modeling, machine learning; app not yet decided
Partner involved	Vragments, Berlin Water Works (BWB), Kompetenzzentrum Wasser Berlin (KWB)	Syndicat interdépartemental pour l'assainissement de l'agglomération parisienne (SIAAP), Sorbonne University (SU), KWB
Communication Target Group	General public (e.g., teachers, pupils from secondary school upwards, students); no experts	General public (anyone who might be interested in the bathing app: residents, boat owners); bathing site managers, authorities
User Group	Expert communicators and environmental educators, e.g., at water utilities (BWB or partner utilities) and authorities or non-governmental organizations who conduct guided tours or participate in further training for teachers	Bathing site managers
Aim	(1) Provide information on drinking water sources in Berlin (2) Explain where drinking water comes from and how it gets into wells, and is cleaned during infiltration	(1) Provide information on bathing authorization and additional information on sites (access, affluence, algae...) (2) Provide information on fecal water contamination
Implementation	Off-site	Two different versions to address accessibility and complexity

In order to analyze the governance settings relevant in each case study, we draw on STS as well as on a governance assessment framework developed by Knoblauch et al. [27]. We look more specifically at the research work in the field of STS that has focused on infrastructure. This work sheds light on infrastructure by treating it "relationally", acknowledging that is made of "a bundle of heterogeneous things" (...) "—which involves both organizational work as well as technology" [6,28]. We base our analysis on a grounded theory methodology [14]. Grounded theory, which inherently builds on an inductive approach, is suitable in research contexts where there is limited knowledge and previous research. Given the limited research on digital solutions that aim at making specific urban water management aspects visible, we develop a hypothesis based on our empirical observations in the two case studies to be explored in future research.

The Invisibility of water infrastructure makes it difficult for the public to directly observe and understand the sustainability stakes that the infrastructure may raise. Indeed, such infrastructure supports water withdrawals or water discharge, which are sometimes harmful to the environment, and such impacts may affect people (pollution, restriction on water availability). Since the 19th century, the functioning of urban water networks has directly affected the environment due to their withdrawals in rivers and aquifers (particularly for drinking water production) and discharges (for rainwater and treated water). Despite large investments in wastewater treatment plants, some wastewater is discharged

directly into the environment from the combined sewer system during intense rainfall. Groundwater overdraft threatens the sustainable and equitable use of water. Exposing this otherwise largely hidden mode of functioning to the public, which is increasingly sensitive to the protection of the environment, could increase public demands for infrastructure to evolve towards greater sustainability.

Building on Bressers et al. [29,30], the framework by Knoblauch et al. [19] allows for a holistic assessment of the potential of digital solutions for awareness-raising and public involvement in urban water management. It focuses on identifying and assessing non-technical factors relevant for the successful uptake and implementation of information and communications technology (ICT) solutions in urban water management. It is also designed to ensure comparability in analyzing water governance systems between different case studies [29,30]. It identifies interlinked dimensions which can foster or hamper the uptake of water-related digital solutions. After applying this framework in the two case studies, modifications to the governance dimensions analyzed were made, resulting in the framework shown in Figure 2. For each of these governance dimensions, we evaluated four so-called governance quality elements, namely scope, coherence, flexibility, and intensity. In addition, we assessed the general governance context for each dimension to capture general characteristics in the case study.

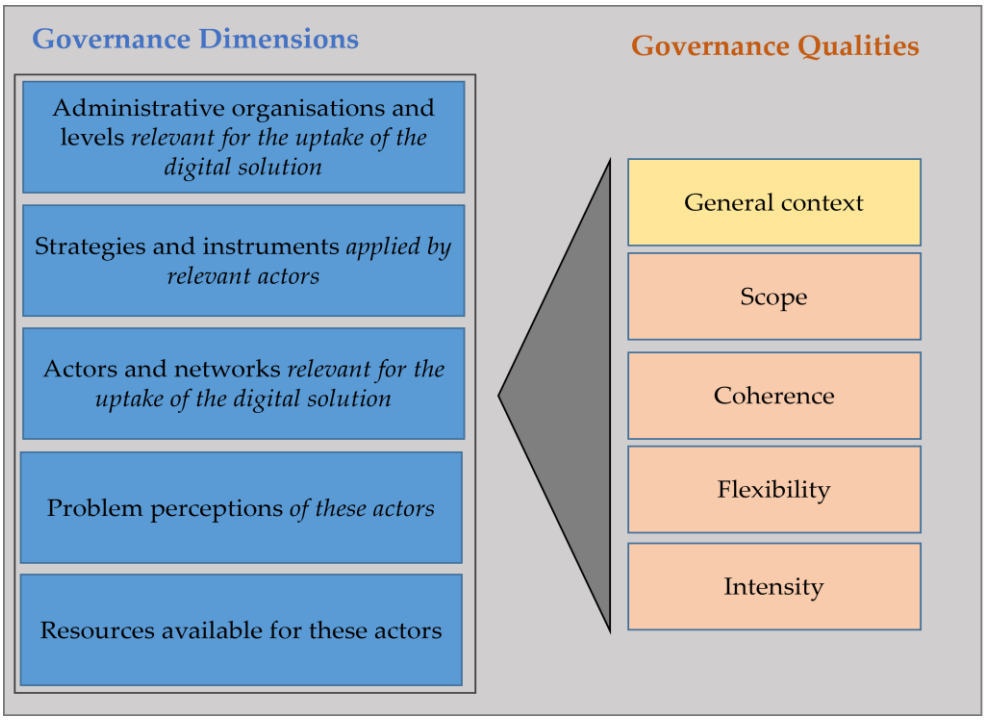

Figure 2. Simplified figure of the Governance Assessment Framework (own figure modified from Knoblauch et al. [27] building on Bressers et al. [29,30]).

To gather precise information, we defined guiding questions for each dimension of the governance structure as proposed by Knoblauch et al. [27]. The guiding questions of the framework structured the analysis of each of the five dimensions along the four criteria of the governance qualities. The guiding questions can best be understood as a starting point for the assessment of individual cases and were adapted to the specific contexts of each case study. An example is provided in Table 2 for the governance dimension "Problem Perceptions".

Table 2. Governance quality criteria for the dimension "Problem Perceptions" (Knoblauch et al. [27] building on Bressers et al. [29,30]).

Governance Quality Criteria	Guiding Questions
Context	• Are different perceptions present in the debate on the uptake of the digital solution? Which are they? And why?
Extent	• How similar/different is the goal associated with the uptake of the digital solution from the status quo? • To what extent do views/arguments/positions support each other, and to what extent are they in competition?
Coherence	• To what extent do actors engage in reframing narratives? Under what circumstances? • Are compromises made in the process of innovation uptake? Why (not)? • Are potential users and their perspectives involved in developing and evaluating digital solutions? Why (not)? • Have there been unforeseen events that have changed the process of the uptake of digital solutions? • Does new knowledge of the system (e.g., ecological, social, economic) play a role in enabling uptake? • To what extent have narratives, power, and regulatory frameworks changed during uptake?
Flexibility	• To what extent does one/several perspective(s) dominate the process of uptake? And why? • Is innovation uptake a primary concern for both users and developers? Why or why not?
Intensity	• How similar/different is the goal associated with the uptake of the digital solution from the status quo?

In each case study, on-the-ground qualitative research was conducted through focus groups and semi-structured interviews with relevant stakeholders (see Table 3) based on the guiding questions developed for each dimension. Initial interviewees were selected based on theoretical sampling (i.e., based on a mapping of actors preidentified by the researchers) in line with grounded theory [14]. Subsequent interview partners were identified through snowball sampling, i.e., by asking the initial interviewers for additional relevant interview contacts.

Table 3. Interviews, focus groups, and Community of Practice meetings conducted (modified from Bouleau et al. [31]).

	Berlin	Paris
Interviews	• Berliner Wasserbetriebe (Berlin Water Utility): scientific staff member and tour guides • Museum guide for future innovations • Senate Department for the Environment, Urban Mobility, Consumer Protection and Climate Action • Expert of environmental engineering firm	• ICT developer: SIAAP • Sanitary authorities in Paris region: Health Regional Agency • Bathing site promoters: Syndicat Marne Vive, Conseil Départemental du Val de Marne, Ville de Paris
Focus Groups	1. Target group: Berlin senate staff, guides, BWB communication staff, September 2021 2. Target group: schoolchildren, July 2022	1. Target group: young bathers, boat-owners, date: May 2021 2. Target group: riparian associations November 2021 3. Target group: bathers and riparians April 2022
Communities of Practice	4. Meetings: September 2019, February 2020, November 2020, October 2021	5. meetings: November 2021, December 2021, January 2022, February 2022, one planned in March 2022.

The material gathered in the focus groups and interviews was systematically attributed to the dimensions of the governance framework. This data assessment process resulted in a state of "saturation", in which additional interviews only supplemented the perceptions and representations already collected in previous interviews [26]. Based on a systematic analysis of the material collected, storylines were developed with consideration of additional literature relevant to each case study. This included both scientific and grey literature, such as policy papers and official regulatory documents.

Both applications in Table 2 are likely to expose specific features of the local water infrastructure that are not well known to the public. In Berlin, the drinking water supply is mainly based on local groundwater resources. A rising demand for water due to the increasing population of the metropolitan area is likely to increase pressure on the water supply [32]. At the same time, interviews conducted by the authors with Berlin water works tour guides indicate that public awareness of the city's drinking water supply is limited, posing challenges to the sustainable use of water resources. In Paris, the possible closure of bathing sites due to poor bacteriological water quality (the criterion considered for health monitoring by the authorities) highlights the occurrence of wastewater discharges during intense rainy episodes in areas with a combined sewer system. The functioning of the sanitation system is poorly known and arouses little interest among the inhabitants (this concerns water, more generally, with a population that is hardly inclined to "participate" [33]. The areas with a separate network (the greater outskirts of Paris) are exposed to wastewater discharges as well, due to ignored misconnections at various levels of the sewerage system. More critically, several tens of thousands of homes (collective or private) are poorly connected (with wastewater flowing into the rainwater, and ultimately into the watercourse). Correcting this problem requires awareness-raising among the population on the subject, and drawing their interest and motivation in the absence of a strong legal constraint to comply [34].

At their core, the two digital solutions are about restructuring and opening up information flows between different stakeholders. While they aim to tackle existing knowledge gaps in a way that differs significantly from previous approaches, they also apply ICT in a new context. The target groups of the app have been defined by the developer teams and validated in the Communities of Practice (CoPs). This resulted in a specification of the target groups over the course of the app development process.

The analysis of these cases aims to shed light on the different dimensions of the governance setting in each case, structured by the guiding questions shown in Table 2. Subsequently, we analyze which part of the public benefits from the digital solution developed.

4. Results and Discussion

In the following section, we describe the results of the analysis of two case studies. The digital solutions developed aim to provide knowledge and raise awareness of (1) groundwater flows in the case of Berlin and (2) bathing water quality in the case of Paris. Both digital solutions are purely aimed at educating and informing and not at participation.

Table 4 below summarizes the findings of Knoblauch et al. [26] and Bouleau et al. [30] for each dimension of the governance setting.

The central water utility in Berlin is the Berliner Wasserbetriebe (BWB). Increasing the efficiency of the existing infrastructure and minimizing impacts on water bodies, e.g., through cost-effective monitoring tools, interoperable data exchange with stakeholders, automated data processing and visualization are major goals of BWB's integrated water management [30]. The city's water policy framework is largely coherent and comprehensive. In 1957, the first law on water protection, the German Water Management Act (Wasserhaushaltsgesetz), was passed, enshrining the idea of sustainable water management. The 1957 law was implemented at the city level in 2005 with the Berlin Law on Water (Berliner Wassergesetz). The key actor in water policy making is the Department for Environment, Transport and Climate of the Berlin Senate (Senatsverwaltung Umwelt,

Mobilität, Verbraucher-und Klimaschutz). The city government of Berlin has passed several policy documents and strategy papers, such as the Berlin Smart City Strategy in 2015 [35] and its consolidated version in 2022 [36] that strengthen digitalization in numerous aspects, including water management. The comprehensive climate plan for the city of Berlin is the 2030 Berlin Energy and Climate Plan (Berliner Energie-und Klimaschutzprogramm 2030) [37]. It calls for smart solutions to be integrated into specific practices to improve adaptation and resilience.

Table 4. Description of relevant governance dimensions in Berlin and Paris.

Dimension	Drinking Water in Berlin	Wastewater in Paris
Administrative organizations and levels relevant for the uptake of the digital solution	High fragmentation of digital water governance at city level; Berlin Water Works as dominant actor; different Senate Departments involved in pushing digitalization strategies	Different public actors involved in wastewater management at regional, departmental, and intermunicipal levels; fragmentation is compensated by existence of strong network of water management practitioners with common professional and technical background
Strategies and instruments applied by relevant actors	Senate strategies to push digitalization at city level in place; strategic framework in place for water management	Existing apps foster user–service interface at national and city level (e.g., healthcare, street cleaning). Public actors develop strategies to digitize water quality monitoring and public awareness of the various aspects of wastewater management
Actors and networks relevant for the uptake of the digital solution	Initially little exchange between relevant actors on digital water governance; CoP perceived as very valuable platform for relevant stakeholders	CoP strengthened the interest and trust between stakeholders in sharing knowledge and data
Problem perceptions of these actors (1) What problem could these tools solve? (2) What challenges exist when introducing these tools?	(1) Little awareness of groundwater issues among general public (2) Technical challenges when developing the AR application; limited funding prevents adding additional features	(1) Poor knowledge of bathing water quality due to lack of relevant public information (2) Revealing the bacteriological pollution of surface waters due to the functioning of water systems could be controversial and raise new claims from public for less pollution from sewage discharges
Resources available for these actors	No sustainable framework to ensure long-term use and maintenance of the digital solution	

In the Paris metropolitan area, responsibilities are spread across different administrative levels and sectors [30]. In the area of wastewater management, there is no single authority formally responsible for coordination between local authorities. This role is partially assumed by the state authorities, which are responsible for the implementation and control of regulations and consider the Syndicat interdépartemental pour l'assainissement de l'agglomération parisienne (SIAAP), the wastewater association of the Paris metropolitan area, as the authoritative actor for the functioning of the wastewater system, although it is not responsible for the operation of the upstream sewerage system. Municipalities are responsible for collecting wastewater and stormwater in small sewer systems that feed into larger infrastructure managed at the supra-municipal level. Department authorities are responsible for wastewater transport, and SIAAP is responsible for the final transport to treatment plants and wastewater treatment. Recent legislation on water policy and management has challenged existing water management structures in the Paris region. Responsibilities for water quality communication have not yet been defined. In the field of wastewater and bathing water quality in Paris, three possibilities for ICT development can be defined [30]. The first is the need for reliable water quality forecasting to optimize

the duration of bathing periods. The second is about the provision of information to the public about the condition of the baths and bathing facilities so that they can appreciate the investments made. A third aspect comes from the internal discussion within SIAAP. The public app could also collect observations made by the population to inform those in charge about the concerns of users at the sites.

It becomes apparent that there are major similarities as well as differences along these dimensions in the two cases. In both cases, a high fragmentation of digital water governance is present at the city level. Governance fragmentation is an obstacle due to the cross-cutting nature of digital water governance, which comprises different sectoral administrations, such as water and environmental affairs, digitalization and innovation, as well as infrastructure development and urban planning. In both Paris and Berlin, city administrations have issued strategies to foster digitalization, such as the Smart City Strategy in Berlin which can potentially enable the development and uptake of digital solutions. In Berlin, there is no explicit focus on urban water management within these strategies. Similarly, openness to digital innovations was observed to be weak in the case of Paris in comparison to other sectors. This was, however, at least partially offset by a willingness to share data and the reliance on existing digital models.

In addition to these findings, we observed a timing paradox in both cases. When public involvement is low, people have little knowledge of how they could contribute to urban water management practice and what their stakes are in relevant processes. Yet designing appropriate digital solutions requires end-users to engage in design at the earliest stage possible and to make choices without much knowledge of the broader context. To this end, focus groups with identified potential future users of digital solutions helped determine a design that considers user expectations for information (both for information delivered by technical managers and for information reported by users to managers). The organization of these focus groups also revealed which section of the public felt concerned or excluded by digital solutions, as well as the potential of the digital solutions for informing the public. In Paris, the focus groups brought together people who showed interest in the reintroduction of bathing in urban rivers, either because they lived along the river or because they frequently swam in the river. During the discussions, several people expressed doubts about the future importance of the use of this information tool, referring to their personal experience as "non-digital natives" or to their professional experience of working with a young audience. Many people might look for information through other media instead of downloading and consulting a dedicated application. Nevertheless, this digital tool is seen as an entry point for informing future bathers about the possible risks of bathing in the river. The dangers are much more varied and significant than just exposure to selected instances of bacteriological pollution, especially if bathing practices develop outside authorized and supervised sites. Some focus group participants also emphasized the role those digital solutions could play in disseminating information on the local environment and the poorly understood sanitation system. In Berlin, focus groups were conducted with both water management practitioners and school children. While the focus group with water practitioners helped to improve the user experience, the focus group with school children provided valuable insights into the interaction of another main target group of the app. A high degree of digital literacy among the children was an enabling factor for the use of the app, confirming the importance of digital literacy, which was also observed as a conducive factor in Paris. The playful introduction to groundwater streams in Berlin was positively received by the children and could potentially be integrated in the local school curricula. The CoPs set up in each city have been beneficial to bringing relevant stakeholders together across sectors. In both cases, they strengthened the interest and trust of actors for sharing knowledge and data and were thus key enablers of the uptake of digital solutions.

With regards to making urban water management aspects visible, the Paris application has the potential to influence the public discourse on water quality issues by raising awareness on the issue of wastewater discharges into water bodies.

In Berlin, in turn, the groundwater application does not provide information on the detrimental effects of groundwater over-abstraction for the sustainability of the city's water system, leaving sustainability issues and future predictions unaddressed. For the current application to be successful in raising awareness of water sustainability issues, the application needs to be accompanied by supplementary educational measures, e.g., in schools, thus forming part of a wider educational program on the groundwater-related challenges in Berlin. Without these additional measures and given the limited knowledge of the public about Berlin's drinking water supply, it can only provide a starting point for further applications to be developed that raise awareness on the consequences of over-abstraction and unsustainable use of water resources by industry and households. Based on these empirical observations, we derive the following hypothesis to be further tested in future research:

Hypothesis 1 (H1). *If politicization of a specific aspect in urban water management is high, digital solutions that make this aspect visible can change the problem perception and can have an influence on the public discourse about urban water management itself.*

Figure 3 illustrates the assumed interlinkages between digital solutions that increase the visibility of urban water management aspects. Eventually, a shift in problem perception of a specific water management issue can influence the public discourse, which has the potential to change practices in urban water management. The governance setting has to be taken into account as an important contextual variable that affects the topic-specific problem perceptions and can also be affected by a changing public discourse, i.e., when topic-specific problem perceptions result in a change in general problem perceptions of water governance and management actors on environmental and sustainability issues. Certainly, there are some analogies to how information feedback can also lead to changed water consumption or sustainability patterns [38], but this connection was not part of this research.

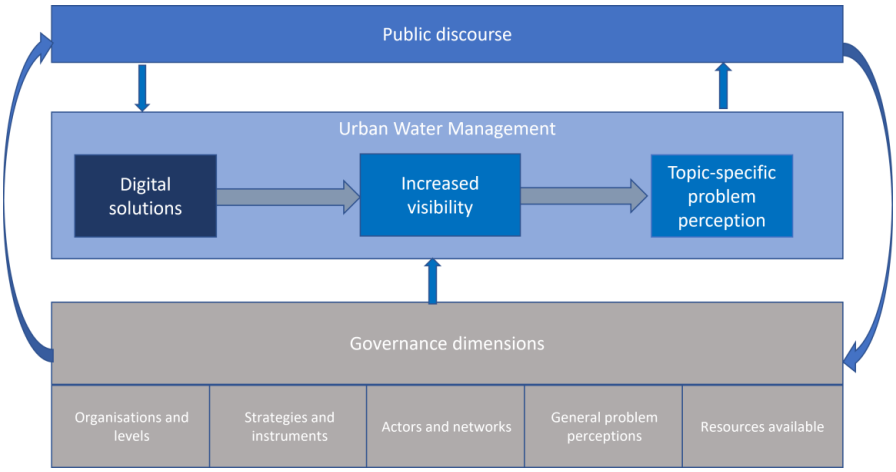

Figure 3. Conceptual diagram based on the hypothesis on the influence of digital solutions for public involvement on the public discourse. The boxes represent the aspects that are discussed in this research, Source: own illustration.

Arguably, the prevalence of traditional, non-digital approaches in urban water management, amongst other factors, points to the challenges that may accompany greater public involvement. Table 5 summarizes some of these hindering factors. Interestingly, many aspects highlight the organizational and institutional challenge that is inextricably linked to the introduction of public involvement solutions.

Table 5. Summarized feedback from stakeholders in urban water management.

Question: What Are the Challenges That May Be Associated with Greater Public Involvement?	Question: What Are the Situations That Must Be Avoided?
• Increased need for water utilities or professional community engagement and moderation • Rising expectations towards water utilities and water managers • Potential conflicting goals/requirements • Explaining complex topics in a simple way needs translation • Representativeness of user feedback is unclear • Potential misalignment between public expectations and available resources • Accountability is not always clear • Potential misalignment between users and decision makers due to communication errors and levels of knowledge	• Decision-making not being in the hands of experts • Confusing users by providing too much data—or, conversely, oversimplifying • Forgetting about the digital non-natives • The processes becoming too complicated when involving the public • Involving the target groups too late • Not being representative • Participation without accompanied education

5. Conclusions

This paper analyzed the conditions under which digital solutions can contribute to making two distinct aspects of urban water management—groundwater flows and bathing water quality—visible, and what effects the resulting increased visibility can have on urban water governance and the public discourse around these two topics.

The digital solutions developed in both cases score low on the ladder of participation [19], as they purely aim to educate and inform the public about groundwater and bathing water quality, respectively [39]. However, in the case of Paris, app users were given the opportunity to provide feedback to bathing site managers, thus going beyond a purely unidirectional stream of information. The current governance conditions, such as a lack of dedicated strategies for digital water services, hinder the development and uptake of digital solutions that go beyond merely raising awareness and sharing information. While the Paris application reveals the problem of wastewater discharges, the Berlin application does not directly show the negative impacts of unsustainable groundwater use. We therefore argue that the potential to change public discourse is limited in Berlin.

The results of the comparative study also show that digital solutions may fail in addressing the needs of all the intended target groups. A reason for this can be an underlying ICT not suitable for certain audiences, such as "digital non-natives" or those who get their information via other means, e.g., social media. Although public interest may facilitate the uptake of the tool, it remains key to communicate the added value of the solutions to the public given the high number of already-existing applications that aim to inform about similar environmental concerns. The analysis underlines the importance of holistic ex ante assessments of the expected societal, ecological, and economic benefits of digital solutions for the respective target groups, to ensure their added value in urban water management. The selection of the right technology is crucial to realize the envisaged benefits. Often, more traditional means of communication, such as educational videos, might be a more cost-effective way of reaching the envisaged target groups compared to digital solutions such as mobile apps. Furthermore, we conclude that digital solutions supporting social awareness should be an integral building block within sustainable urban water management and infrastructure development.

This study has limitations. First, only two cases, which had different foci, were compared. While the Berlin application was developed primarily for information purposes, the Paris application aims not only to inform about bathing water quality, but also to directly trigger a behavioral change regarding water resources. Second, in terms of methodology, it remains difficult to uncover the impact of digital solutions for public involvement based only on data analysis of focus groups, interviews, and documents. Further studies are

needed to explore the hypothesis derived in this paper. Future research could also examine whether the developed solutions are able to induce behavioral change. This will require more long-term studies that trace these changes over time.

Generally, the understanding and awareness about water issues is lacking at all governance levels. This partly has to do with water being perceived as a purely technical matter by most actors [21]. Along the lines of Stein et al. [21], we argue that in order to assure adequate acceptance and to promote the benefits of digital solutions, they must be explained to the user in comprehensive clarity and depth. Innovative digital involvement techniques, such as serious gaming, augmented reality, virtual reality, etc., can foster stakeholder engagement, education, and policy communication in the water sector. In this regard, the education sector also plays an important role in raising awareness around water-related challenges, as well as stimulating behavioral change, research, and knowledge-sharing. In our view, digital education could start at a young age, e.g., by better integrating water issues into curricula or training teachers to use digital tools for environmental education. Moreover, research projects should continue to foster the cooperation between administrations, technology developers, utilities, researchers, and citizens to pilot innovative formats. As mentioned above, more user-friendly digital technologies that simplify complex water issues need to be promoted.

To go beyond the mere informative dimension and allow for more in-depth public involvement, for example via a feedback page for technical and administrative staff, the hiring of staff and the designation of a responsible authority will be needed. This could be a much bigger challenge than the development of the application. All in all, more comparative studies are needed, also focusing on those digital solutions that are more likely to allow for active and ongoing user feedback.

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References

1. Romano, O.; Akhmouch, A. Water Governance in Cities: Current Trends and Future Challenges. *Water* **2019**, *11*, 500. [CrossRef]
2. Larsen, T.A.; Gujer, W. The Concept of Sustainable Urban Water Management. *Water Sci. Technol.* **1997**, *35*, 3–10. [CrossRef]
3. Adem Esmail, B.; Suleiman, L. Analyzing Evidence of Sustainable Urban Water Management Systems: A Review through the Lenses of Sociotechnical Transitions. *Sustainability* **2020**, *12*, 4481. [CrossRef]
4. Marlow, D.R.; Moglia, M.; Cook, S.; Beale, D.J. Towards Sustainable Urban Water Management: A Critical Reassessment. *Water Res.* **2013**, *47*, 7150–7161. [CrossRef]
5. Graham, S. When Infrastructures Fail. In *Disrupted Cities*; Routledge: New York, NY, USA, 2009; ISBN 978-0-203-89448-4.
6. Star, S.L.; Ruhleder, K. Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Inf. Syst. Res.* **1996**, *7*, 111–134. [CrossRef]
7. Bendz, A.; Boholm, Å. Indispensable, yet Invisible: Drinking Water Management as a Local Political Issue in Swedish Municipalities. *Local Gov. Stud.* **2020**, *46*, 800–819. [CrossRef]
8. Moglia, M.; Cook, S.; Tapsuwan, S. Promoting Water Conservation: Where to from Here? *Water* **2018**, *10*, 1510. [CrossRef]
9. Ramos, H.M.; McNabola, A.; López-Jiménez, P.A.; Pérez-Sánchez, M. Smart Water Management towards Future Water Sustainable Networks. *Water* **2020**, *12*, 58. [CrossRef]
10. Singh, M.; Ahmed, S. IoT Based Smart Water Management Systems: A Systematic Review. *Mater. Today: Proc.* **2020**, *46*, 5211–5218. [CrossRef]
11. International Water Resources Asssociation. *Smart Water Cities Project–Phase 1 Report*; International Water Resources Asssociation: Paris, France, 2021.
12. Mukhtarov, F.; Dieperink, C.; Driessen, P. The Influence of Information and Communication Technologies on Public Participation in Urban Water Governance: A Review of Place-Based Research. *Environ. Sci. Policy* **2018**, *89*, 430–438. [CrossRef]
13. Elelman, R.; Wencki, K.; Chen, A.S.; Englund, A.; Anzaldua, G. *The Need for Digital Water in a Green Europe: EU H2020 Projects Contribution to the Implementation and Strengthening of EU Environmental Policy*; Publications Office of the European Union: Luxembourg, 2021.
14. Charmaz, K. *Constructing Grounded Theory: A Practical Guide through Qualitative Analysis*; Sage: London, UK; Sage: Thousand Oaks, CA, USA; Sage: New Delhi, India, 2006.
15. Petitimbert, R.; Bouleau, G.; Guimont, C. (Re)politicization of Climate Change Mitigating Projects: Environmental Forms and Motives of the Seine Nord Europe Canal. *Eur. J. Futur. Res.* **2022**, *10*, 7. [CrossRef]
16. Furlong, K. Small Technologies, Big Change: Rethinking Infrastructure through STS and Geography. *Prog. Hum. Geogr.* **2011**, *35*, 460–482. [CrossRef]
17. Manny, L. Socio-Technical Challenges towards Data-Driven and Integrated Urban Water Management: A Socio-Technical Network Approach. *Sustain. Cities Soc.* **2022**, *90*, 104360. [CrossRef]
18. Eggimann, S.; Mutzner, L.; Wani, O.; Schneider, M.Y.; Spuhler, D.; Moy de Vitry, M.; Beutler, P.; Maurer, M. The Potential of Knowing More: A Review of Data-Driven Urban Water Management. *Environ. Sci. Technol.* **2017**, *51*, 2538–2553. [CrossRef]
19. Arnstein, S.R. A Ladder of Citizen Participation. *J. Am. Inst. Plan.* **1969**, *35*, 216–224. [CrossRef]
20. Wilcox, D. Community Participation and Empowerment: Putting Theory into Practice. *RRA Notes* **1994**, *21*, 78–83.
21. European Research Executive Agency (European Commission); Stein, U.; Bueb, B.; Englund, A.; Elelman, R.; Amorsi, N.; Lombardo, F.; Corchero, A.; Brékine, A.; Lopez Aquillar, F.; et al. *Digitalisation in the Water Sector Recommendations for Policy Developments at EU Level*; Publications Office of the European Union: Luxembourg, 2022; ISBN 978-92-95080-52-2.
22. Hurlbert, M.; Gupta, J. The Split Ladder of Participation: A Diagnostic, Strategic, and Evaluation Tool to Assess When Participation Is Necessary. *Environ. Sci. Policy* **2015**, *50*, 100–113. [CrossRef]
23. Few, R.; Brown, K.; Tompkins, E.L. Public Participation and Climate Change Adaptation: Avoiding the Illusion of Inclusion. *Clim. Policy* **2007**, *7*, 46–59. [CrossRef]
24. Bloomfield, D.; Collins, K.; Fry, C.; Munton, R. Deliberation and Inclusion: Vehicles for Increasing Trust in UK Public Governance? *Environ. Plan. C: Gov. Policy* **2001**, *19*, 501–513. [CrossRef]
25. Hart, G.P. *Disabling Globalization: Places of Power in Post-Apartheid South Africa*; University of California Press: Berkeley, CA, USA, 2002; Volume 10.
26. Patton, M.Q. Two Decades of Developments in Qualitative Inquiry: A Personal, Experiential Perspective. *Qual. Soc. Work* **2002**, *1*, 261–283. [CrossRef]
27. Knoblauch, D.; Felicetti, L.; Stein, U. *Policy Matrix. Screening of Digital, Data and Water Policies*; Water Policy Association: London, UK, 2020.
28. Slota, S.C.; Bowker, G.C. How Infrastructures Matter. In *The Handbook of Science and Technology Studies*; MIT Press: Cambridge, MA, USA, 2017; p. 52954.
29. Bressers, H.; de Boer, C.; Lordkipanidze, M.; Özerol, G.; Kruijf, J.; Furusho, C.; Corinne, L.; Kampa, E.; Stein, U.; Tröltzsch, J.; et al. *Water Governance Assessment Tool, with an Elaboration for Drought Resilience*; DROP Governance Team, DROP INTERREG Project; Twente University: Twente, The Netherlands, 2013.
30. Bressers, H.; Bressers, N.; Larrue, C.; Kuks, S. The Governance Assessment Tool and Its Use. In *Governance for Drought Resilience: Land and Water Drought Management in Europe*; Bressers, H., Bressers, N., Larrue, C., Eds.; Springer: Cham, Switzerland, 2016; pp. 45–65. ISBN 978-3-319-29669-2.

31. Gabrielle, B.; Gaële, R.-K.; Ulf, S.; Benedict, B.; Fausto, F.; Stephan, G.; Linda, R.; Francesco, F.; Adriano, M.; Enrico, M.; et al. *D3.5: Perception, Acceptance and Use of Digital Solutions*; Zenodo: Geneve, Switzerland, 2022. [CrossRef]
32. Senatsverwaltung für Umwelt, Mobilität, Verbraucher-und Klimaschutz. *Masterplan Wasser Berlin. 1. Bericht*; Senatsverwaltung für Umwelt, Mobilität, Verbraucher-und Klimaschutz: Berlin, Germany, 2022.
33. Bouleau, G.; Barbier, R.; Halm-Lemeille, M.-P.; Tassin, B.; Buchs, A.; Habets, F. Despite Great Expectations in the Seine River Basin, the WFD Did Not Reduce Diffuse Pollution. *Water Altern.* **2020**, *13*, 534–555.
34. Lefebvre, F. La Politique de Mise En Conformité Des Branchements D'assainissement. Master's Thesis, Université Paris 1 Panthéon Sorbonne, Paris, France, 2022.
35. Senate Department for Urban Development and the Environment. Smart City Strategy Berlin. 2015. Available online: https://www.stadtentwicklung.berlin.de/planen/foren_initiativen/smart-city/download/Strategie_Smart_City_Berlin_en.pdf (accessed on 3 January 2023).
36. Die Regierende Bürgermeisterin von Berlin–Senatskanzlei. *Gemeinsam Digital: Berlin. Die Smart City-Strategie Für Die Hauptstadt*; Die Regierende Bürgermeisterin von Berlin–Senatskanzlei: Berlin, Germany.
37. Senatsverwaltung für Umwelt, Verkehr und Klimaschutz. *BEK 2030-Berliner Energie- und Klimaschutzprogramm 2030*; Senatsverwaltung für Umwelt, Verkehr und Klimaschutz: Berlin, Germany, 2019.
38. Liu, A.; Mukheibir, P. Digital Metering Feedback and Changes in Water Consumption—A Review. *Resour. Conserv. Recycl.* **2018**, *134*, 136–148. [CrossRef]
39. Stein, U.; Bueb, B.; Rouillé-Kielo, G.; Bouleau, G. Can Digital Solutions Enhance Public Involvement in Urban Water Management? Evidence from Case Studies in Berlin and Paris. In Proceedings of the International Water Association (IWA) World Water Congress, Copenhagen, Denmark, 11–15 September 2022. (Unpublished Manuscript)