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RESEARCH ARTICLE

REVISED Insights from the co-creation process in communities of practice for urban water management

[version 2; peer review: 1 approved, 4 approved with reservations]

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Abstract

This article presents a practical case of a co-creation process within the framework of the European project Digital Water City (DWC). DWC sought to address the context and challenges of water in Europe with a participatory approach of co-creation as an integral part of Communities of Practice. To situate the concepts within their theoretical framework, the different approximations of co-creation and Communities of Practice (CoPs) are examined. The article analyzes the ways in which they have been used and applied in DWC as well as the ways in which the project has managed to articulate them at different levels. It discusses what has been done so far, whether the objectives related to co-creation have been achieved, what its added value to the project was, and the possible obstacles and successes. In order to gather this information, five case studies are presented and illustrated with a questionnaire that was carried out with the cities, researchers and key innovators. Results show that DWC´s co-creation process succeeded in incorporating end-users' needs into the development of the digital solutions created, giving them a constructive role in the value-creation process, and bringing together different stakeholders from public and private sectors as well as researchers. It was also highlighted that the process and its format need to be adapted to each specific context and a culture of co-creation needs first to be established. The co-creation process and the DWC CoPs also raise governance questions and create new partnerships.

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Keywords
water sector; communities of practice; co-creation process; digital solutions



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REVISED **Amendments from Version 1**

This article has undergone revisions to address the detailed feedback provided by reviewers, including changes in the introduction and objectives, revised to include a more clear statement of objectives, better aligning with the abstract and framing the research questions; in clarity, for example the methodology section was reorganised to connect data collection methods explicitly with the research questions, providing a clearer framework for the study; the operationalisation of Communities of Practice (CoPs) was better explained, including the differences among cities in Level 1 CoPs, clarifying scope and objectives for each. The redaction of multi-scale and multi-actor aspects of CoPs were revised for better understanding; changes were made in the presentation of the survey and data, providing details on participants, tables and figures were revised for clarity, uniformity and terminology across the text was standardised; the unique context of each city and the importance of context were better acknowledged, improving phrasing and clarification; in the section of recommendations, feedback from stakeholders and end-users was emphasised as integral at all stages of development; and edits were made to improve readability, address grammatical issues, and restructure the text to enhance the general flow of the article.

Any further responses from the reviewers can be found at the end of the article

Introduction: urban water management in Europe under changing environments

The EU water sector is facing increasing issues exacerbated by mounting pressures, e.g. growing population, urbanization and climate change. Increased urbanization, agricultural and industrial activities, lead to pollution, overexploitation and modification of water bodies (Anzaldúa *et al.*, 2019). Furthermore, almost three quarters of Europeans live in urban areas, with an upward trend that is projected to reach 83.7% by 2050 (UN, 2018). Population growth, concentrated in European cities, will be accompanied by an increase in demand for water both inside and outside urban spheres. The main drivers will be agricultural production as well as industrial (energy and manufacturing) and domestic water use in cities (Water Europe, 2017). Water scarcity - broadly defined as the mismatch between the resource availability and its consumption - occurs due to the increase in water demand and a reduction in availability. This increasing demand is a serious problem in arid and semi-arid areas of Europe. Concern in the water sector is all the more widespread as a result of climate change and its impacts (EEA, 2021). Social and environmental systems are put under pressure due to rising risks of floods, an increased frequency and intensity of extreme precipitation. Too little or too much water can have adverse effects on water quality. For example, seawater intrusion and increased salinity can be driven by overexploitation of aquifers, while extreme rainfall can wash agricultural pollutants into rivers and lakes (EC, 2019). Both scarcity and abunwance of water can have detrimental effects on water quality, and when water quality is threatened, it can also reduce the availability of water for human consumption and for ecosystems sustenance.

These issues have implications for the entire water sector and all the involved stakeholders, particularly in the urban context. Urban water management refers to the planning, operation, and maintenance of systems and services related to water supply, sanitation, wastewater treatment, and infrastructure in urban areas. It encompasses the management of water resources to ensure access to clean water, efficient sanitation services, and sustainable infrastructure solutions for urban populations. Every year, billions of dollars are invested in water treatment and sanitation infrastructure. These investments aim to improve heath protection, performance and public engagement. In this context, and given the environmental, social, economic and structural issues, the management of the water cycle and its associated planning, development and operation are changing. These changes represent various challenges for the entire sector and its players.

Sector-specific challenges arise in dealing with the macro-environmental changes mentioned above and relate to governance aspects (EEA, 2018), such as

- ensuring good policy fit (policy and regulation standards and boundaries)
- overcoming the limits of rigid institutional architectures, specifically between and within EU Member States
- addressing the slow innovation rate as well as low awareness and engagement of users, and providing supervisory measures to face inappropriate applications leading to substantial levels of illegal harvesting or use.

Another challenge concerns the aging and lacking infrastructure. Finally, users' awareness and engagement are fundamental points (Dige *et al.*, 2017; Silva Pinto *et al.*, 2018). These challenges can be overcome by raising awareness on resource management and use, as well as the uninterrupted access to drinking water and its implications.

In order to face these challenges, digital technologies can help. In this context, digital water technologies offer solutions by enhancing the efficiency of management systems, improving real-time monitoring, enabling better data-driven decision-making. These technologies can help reduce water waste, optimize distribution networks, and address both water scarcity and water quality issues by providing tools for early detection of problems and predictive analytics. Their development through a participatory approach can foster collaboration among stakeholders through more transparent governance and better information sharing.

However, the integrated multi-scale governance of the water sector involves a complex interaction of agents (Anzaldúa *et al.*, 2019), including political, economic, social, academic actors, etc. Moreover, it is necessary to focus on solution integration and inclusive governance for successful adoption. At the same time, long-term implementation of utilities can often only be derived from a transparent approach to social communication and co-creation (Stein *et al.*, 2022) as well as from enhanced participation of the various stakeholders. This process faces a low level of maturity of digital solutions concerning the aspects of standardization, interoperability, cybersecurity and

governance. The water value chain encompasses all stages of water management, from sourcing and treatment to distribution, usage, wastewater management etc., and there is also a lack of hard evidence of the benefits provided by digital solutions at each level. Promising solutions often do not reach real applications due to the lack of social and technical preparation, and a mismatch with expectations and needs of end-users.

Co-creation offers a collaborative approach to addressing complex challenges by actively involving end-users and stakeholders in the development of solutions. As highlighted in research, integrating the lived experiences of users enables more effective and adaptive responses to pressing needs, making it a participatory approach in navigating the environmental, social, and governance complexities faced by sectors such as water management.

Within this context, the digital-water.city project (DWC) developed local technological solutions over three years for five European cities (Berlin, Copenhagen, Sofia, Milan and Paris). By gathering different actors through a transversal and participative project across Europe, DWC aimed to strengthen and maximize their collaboration. In order to achieve this, the project established multi-scale and multi-actor Communities of Practice (CoPs). The article analyzes the ways in which they have been used and applied in DWC as well as the ways in which the project has managed to articulate them at different levels. Within these CoPs, a co-creation process was carried out throughout the project. This paper explores the learning processes of co-creation facilitated through the CoPs framework within the DWC project that developed and applied digital water innovations, emphasizing collaboration, mutual exchange, and adaptive practices.

This paper presents the process and raises the following questions: (1) What is the role and impact of the co-creation process within the CoPs of the DWC project? (2) How has the co-creation process contributed to the achievement of the objectives pursued? (3) What lessons can be learned to support the success of future co-creation activities in the field of water management? To answer these questions, five case studies are presented and a questionnaire was set up and answered by the cities, project leaders and innovators. This study employs a mixed methods approach, combining data collection through surveys, interviews, and participatory techniques to comprehensively explore the co-creation processes and their outcomes. The results are presented and discussed in this article.

Setting the scene: conceptualization of value co-creation and communities of practice

The concept of value co-creation

The concept of value co-creation was introduced in the early 2000s by Prahalad and Ramaswamy (Leclercq *et al.*, 2016). A certain number of authors have participated in situating the theoretical and practical approximations of the concept related to their field of research and application (among others, Chen *et al.*, 2012; Grönroos, 2008; Ind & Coates, 2013; Vargo, 2008; Zwass, 2010). However, the term lacks a consensus regarding its conceptualization (Leclercq *et al.*, 2016). In this sense, Torraco (2005) proposed to deconstruct the concept, while other recent publications emphasize the need to deepen knowledge on the construct of the term with regard to its conceptualization (Chen *et al.*, 2012; Ind & Coates, 2013), components (Ind & Coates, 2013), consequences (Fuchs *et al.*, 2013; Thompson & Malaviya, 2013), drivers (Nambisan & Baron, 2009), different underlying processes (Vargo *et al.*, 2008), and measurement (Coviello & Joseph, 2012; Payne *et al.*, 2008).

Based on the literature review of Leclercq, Hammedi and Poncin (2016) of 181 articles published, the concept was defined as "a joint process during which value is reciprocally created for each of the actors (individuals, organizations or networks). These actors engage in the process by interacting and exchanging their resources. Interactions take place on an engagement platform where each actor shares their own resources, integrates resources offered by other actors, and potentially develops new resources through a learning process" (Leclercq *et al.*, 2016, p6). The key components are: the value created, the actors involved and the engagement platforms.

The concept has been used and applied in different areas. For example, understanding the mechanisms of co-creation of value has been perceived as a priority in fields such as marketing research (Ostrom *et al.*, 2010; Ostrom *et al.*, 2015), brand image (Hatch, 2012; Merz *et al.*, 2009; Tynan *et al.*, 2010), distribution (Andreu *et al.*, 2010), innovation (Füller & Matzler, 2007; Füller *et al.*, 2011; Spohrer & Maglio, 2008), online communities (Schau *et al.*, 2009), services (Vargo & Lusch, 2008), customer relations (Roggeveen *et al.*, 2012), etc. In terms of cooperation between agents, the academic world has investigated how collaborations between companies and end-users could be set up, such as collaborations of companies with consumers, the development of new products (Riggs & Von Hippel, 1994; Von Hippel & Katz, 2002), services (Grönroos, 2012), etc. Along with the necessity to cooperate with the end-users of applications and products developed, the importance of integrating other stakeholders - such as suppliers, public institutions, collaborators - into the processes has been underlined (Prahalad & Ramaswamy, 2004a). A number of authors plead for a "transition", moving from a transactional perspective towards one that is more collaborative (Leclercq *et al.*, 2016). Moreover, the contributions on the need for an evolution of marketing also highlight how the process of co-creation of value is enabled through the exchange of both knowledge and skills (Prahalad & Ramaswamy, 2004a; Vargo & Lusch, 2004).

Value co-creation is an important paradigm in which a common body of theoretical statements has been developed and applied to different contexts. Outcomes from previous research showed that marketing and service science play a major role; however, hundreds of papers also acknowledge the constructive role for the end-user in the process (Galvagno & Dalli, 2014).

The role of subjective and lived experience of customers in value co-creation is an emerging theme in research, to gain a better understanding of how customers live the experience and how this could improve the effectiveness of companies looking to integrate customers and their employees into their processes (Galvagno & Dalli, 2014).

The quadruple helix approach for co-creation

In its Open Innovation 2.0 policy approach (Curley & Salmelin, 2013), the European Union has adopted the quadruple helix model as a suggested approach for co-creation. According to this approach, adequate and operational solutions to meet challenges will emerge from the active involvement and collaboration between various key agents mentioned above: universities, businesses, civil society and public administration. The model showcases the fields of opportunities in which the actors are represented by "helices" where agents get involved together in order to ensure a reasonable digital transition. By acting in the areas of opportunity, the different stakeholder groups can influence the digital contribution in the water sector, highlighting the benefits and mitigating the risks and the barriers, and generating new possibilities, solutions and opportunities. The quadruple helix model is shown in Figure 1.

As explained by Anzaldúa *et al.* (2019), in terms of key stakeholders:

- The **Public Administration** plays a central role. They set the regulatory frameworks that the business sector needs to follow and respect; they facilitate control, compliance of solutions, standardization and prevention (for example for cyberattacks, illegal use of data, reasonable regulations of the private sector, etc.). Adequate public policies clarify responsibilities and obligations for the digital solutions installation and ensure positive social and environmental impacts. The administration also ensures the co-financing of training programs concerning the sector and its challenges.

- The **academic community** represents the other series of key agents. Researchers contribute to the modeling of applications (data, semantics, critical perspective, highlighting limitations, etc.). Advances in academic research play an important role in the process of raising awareness about digital technology and its utility for water management and treatment, as well as in advancing data democratization and information accessibility.

- The **economic and business sector** is considered another group of key actors. Companies are getting involved in public-private partnerships and generating investment in infrastructure and technologies. They have to take into account the current requirements of data protection laws and ensure that investments respect public regulations framework, remain reasonable by seeking a balanced and responsible deployment of digital solutions. They actively collaborate with academic researchers and can help to test new services. They have to adequately adapt their business models regarding the indications of the other actors' needs, concerns and expectations.

- **Civil society** is a fundamental actor. It allows the public authorities and the private sector to assume their responsibilities for the decisions implemented, as well as their consequences. It is involved in training, engagement procedures and awareness-raising actions. This can help foster a better understanding of the supply

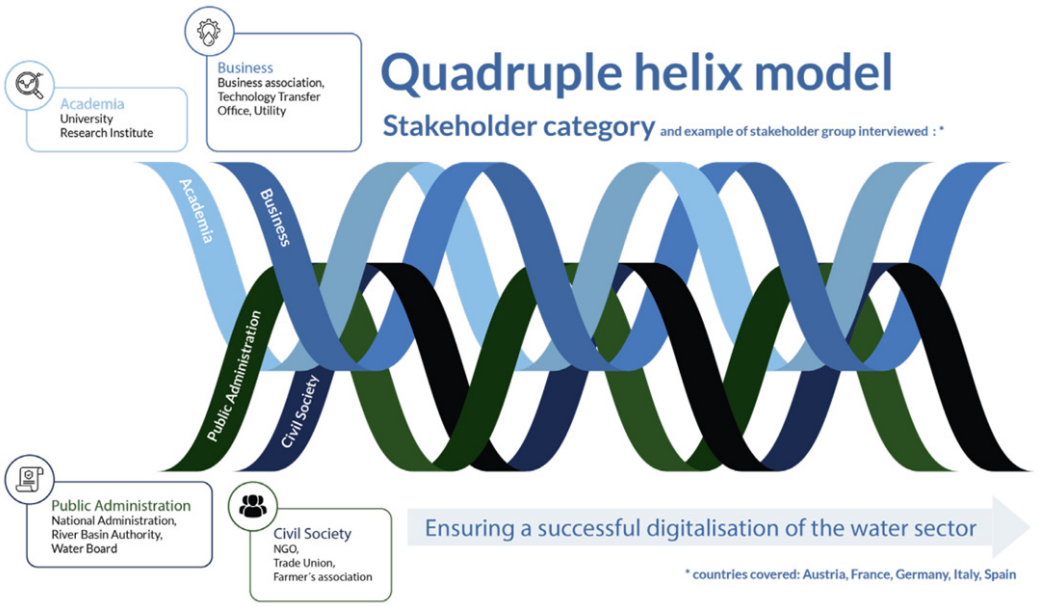


Figure 1. Anzaldúa *et al.* (2019) Quadruple helix model based on Carayannis & Campbelle (2009) and McIntosh & Gebrechorkos (2014).

and sanitation services, their associated costs, and highlight the perspectives and needs of civil society.

This categorization of stakeholders into different groups follows the typology of McIntosh & Gebrechorkos (2014); the classification refers to the roles they play, specifically for the digitalization of the water sector. In the case of DWC, collaboration was facilitated between different actors, such as academics, companies, public administration, and end-users, chosen based on the quadruple helix model to represent key stakeholders, with the objective to develop and demonstrate digital solutions. As mentioned in the co-creation literature, there is a necessity to cooperate with the end-users of developed products, and integrate other stakeholders into the processes, such as public institutions and collaborators (Leclercq *et al.*, 2016; Prahalad & Ramaswamy, 2004a).

The use of communities of practice for the adoption of the quadruple helix approach

Although the idea behind communities of practice has existed for much longer, the term "community of practice" was conceptualized and defined in the late 1980s (Lave & Wenger, 1991). In its original conceptualization as proposed by the authors, communities of practice (CoPs) are formed by people engaging together in a process of collective learning.

CoPs have been conceptualized and practiced in many sectors and places. By creating a space for mutual learning and cooperation, these communities bring together groups of people who have a common concern or interest in a subject (Wenger, 2010). In their formal definition, CoPs are "groups of people or organizations who share a concern or a passion for something they do and learn how to do it better as they interact regularly" (Wenger-Trayner, 2015). Communities of practice can be seen as a social learning system (Wenger, 2010). Learning in the interactions produces a social system where practice reflects one's own commitment to the situation. The dimension of identity enters into this process, where identification or dis-identification with and within the community takes place. The contributions of psychology showed how having the feeling of belonging to a group contributes to the constitution of identity itself. Theories of social identity and identification, from their foundations in social psychology - in this case applied to organizational psychology - demonstrated that people's self-identity concepts are partly constructed from the groups or collectives to which they think they belong (Lee *et al.*, 2015; Tajfel, 1978; Tajfel & Turner, 1985). An essential aspect of the CoPs is thus the **community** itself. Several groups of people choose to engage in common activities and meetings, sharing information and developing skills and solutions together, making them members of a community. The process of interrelations and knowledge exchange allows them to learn together, and to understand the position and concerns of each member. Learning can be the reason the community comes together, or it can be the result of the members' interactions.

In order to be considered a community of practice, certain characteristics are fundamental: interactions of CoP members with each other in formal and informal settings, knowledge sharing between them, collaboration to create new knowledge and the fact that CoP groups can promote the development of a shared identity between members (Li *et al.*, 2009), even if these characteristics are not systematically present in the CoPs. They are also part of larger social systems involving other communities, structures, groups, etc., constituting the social world in which people and groups learn through a multiplicity of practices.

The concept of communities of practice has influenced, at a theoretical and practical level, a wide variety of academic fields, as well as the education sector, governments, public health, civil sector, private sector, etc. In the private sector, it is above all a space for peer-to-peer learning among practitioners in order to develop skills and capacities, and carry out different missions. In general, the communities of practice offer a promising organizational form to enable the development and implementation of socially beneficial innovation (López-Gunn *et al.*, 2021) while involving the range of stakeholders and sectors considered by the quadruple helix approach.

Communities of practice to support digitalization in urban water management

As explained above, the water sector represents a complex network of issues and actors. This paper describes the activities conducted within the frame of the H2020 digital-water.city project (DWC) to bring together key actors and agents and make them work together in a framework, helping and assessing them to collaborate and provide relevant solutions towards the digitalization of urban water management in European cities.

DWC has adopted the use of communities of practice as a central tool to help face these issues through collaboration between different actors and overcome barriers. The aim was to achieve an interdisciplinary and transdisciplinary approach through the integration of outcomes from several disciplines, and from academic, non-academic and non-formalized knowledge. This means that CoPs participated in both the formulation of objectives and the expected results.

The definition of communities of practice (CoP) is used in the project as: *a group of large and diverse actors who may be relevant to solving a problem and may be available to share and join experiences, skills, ideas, resources, actions to go further by adopting collective principles and shared societal challenges*. The CoPs create a dynamic learning process and a living collective body which, in the case of DWC, is meant to evolve by building trust between partners and achieving goals together : developing digital solutions adapted to the needs, and facilitating their local adoption. CoPs are built of public, academic and private stakeholders from different backgrounds, fields and expertise, with the common goal of contributing to the development of solutions for water and sanitation infrastructure challenges.

The integrated multi-scale management of the water sector and its complex interaction of political, social, academic and

economic agents is a challenge that DWC had to face, considering the fact that each agent has specific needs, expectations and concerns.

In order to implement the participatory process of learning through exchange and to accommodate this multiplicity of stakeholders, DWC's distinctive and unique feature was the establishment of different CoPs at three levels, as shown in Figure 2 below.

- Local CoPs (level 1), which have been operationalized in four European cities (i.e. Berlin, Copenhagen, Milan and Paris), mainly focus on the solutions within their local contexts. Local CoPs have aimed to: create a long-term collaborative environment at the city level during the project; increase knowledge exchange among local actors; support the integration of stakeholder knowledge and expectations into the development of solutions; and co-build trust of external stakeholders in the future use of solutions. Local CoPs have provided direct support for testing and implementing solutions in practical contexts, building trust in the usefulness and relevance of what was developed, and receiving specific user requirements and needs identified throughout the later stages of development. This is all the more relevant as innovations may tend to focus on technical aspects and partially neglect to take into account problems or difficulties related to the daily routines of end users. In addition, each of the cities faced different contextual challenges, and solutions and activities needed to be adapted by collaborating with local key actors and populations.

- Project CoP (level 2) provided a useful mechanism to facilitate knowledge exchange between DWC cities (mutual learning) and between DWC cities and technical partners (cross-fertilization). In terms of mutual learning, it was an opportunity for the cities to exchange their experiences regarding the new solutions, while comparing them to current solutions used to address similar problems. The objective of these activities was to identify drivers of and barriers to their adoption. Key aspects to be addressed include reflecting on the results of the local demonstration: what worked well (key factors), what were the implementation issues (main barriers and drawbacks), what could have been done differently, and what would be considered for reproduction in another setting? In terms of cross-fertilization, this CoP provided a space for discussion around cross-cutting topics addressed by the project (such as cyber-security, interoperability, digital governance, etc.), where technical partners and DWC cities met and shared doubts and experiences.

- Trans-project CoP (level 3) focused on networking and grouping activities with other related projects and actions. This CoP benefited from the DigitalWater2020 initiative, which partnered five sister projects funded under the H2020 program (i.e., SCOREwater, Fiware4Water, Aqua3S, Naiades, and DWC) to identify synergies and collaboration opportunities in several aspects, i.e., data models and ontology, sensors, markets, and communication.

These CoPs have been active for three years and involved the participation of hundreds of people representing different organizations (although often participating on the basis of their own expertise and knowledge). After this large effort in terms of organization of activities and devoted resources, this paper intends to answer three questions:

(1) What is the role and impact of the co-creation process within the CoPs of the DWC project?

(2) How has the co-creation process contributed to the achievement of the objectives pursued?

(3) What lessons can be learned to support the success of future co-creation activities in the field of water management?

Methodology for assessing the impact of co-creation and CoPs

To answer these questions, a mixed-methods approach was employed, combining multiple case studies, initial workshop, surveys and interviews. This mixed approach offers advantages for researchers in addressing the complexity of these research

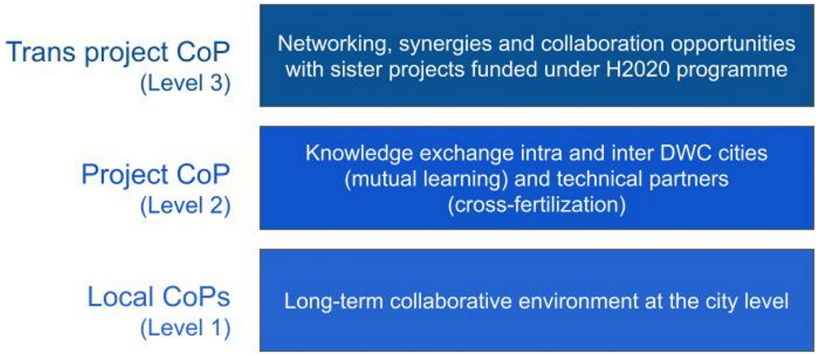


Figure 2. Multi-level Communities of Practice of DWC.

problems and issues (Plano Clark *et al.*, 2018). Combining methods allows combining external and objective observations and more subjective and socially constructed aspects.

Data collection

The primary data sources include:

- Case Studies: Five DWC pilot cities (Berlin, Copenhagen, Milan, Paris, and Sofia) were chosen as case studies. These cities were established as pilot sites during the proposal stage of the EU-funded project due to their distinct urban and water management challenges and their representation in the consortium.

- Workshop: An initial world café with stakeholders facilitated reflective dialogue on commonali ties and differences in their approaches and expectations for the local CoPs:

- Survey and interviews: A structured questionnaire was circulated to project leaders and other key stakeholders who were actively involved in the CoPs. The decision to work with the pilot leaders was made because these actors have a complete view of the full process undertaken and can help document the main achievements and shortcomings, whereas other stakeholders generally have only partly participated in some of the activities organized by the local CoPs. In the case of each pilot city, either public or private entities were involved, which share a strong interest in developing and adopting innovations for improved digital management of their assets and infrastructure. They were selected for their comprehensive understanding of the full process of co-creation. Follow-up semi-structured interviews were conducted to further elaborate on survey responses and discuss achievements, shortcomings, and lessons learned.

Data synthesis

The collected data were synthesized through a systematic review of:

- Responses to the survey, analyzed to identify patterns of impact and areas for improvement.

- Key themes from interviews and workshop discussions, focusing on the objectives pursued, outcomes achieved, and lessons for future initiatives.

- Documentation of CoP activities, including meeting minutes, event reports, and recorded outputs, to validate and contextualize stakeholder feedback.

Alignment with research questions

The methodology was designed to directly address the research questions:

- Role and impact of CoPs: The survey and interviews documented the activities and outcomes of CoPs at both the local and project levels, highlighting their role in fostering collaboration and achieving goals.

- Contribution to objectives: Data from the case studies and workshop discussions were analyzed to evaluate how the co-creation process supported the development and adoption of digital water innovations.

- Lessons for future co-creation process: Common themes emerging from stakeholder reflections can be used to reflect key insights and be used as practical recommendations for future project.

Outcomes

DWC local CoPs in action

Case Studies insights and initial characterization of the local CoPs. The DWC project and the development of local digital solutions were active in five European urban and peri-urban areas representing 30 million European citizens. Due to the context and key challenges varying across the five participating cities, the format of the Local CoPs (CoP level1) was organized in different ways throughout the project, as shown in the Table 1, Table 2, Table 3, Table 4 and Table 5.

Workshop World Café exercise and identification of differences and commonalities. As an initial step, the DWC cities participated in a World Café exercise organized in the initial months, which allowed for the elucidation of commonalities and differences in their approaches and expectations for the local CoPs:

Based on the discussions, a number of common points among several DWC cities were identified:

1. Cities are generally very interested in **exchanging experiences** with other cities, e.g. learning how other cities are implementing the solutions or which kind of barriers or limitations have been identified. Thus, **mutual learning** was clearly identified as the key aim for the project CoP.

2. Some of the cities envisaged **collaborations with ongoing projects** or initiatives at the local scale. These kinds of networking activities should provide opportunities for improved adoption and/or dissemination of the expected results, and the local CoPs were recognized as valuable vehicles to support these kinds of interactions.

3. A crucial aspect to be decided was **when to engage with the relevant stakeholders** (e.g. from the beginning, once initial results are available, when solutions are sufficiently tested, at the end of the project for communication and dissemination purposes, etc.). Every pilot city made its own decision on this aspect depending on its specific context.

4. One of the key reasons identified for involving stakeholders into the project activities was **building trust** through the stakeholder engagement in the local CoPs. Related to this point, it was argued that the involvement of operational teams may be particularly

Table 1. **Berlin Local CoPs (CoP level1).**

 Led by **Berliner Wasserbetriebe (BWB)** **Key Stakeholders**: Berliner Wasserbetriebe (BWB), Berlin Senate, Berlin Waste Management (BSR),State Office for Health and Social Affairs Berlin (LaGeSo), German Federal Environmental Agency (UBA), Kompetenzzentrum Wasser Berlin (KWB), Berlin Partner
Goal and ambition: The objectives for Berlin were to improve the performance of the sewer and drinking water infrastructure and foster public involvement in urban water management. Several innovations will reduce the environmental impacts of the sewer network. The work focused on illicit connections, combined sewer overflows and optimizing the maintenance and planning of water wells. Water management was considered in the entirety of the city, allowing local stakeholders to benefit from the solutions. The expectations and requirements of local stakeholders were included in the development of the digital solutions.
Digital water innovations supported: The augmented reality App "Grundwasser sichtbar machen" developed for Berlin aimed to visualize geology and groundwater and highlight their importance as a drinking water supply and to make this invisible part of the water cycle visible. The application will be used for many communication objectives (education, tourism), with the overall goal of raising knowledge about the origins of drinking water and communicating the relevance of groundwater for municipal water supply. As a result, the application addresses three key issues: 1) Where does the drinking water come from? 2) How does water enter the wells? 3) How is water cleaned during the soil-aquifer transition?
How the CoP worked. Formal decision making and/or only information. What was discussed: The CoP worked through meetings and workshops (using a brainstorming/exchange approach), including a presentation of the project (structure, key goals and ambitions), the digital solutions being developed and implemented in Berlin, and through participatory workshops. The methods and results obtained in the meetings were presented to the other DWC cities in the project's general assembly.
Key challenges related to local digital water governance aspects: The urban water cycle is partially closed and challenged intensively by competing uses and pressures such as drinking water production, discharges of stormwater and treated wastewater; combined sewer overflow (CSO) and recreational purposes. The increasingly digital agenda of Berlin leaves room for the application of ICT technologies in water management. However, the growing amount of digitalization programs and legislatives schemes has not yet been quite impactful in the water sector. Local policies for the digital sphere take the form of action plans and strategies rather than legally obligatory regulations. The interaction between digital and water policies is not yet well established. There is currently little cross-sectoral focus on the use of digital technologies on water management and environmental education. Relevant networks that foster collaboration and cooperation in digital water still need to be developed.

Table 2. **Paris Local CoPs (CoP level1).**

 Led by **Syndicat Interdépartemental pour l'Assainissement de l'Eau (SIAAP)** **Key Stakeholders**: Syndicat Interdépartemental pour l'Assainissement de l 'Eau (SIAAP), Institut national de recherche pour l'agriculture, l'alimentation et l'environnement (INRAE), The City of Paris; The health and environmental authorities; The Seine-Normandy water agency; The Direction of the services for water and sewerage of the Val de Marne département; The Direction of water and sewerage of the Seine Saint Denis département; The Direction of water of the Haut de Seine département; The Syndicat Marne Vive.
Goal and ambition: One of the goals of the project was to involve the future stakeholders (citizens and bathing sites managers) in the development of two specific digital solutions, a "Public" app and an "Expert" app.
Digital water innovations supported: The innovations supported were the development of two specific digital solutions: an "Expert" application destined to bathing site managers that will regroup all the information needed to decide whether to open or close a bathing site and a "Public" application destined to inform the citizens of the status of the bathing site of their choice.
How the CoP worked. Formal decision making and/or only information. What was discussed: One of the original aspects of the CoP was the fully participatory nature of both applications, which brought together all the actors working on the Paris bathing situation, as well as representatives of other cities interested in opening a bathing site. The CoP worked with regular meetings and workshops. In the Paris experiment, the focus group method (focused discussion where the interaction between the participants creates the data) was used to assess the expectations and apprehensions of the "general public" with regard to the return of bathing in urban streams. This method guided the development of the digital application intended for future users of bathing sites.
Key challenges related to local digital water governance aspects: In a framework of supporting the organization of the next 2024 Olympic Games, a working group involving a large number of stakeholders and actors (including SIAAP) collaborated to improve water quality status and monitoring in river Seine. SIAAP is an active member of this "bathing task force" which has been established in order to reach the goal of sufficient water quality for bathing. One of the challenges was to involve the citizens and the future bathing site managers in the development of the digital solution for the Parisian region project. The Paris case also faced several political challenges regarding bathing site implementation and the overall question of bathing.

Table 3. Milan Local CoPs (CoP level1).

Led by **CAP Holding, Università di Milano, Università Politecnica delle Marche** **Key Stakeholders**: CAP Holding, Università di Milano, Università Politecnica delle Marche, three large farmers' associations and public bodies (COLDIRETTI, Confagricoltura, ETC-Villoresi), Milan municipality.
Goal and ambition: Deployment of a reused wastewater network for agricultural irrigation in the Milan area, addressing challenges related to water quality and sanitation.
Digital water innovations supported: A match-making tool which links water demand for irrigation and safe water availability, the active unmanned aerial vehicle for analysis of irrigation efficiency, the serious game on the Water-Energy-Food-Climate nexus, and the Early Warning System for safe reuse of treated wastewater for agricultural irrigation. The serious game developed by the Marche Polytechnic University as a tool for communicating and understanding the process of irrigation reuse of purified wastewater and Water-Energy-Food-Climate nexus
How the CoP worked. Formal decision making and/or only information. What was discussed: The CoP worked with regular online and face-to-face meetings, including presentations of the development progress of the solutions, updates on implementation, demo, testing activities and hands-on play sessions. Feedback from the stakeholders was collected using Slido software, adapting to the relevance of the solutions for the Milan context. The specific testing activities were for the development of an integrated wastewater management and reuse system - with a particular focus on risk management aspects, the Early Warning System, digital tools to support Early Warning at the Peschiera Borromeo wastewater treatment plant, match-making tool and next irrigation test campaigns with reused water, as well as the serious game on Water-Energy-Carbon-Climatic nexus.
Key challenges related to local digital water governance aspects: The challenges were: the preferred time-period to receive information about availability of re-used water for its use in irrigation; importance of the consideration of the carbon footprint of water used for irrigation; relevance of solutions for the improvement of agricultural productivity and sustainability; and initial interest from stakeholders to the presented solutions.

Table 4. Copenhagen Local CoPs (CoP level1).

Led by **BIOFOS** **Key Stakeholders**: Ongoing operational group for integrated water management involving BIOFOS and other water utilities (HOFOR, NOVAFOS, Frederiksberg) in the Copenhagen greater region
Goal and ambition: The objectives for Copenhagen were to reduce environmental impacts and flooding and improve the stability and biological capacity of the wastewater treatment plant (WWTP). The project aims to reduce environmental impacts and flooding through flow forecasting and real-time control between the sewer network and a wastewater treatment plant.
Digital water innovations supported: The web-based tool SAMDUS is an interoperable visualization platform that provides data and analytics to all stakeholders responsible for the integrated management of sewer networks and wastewater treatment plants (WWTPs) in an urban area. The platform enables the sharing and visualization of data from a series of sensors, models and decision support systems. It integrates the total system dynamics and facilitates real-time decision-making across all utilities and entities, increasing preparedness for high-flow events; Another solution is the sewer flow forecast toolbox, which is a machine-learning (ML) based tool for forecasting flow in the sewer network and inflow to the wastewater treatment plant (WWTP), with forecast lead time of up to 48 hours. The tool is based on a combination of (1) real-time water level and flow sensor data from the sewer system, (2) rain gauge data, (3) weather radar observations and nowcasts, and (4) weather forecasts from numerical weather prediction models. The solution provides an accurate flow modeling forecast and horizon to support the integrated management of the sewer network and WWTP. A third solution is a Decision Support System (DSS), which is an innovative tool for the sustainable operation of the integrated sewer network and wastewater treatment plant (WWTP). It is based on a series of level and flow sensors within the sewer network, WWTP operation data and accurate flow forecast at the inflow of the WWTP. The goal of the DSS is to optimize treatment capacities, pumping strategies and in-sewer flow allocation to make the best use of existing infrastructure for stormwater handling.
How the CoP worked. Formal decision making and/or only information. What was discussed: The Copenhagen case reunited a group of stakeholders to meet regularly and share expectations which can be used for the product development. The CoP process worked through an ongoing operational group for integrated water management involving BIOFOS and other water utilities in greater Copenhagen. This group includes the key actors to support the development of the digital solutions being developed and tested in Copenhagen. Feedback from other water utilities was very relevant to the development of the "Web platform for integrated sewer and wastewater treatment plant control", which is also directly related to other two DWC solutions (i.e. sewer flow forecast toolbox, and the interoperable DSS for stormwater management). A presentation of DWC Copenhagen and the solutions, and several workshops were organized where information was collected in a systematic way, bringing together different views and expectations for the solutions and then further exploring the comprehension of the overall context and the specific attributes which may be desirable for the key stakeholders.
Key challenges related to local digital water governance aspects: BIOFOS takes care of wastewater treatment in Copenhagen, while HOFOR supplies 1.1 million customers with drinking water, district heating and wastewater management. Current challenges are: real-time control of stormwater being hampered by lack of accuracy of the wastewater treatment plant's flow forecast and lack of interoperability between the data management systems of BIOFOS and HOFOR.

Table 5. Sofia Local CoPs (CoP level1).

 Led by **Sofiyska Voda AD** **Key Stakeholders**: Veolia group, Clean & Circle Competence Center, Municipalities of Sofia region, Bulgarian water utilities, scientific community in Sofia (University of Architecture, Civil Engineering and Geodesy in Sofia and others), commercial companies carrying out digital installations.
Goal and ambition: The objective in Sofia was to create awareness in target audiences about the project objectives and progress.
Digital water innovations supported: The solution developed was the low-cost temperature sensors for real-time combined sewer overflow (CSO) and flood monitoring, which is based on the deployment of a network of innovative sensors to estimate emissions from combined sewer overflows (CSO) across a large number of points in a sewer system. CSO events and their duration can be detected by shifts in temperature within the sewers, thanks to the temperature difference between the air phase and stormwater discharge.
How the CoP worked. Formal decision making and/or only information. What was discussed: A series of information and dissemination activities was organized about the DWC project, both among employees and citizens. The DWC project was also presented to the young audience – high school students from the Sofia High School of Construction, Architecture and Geodesy "HristoBotev", and Open "Sewer" classes in front of the same high school.
Key challenges related to local digital water governance aspects: One of the key challenges was to increase sewer maintenance efficiency in order to reduce blockages and flooded properties, as well as increase customer satisfaction. Another challenge was the need to optimize future investments by improving data availability on combined sewer overflows and reduce operational costs for sewer cleaning and inspections.

remarkable in order to improve the usability of some solutions.

5. **Data exchange** was considered a significant challenge for many of the cities. There is a need to better understand which data exchange is needed, and which data can be exchanged, i.e. open data/critical data. It was identified as a significant potential to help unravel these aspects through the local CoPs.

In addition to the common points, a number of differences were recognized:

1. There are different needs regarding stakeholder **involvement**, i.e. ranging from a strong interest by stakeholders to cooperate in the co-development of some solutions to cases where the need of stakeholder involvement is very limited. It was agreed that this factor needs to be strongly taken into account for the design of the activities of the Local CoPs.

2. The required **stakeholder involvement** can be related to different stages of development, namely:
   - contribution for the specification of **technical characteristics**
   - consideration of **expectations of end-users** throughout the solution design and development
   - **convincing** end-users and stakeholders **about the benefits** from the implementation
   - increase of **communication and dissemination** of the results

3. There are differences in **problem awareness** of public authorities. For some Digital Solutions (DSs), there is a clear willingness of public authorities to cooperate to reduce existing problems (e.g. bathing quality) whereas it is not fully clear whether public authorities have a real interest in strongly contributing to sort out other problems (e.g. detection of illegal sewer connections). As for the latter case, there was an acknowledgement of the need to make an effort to involve authorities so as to motivate them to work on the topic.

4. The discussions showed that in the different cities, **digitalization has been integrated quite differently.** Often, technical aspects of implementing new technologies and making them work prevail over Information and Communication Technology (ICT) governance and policy aspects.

All these points have been considered for the identification of the impact delivered by the local CoPs.

Reflecting on the process of co-creation and insights from survey and interviews

The aim of reflecting on the general process of co-creation was to get standardized and comprehensive feedback building on the direct feedback collected from the cities and project leaders.

As a first step, a survey was circulated to the pilot leaders to document the scope of co-creation activities within the DWC CoPs. In most of the cases, a follow-up interview was conducted to complete the information and discuss potential improvements in the participatory work plan that could better support co-creation within the CoPs. These were semi-structured interviews following a predefined questionnaire, divided into six parts: Objectives (co-development of solutions to overcome barriers from innovation to practice; Collect user requirements; Business development and contribution to value; Collaboration in co-creation); Process; Unexpected results. For each

category, the details of the questions are presented in the Table 6 below.

The survey, produced as a questionnaire, was applied to pilot leaders, to consortium researchers and stakeholders involved in the local CoPs, as well as to some innovators (see Figure 3). A total of 13 respondents participated in the study.

The answers to the survey were collected during an online meeting, creating an informal space from a broader dialogue and debate on co-creation within DWC, thus allowing the actors to discuss and share their experiences at the final stage of the project.

The participatory approach of the project was implemented within the Communities of Practice, at different levels, as presented previously. This section presents the results of the survey for each group of questions and incorporates the reflections about co-creation within local CoPs. The detailed answers to the survey can be found in Table 7.

Table 6. Questions to collect feedback on the co-creation process of the DWC Communities of Practice.

Objectives	Questions
Co-development of solutions to overcome barriers from innovation to practice	*Has co-creation been achieved? If yes, at what level (project activities/between cities/within the city)?*
	Has this co-creation process contributed in any way to improving the development of digital innovations?
	Were the set goals achieved?
Collect user requirements	*Have the needs of all users been collected? Yes/No. If yes, in what way? If not, why?*
	Who were the actors most involved in this co-creation? (Please explain)
Business development and contribution to value	*How does co-creation contribute beyond what the economy offers? Possible answers: Specific solutions to a specific problem based on the development of existing generic solutions / Solutions more adapted to the operating process / New solutions not yet considered by the market / Other*
Collaboration in co-creation	*Does co-creation in CoPs offer new opportunities for cooperation with other stakeholders? Possible answers: Definitely yes/somewhat/not really (You can find space below to expand on your answer if you wish)*
	In case the co-creation did not achieve the objectives, could you explain why?
	If the expected co-creation is not produced, what do you think are the main causes or barriers? Possible answers: Technologies are not developed/ Lack of stakeholders/ The design of the participatory process is not adequate/ Lack of communication/adequate dialogue/ Online communication barriers/ Other
Process	*Was the co-creation process (format, activities, actors, etc.) implemented adequate to achieve the objectives? Yes/No (You can find space below to expand on your answer if you wish)*
	How did this co-creation process go? Possible answers: During CoPs/ Individual interaction/ Information sharing/ Other
	How could this process be improved?
	Why would co-creation be considered fundamental/necessary?
Unexpected results	*What unexpected results did co-creation bring? (You can find space below to expand on your answer if you wish)*

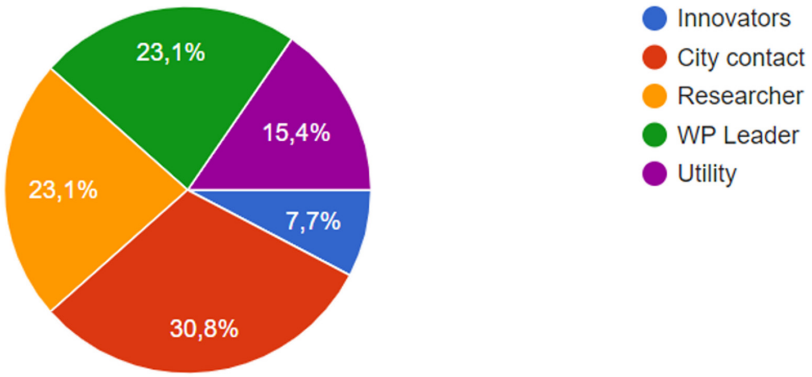
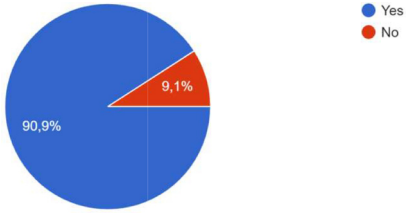
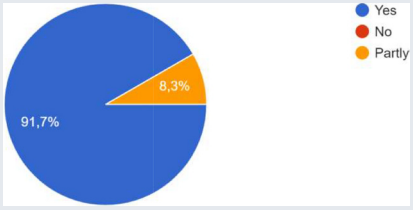


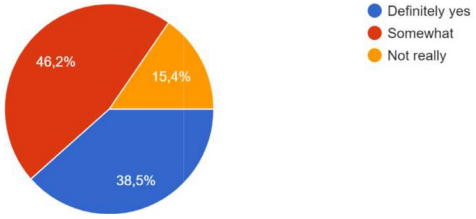
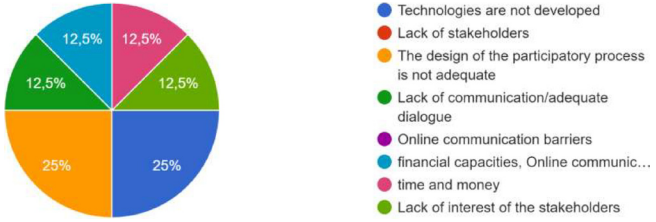
Figure 3. Participants of the survey.

Table 7. Detailed results of the survey on the participatory approach within Communities of Practice and reflections on co-creation at local levels.

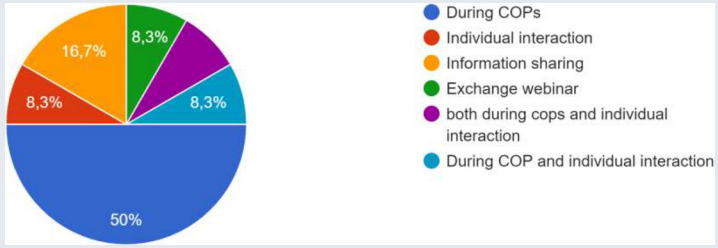
Objectives	Questions	Answers
Co-development of solutions to overcome barriers from innovation to practice	*Has co-creation been achieved? If yes, at what level (project activities/ between cities/within the city)?*	Yes, at the city level (local level)
		Yes, project activities
		Yes, project activities and exchanges between cities
		Project activities
		Yes, at the local level
		Yes, on project activities
		Yes, in the city and between Paris and Berlin (both at local level, and the project level)
		Not at the local level, but at the project level
		Co-creation at local/city level as well as at project level has been achieved
		From our point of view (with a lack of visibility on the co-creation process of applications), co-creation has been particularly effective at the city level where the opinions gathered during communities of practice and focus groups have been incorporated into the development of applications.
	Has this co-creation process contributed in any way to improving the development of digital innovations?	
	Did the goals set were achieved?	

Objectives	Questions	Answers
Collect user requirements	*Have the needs of all users been collected? Yes/No. If yes, in what way? If not, why?*	Yes, through CoP and involvement in product development.
		Yes, during multiple meeting organized (once a month) and email exchange with tables to fill in
		Yes, we arranged meetings with utilities to know their needs
		Difficult to say in our developments. Probably not the needs of all users, but quite a few needs were collected and addressed.
		Depends on cities
		Yes. but not all is implemented.
		Yes. But for the public app, we had to take into account the digital divide, the fact that many water users are not app users. So app users are a smaller population than what we initially thought
		I think so.
		Requirements for digital solutions, potential features have been collected during workshops and CoP actions.
		It would be illusory to try to represent the views of all future users of the applications - this is also one of the points that the project has helped us to understand. Enrolment in the co-creation process can only involve motivated individuals/ organisations (e.g. swimmers who already practice open water bathing or residents living close to future bathing sites who feel concerned by the issue and/or for whom the question of legitimacy to express themselves on the topic is less of a barrier).
	Who were the actors most involved in this co-creation? (Please explain)	Corresponding authorities.
		Stakeholders and the public.
		ICRA, BWB and Sofiyskavoda.
		Researchers & operators.
		BWB, P4uw, SIAPP, Amsterdam.
		Researchers, WWTPs, software developers.
		City leader + innovators.
		Innovator and BIOFOS as a user... Stakeholders partly via 2 workshops. BIOFOS on a regular basis.
		Wastewater managers and future bathing site managers
		Intra project partners.
		Utility and city representatives in local CoP; technology providers for digital solutions discussed
		It is more relevant and easier to answer this question from the example of the communities of practice because the focus groups only brought people together once. All our attempts to reproduce the experience failed, which testifies to the difficulty of maintaining the involvement of people expressing themselves in an individual capacity in a process of co-creation of an application - all the more so as the participants in these focus groups were systematically critical of the temporality of this co-creation process: how can we build an application aimed at providing information on bathing sites when these do not exist? The participants in the communities of practice were more likely to maintain their participation over the months. It can be noted, however, that the most consistent participants were the institutions that were best informed and "motivated" by bathing, while the representatives of municipalities that were still hesitant about their desire to create sites participated in a fluctuating way (absence from meetings and lack of intervention during them).

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Objectives	Questions	Answers
Business development and contribution to value	*How does co-creation contribute beyond what the economy offers? Possible answers: specific solutions to a specific problem based on the development of existing generic solutions/ Solutions more adapted to the operating process/ New solutions not yet considered by the market/ Other*	Specific solutions to a specific problem based on the development of existing generic solutions/Solutions more adapted to the user needs.
		The idea was to use a co-creation process so that the tools developed correctly match the demand of the stakeholders and the public. The stakeholders contributed to building the tools by specifying the content. We believe that if they participated in the development process they would be more willing to use the tool afterwards: they would have trust in it!
		Solutions more adapted to the operating process.
		Better feedback to new solutions - reducing failure rate of products.
		Solutions better adapted to the operating process.
		Specific solutions to a specific problem based on the development of existing generic solutions/Solutions more adapted to the operation process.
		Specific solutions to specific needs expressed by users: alerts for the expert app, additional information for the public app.
		Solutions more adapted to the operating process.
		Agile development of digital solution made, solutions more adapted to the operating process.
		I don't know.
Collaboration in co-creation	*Does co-creation in CoPs offer new opportunities for cooperation with other stakeholders? Possible answers: definitely yes/ somewhat/not really (You can find space below to expand on your answer if you wish)*	
	In case the co-creation did not achieve the objectives, could you explain why?	The co-creation process is quite time intensive. There was no established culture of co-creating. Thus, the learning curve was steep for all actors involved.
		Lack of time for the procedure
		Hard to involve external partners in new processes without funding
	If the expected co-creation is not produced, what do you think are the main causes or barriers? Possible answers: Technologies are not developed/Lack of stakeholders/The design of the participatory process is not adequate/ Lack of communication/ adequate dialogue/Online communication barriers/ Other	

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Objectives	Questions	Answers
Process	*Was the co-creation process (format, activities, actors, etc.) implemented adequate to achieve the objectives? Yes/No (You can find space below to expand on your answer if you wish)*	Yes
		Yes! We wanted them to participate without blocking too much of their time, so we decided to fix one meeting per month and exchange information via emails.
		It was a starting point
		We had a great exchange webinar about illicit connections (ds9) as follow up action of the CoPs. Discussed different techniques and strategies to deal with illicit connections
		Yes.
		Yes.
		Yes. But can be done better.
		The co-creation process that was put in place took time to set up; it required prior preparation work to find the format most likely to attract the participants (work carried out by Sofia Housni). The institutional stakes were high in Paris with a diversity of actors and territories represented in the CoPs, with a divergent level of knowledge and involvement in the bathing issue. The key step that enabled the effective calibration of the CoPs was the preliminary individual interviews with the representatives of the invited institutions to explain the approach and find out about the institution's position on the subject. Another fundamental step was to agree on the mode of deliberation for collective decision-making. Digital tools were effectively used to this end to survey participants' opinions.
	How did this co-creation process go? Possible answers: During CoPs/ Individual interaction/ Information sharing/ Other	

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Objectives	Questions	Answers
Process	*How could this process be improved?*	Align the co-creation process closer to the user's needs.
		We believe that it went really well considering the amount of people involved and we offered different optiono so that everybody had a say such as specific individual meetings outside of COPs meeting
		More physical meetings
		Design of the event, better highlight the needs and added value of the co-creation
		Smaller ambitions.
		More structured results from the CoPs
		Hard to do. Stakeholders in CoP do not have capacity and budget for more involvement in the co creation
		An important lesson from the process of co-creation that we invite reflection on is that of the embeddedness of this practice in other wider practices and concerns. Sensitivity to this point must be kept in mind in order to maintain the involvement of the participants and make it effective (one must be ready to see the initial plan bifurcate by listening to the actors' concerns and constraints). In the case of bathing, participants needed to be informed of the implication of future site management beyond the sole issue of water quality. Their confidence and involvement in the co-creation process was maintained by listening and responding to these concerns.
	Why would co-creation be considered fundamental/ necessary?	Because it establishes a joint learning culture.
		Involving the future users in the development of the tool allowed us to create something that perfectly answers their demands, and we were able to build trust in the tool so that they could use it with a lot of confidence
		For us, because we were able to know the specific needs of our partners
		Different sectors - different backgrounds and competencies
		To develop solutions people want to use.
		Because the assumptions made by developers about users' need are often biased
		It is a platform for sharing.
		The case of the development of the "general public" application in Paris demonstrates the importance of the co-creation process, which allows stakeholders to be heard beyond the commercial approach of assessing the application's ergonomics or the accuracy of the technical information on water quality. It has thus made it possible to identify the need to integrate awareness and prevention pages on the risks associated with swimming (linked to navigation, the presence of dangerous objects in the water).

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Objectives	Questions	Answers
Unexpected results	*What unexpected results did co-creation bring? (You can find space below to expand on your answer if you wish)*	Cooperation between the different actors (those who had a better understanding of the tools and the situation and those who didn't), cooperation with outside participants
		Communication
		Prioritizing. Only select those features that are relevant to the most end-users. One must be aware of benefits and performance. This was more important than the feature itself here in Copenhagen.
		New questions of governance.
		(see previous answer on the need for information beyond the sole water quality issue).

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Achievements

The co-creation has resulted in several achievements and successes. The majority of respondents indicate in particular that this co-creation process contributed to improving the development of digital solutions through different aspects.

- Cooperation:

As explained by the participants, co-creation allowed more cooperation by bringing together different actors from public, private and research fields. It allows stakeholders to be, as said one participant, "heard beyond the commercial approach of assessing the application's ergonomics or the accuracy of the technical information". Co-creation brought more communication and "cooperation between the different actors (those who had a better understanding of the tools and the situation and those who didn't)" and cooperation outside the participants' project. Co-creation was fundamental because it made work "different sectors" from "different backgrounds and competencies", and established between the actors of a project a "joint learning culture". and that these mutual learning spaces offered new opportunities for cooperation with other stakeholders.

- End-users needs:

One of the main achievements of co-creation is that the needs of users have been collected. One participant indicated that "probably not the needs of all users, but quite a few needs were collected and addressed" and another participant explained that through co-creation it has been able to make them understand that it is not possible to represent the viewpoints of all users of the solutions developed.

Including end-users' feedback made it possible to "develop solutions people want to use", and was necessary "because the assumptions made by developers about users' needs are often biased", as mentioned by some participants. Co-creation provides the means to gain an in-depth understanding of the needs and requirements of the future users.

In the case of Berlin, users' fear of information overflow was identified, as was the lack of staff and resources to maintain and operate the digital solutions after a pilot phase, as well as the trade-off between the required easy availability of data and the need of secure data to protect critical infrastructure. Some participants highlighted the high specificity of the solutions developed "to a specific problem based on the development of existing generic solutions" (for example, certain features were improved, and the system was designed to allow the easy addition of new scenarios with minimal additional development effort.). Through co-creation, this could lead to a reduction of a product's failure rate, or to solutions that are better adapted to the needs of end-users.

In the case of Copenhagen, through co-creation, the identification of several key aspects has led to enhanced product development (for example, water utilities are either do not regularly use current systems for data sharing, or they limit their use to the analysis of rain events or for getting a quick overview over WWTP and sewer system performance). In terms of expected improvements, the utilities identified several specific attributes, such as scenarios calculation and evaluation, integrated graphs, an overview of different variables, etc. Moreover, participants recognized a number of expected benefits (e.g. increased cooperation, improved internal and external communication and savings in operation costs) and expected experience in the use of the system (e.g. easy data visualization and download).

In Milan, an important lesson learned is that, although these stakeholders provided highly valuable feedback, it was concluded that a greater involvement of end-users into this exercise can help to better tune-up and refine the tool.

In Sofia, co-creation focused on communication of results (i.e. how to regularly report on the collected data and generated information to the stakeholders) as well as on promoting the use and further adoption of the digital solutions and the information generated through their use.

In Paris, the end-users' feedback has been incorporated into the applications. In the case of the Paris region, the discussions during a Focus Group organized went far beyond the question of the digital tool, and the reactions collected are valuable lessons concerning the general issue of bathing in Ile-de-France (Rouillé-Kielo & Bouleau, 2021). The participants had the particularity of being interested and invested in the subject of the return to swimming and/or the deployment of digital information tools. These people could share their knowledge of the territory and/or the subject, even if they sometimes had to be reassured about their legitimacy to express themselves and to be listened to. Mutual acquaintance or commonalities between participants constituted strong enough foundations to allow a free flow of speech. Regarding the subject of bathing and risk, the discussions during the participatory process raised other questions and largely went beyond the framework of the development of digital applications and concerned the adaptation of facilities and communication to future bathing uses. Many participants insisted on the fact that the existence of different audiences should be anticipated at bathing sites, depending on the type of bathing site. These audiences will not have the same expectations in terms of equipment, information, opening hours, and should be taken into account to adapt the offer to a site or between several sites on the metropolitan territory. The question of conflicts of use on the banks and in the water was therefore a central element in the discussions. It concerned the question of the preservation of biodiversity which could be threatened by overcrowding. A final type of conflict mentioned during these discussions is between legitimate and non-legitimate uses. In one of the focus groups, it was also pointed out that there is a need to take into account the current uses which, should not be marginalized or phased out due to the development of the practice of bathing and the changes brought about by the public frequenting these places.

- Trust:

With the co-creation process, the actors of the project indicate that the solutions developed could be suitable for

both stakeholders and public, by strategically specifying the content thus, allowing trust in the solutions developed. One participant explained "we believe that if they participated in the development process, they would be more willing to use the tool afterwards: they would have trust in it!" It was important to maintain the "involvement of the participants and make it effective (one must be ready to see the initial plan bifurcate by listening to the actors' concerns and constraints)" and that listening and responding to their concerns was key to maintain the "confidence and involvement in the co-creation process". Co-creation was necessary because it increases confidence in the solutions. One participant pointed out that "involving the future users in the development of the tool allowed us to create something that perfectly answers their demands, and we were able to build trust in the tool so that they could use it with a lot of confidence".

- Governance

Co-creation also raised challenges, first in terms of communication because of the importance of raising awareness among users and populations, and governance. In the Paris case, for example, it allowed for "new questions of governance", faced political questions to be raised, concerns about swimming in open waters, which technical data to share and to make the decision on the status of a bathing site.

Format and process

The participants agreed that the co-creation process (format, activities, actors, etc.) implemented was adequate to achieve the objectives.

The **workshop format** was specifically used, a participatory activity where the CoP members were asked for their opinion on potential barriers to the implementation of digital solutions, synergies with their work and their expectations of the DWC project.

In the Berlin case, for example, dedicated workshops with future end-users were held to specify user requirements and test prototypes. This included the ideation of features of the well diary, as well as UX and UI design. This has been essential to support the development of the digital solution and has enabled the DS provider to tailor these products to actual users' needs.

In Milan, the third DWC meeting of the CoP had an important focus on co-creation. In this case, a demo version of the serious game on the water, energy, food and climate nexus was presented and discussed with a group of stakeholders. Some educational workshops were also organized. In a similar manner, the DWC Milan leaders have approached several farmers (in collaboration with some of the stakeholders participating in previous CoPs) to directly involve them in the demonstration activities of the matchmaking tool and the related innovations. Again, the reception of this initiative has been very positive and a workshop involving a significant group of farmers and farmers' representatives was organized.

In the Paris case, INRAE conducted a series of focus groups in order to collect feedback (Rouillé-Kielo & Bouleau, 2021) from the citizens, organizing a feedback session on all the interviews and focus groups conducted during the project, which were very effective. Several exchange meetings were also organized, with bathing site managers in France sharing their experience in managing a bathing site, a meeting included the exchange of experiences on alternative measurement tools of E.coli that have been used by several institutions.

Some **webinars** were also organized to generate new constructive exchanges. As expressed by one participant: "Great exchange webinar as follow-up action of the CoPs, discussing different techniques and strategies to deal with illicit connections", for the case of Berlin.

The format offered different options so that everybody had the possibility to meet outside of the main CoPs meeting. In order to understand what kind of format would be the most appropriate, preparations were required. As one participant said, the "key step that enabled the effective calibration of the CoPs was the preliminary individual interviews with the representatives of the invited institutions in order to explain the approach and find out about the institution's position on the subject.

Regarding the format, participants also noted that it was important to "participate without blocking too much of their time so we decided to fix one meeting per month and exchange information via emails".

For the process, co-creation has been carried out, whether at the local level, the city level, the level of project activities, or all three. One participant specified that co-creation was particularly effective at the city level, and that focus groups were added in the methodology. The intervention of 'practitioners' already experienced in CoPs and thus able to share their daily experiences, difficulties and adaptation strategies had a very positive effect on the co-creation process in one of the Local CoPs. In some CoPs, it was the public authorities who were most involved; in other CoPs, it was the innovators, private sector actors and/or researchers. One participant specified that the actors' involvement also depended on their 'motivation' which was influenced by the degree to which the subject affected them. Co-creation processes occurred during the CoPs, as well as through individual interaction and information sharing, as shown the Figure 4.

In the Berlin case, the local CoP raised the question of data exchange between the cities' stakeholders on topics such as groundwater, surface water and rain data. Setting up a common ground in order to work on a secure and centralized data hub for water infrastructure and environmental data will provide a very important foundation for future expansion of the developed digital solutions.

In Copenhagen, the results of the dedicated workshop on the SAMDUS tool have allowed for the integration of key

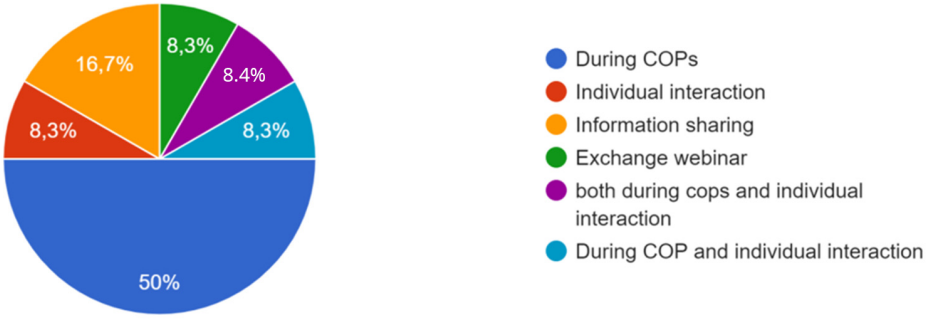


Figure 4. Answers on how the co-creation process occurred.

aspects in the solution development roadmap. BIOFOS and DHI have embraced an agile approach for the progress of the SAMDUS web platform. During the workshop, requirements were identified and directly addressed. Beyond this, these requirements were used as criteria for the definition of targets in the development sprints included in the process.

In Milan, a strategy developed during the process was the identification of key "intermediaries" to get in touch with them. Additionally, a collaboration between the Milan municipality and some local high schools was established and a number of educational activities were organized to present the serious game tool and collect some final feedback to be used as direct input for completing the app.

In the Paris case, the fully participatory conception of both applications brought together all the actors working on the bathing situation in the Paris area as well as representatives of all the cities that might open up a bathing site.

Difficulties and limitations

One of the limitations mentioned was that time-intensive nature of the co-creation process ("takes a lot of time"; "took time to set up"; "co-creation process is quite time intensive"). There was also "time lack for the procedure". Another difficulty mentioned was to "involve external partners in new processes without funding". Moreover, some participants indicated that "more results" could be shared in a platform, for example. Another limitation mentioned was that the process could be "closer to the user's needs", and that the format could integrate "more physical meetings", could provide "more structured results from the CoPs", and integrate other stakeholders, or have "smaller ambitions".

A difficulty was that "stakeholders in CoP do not have capacity and budget for more involvement in the co-creation". Some other difficulties were also mentioned, specifically during the online interactive session where some participants debated on modes of communication and political issues and sensibilities, noting that sometimes it was necessary to make a decision and "not open too much"- also because of budget questions based on specifications.

Another aspect was the importance of "prioritizing". One participant indicated that to select the features that are relevant to the most end-users, one must be aware of benefits and performance.

When co-creation was not achieved, the main barriers could have different causes, as shown in Figure 5 below.

Discussion

The methodology proposed by the DWC project for co-creation put in place a process aiming to interact with and facilitate an exchange between different actors, who were encouraged to share their knowledge and resources. Their **regular interactions** made them share "their own resources, integrate resources offered by other actors, and potentially develop new resources through a learning process", as suggested by the definitions of co-creation in the literature (Leclercq *et al.*, 2016, p6).

The survey on co-creation within the CoPs and the case studies on the local CoPs showed that one of the objectives, if the context allowed it, to include end-users' needs in the development of the solutions, which is congruent with the literature on co-creation, acknowledging a more constructive role for the customer or end-user (Galvagno & Dalli, 2014). The necessity of integrating **other stakeholders** into the processes, along with end-users has been underlined as an added value (Prahalad & Ramaswamy, 2004a). These other stakeholders could include suppliers, public institutions, collaborators. Furthermore, the participative approach of the co-creation process also increases the trust in the solutions developed as the needs and understand and collect expectations.

However, in the Local CoPs, there were some cases where co-creation mostly occurred within companies, because co-creation was not part of the CoP – instead, it occurred internally, as they designed the tools together with users.

The issue of time and effort was not seen the same way by all participants. Some actors of the DWC project highlighted that the process and setting up interactions was taking a lot of time, although other participants expressed that implementing



Figure 5. Main causes of barriers when the expected co-creation was not achieved.

a co-creation process would, from a long term perspective, cost less time and money because the solutions would be better adapted to the needs.

Regularity was highlighted as a central element of the process, as well as **adaptability** to the needs of the different actors joining the process.

Regarding the DWC CoPs in general, key issues have been the users' interest in and relevance of the topics discussed, as well as the subject of the solutions developed. These issues are the foundations of the creation of a community of practice where actors must share a concern or a common subject to constitute the community. Furthermore, as the concept of communities of practice suggested (Wenger-Trayner, 2015), the "process of collective learning" and sharing mutual knowledge was highlighted by the participants. During the online debate session, it was indicated that one of the central points in constituting the communities was the "**sense of commitment**", where several groups of people deliberately choose to engage in regular interactions, common activities and meetings, sharing information and developing skills and solutions together, making them members of a community, as the literature on communities of practice highlighted (Wenger, 2010).

Finally, another important added value of the co-creation process within the CoPs is that, as explained by some actors, the process would allow them to raise questions in terms of **governance and communication**, and to create new partnerships.

Co-creation within the DWC CoPs facilitated collaboration among diverse stakeholders. In some cases, co-creation primarily took place within organizations, not always fully within the CoPs. The process contributed to achieving the project's goals by improving communication, collaboration, participation, building trust, adapting solutions to user needs, and enhancing product development through end-user feedback. Key lessons include the importance of regular engagement, a sense of commitment and how co-creation raised governance issues and led to new partnerships.

The co-creation process has proven to be valuable in several key areas. It fostered cooperation between diverse stakeholders, including public, private, and research sectors, enabling joint learning and enhancing communication beyond commercial interests. It also facilitated a deeper understanding of end-users' needs, resulting in more relevant for digital solutions. By incorporating end-users' feedback, co-creation can led to better product development, adapting solutions to specific challenges and improving their applicability in real-world scenarios.

Conclusions and recommendations

Co-creation was a complex process to set up in order "to establish a culture of co-creation", adapting the objectives, expectations and format. The role varied depending on the cases and users' needs. For some Local CoPs, the co-creation was established through a participatory process between private actors, public institutions and researchers. For some other CoPs, the co-creation occurred more directly at a company level, integrating interactions with end-users. End-users' feedback has been collected, allowing for **greater trust in the solutions** because they are co-created and **adapted to the needs and specificities of the different contexts**.

Co-creation was instrumental in facing some of the sector-specific challenges mentioned before, such as low awareness and engagement of users. As several actors mentioned, the DWC co-creation process and the methodologies of cross-level and cross-sector communities of practice allowed for reflection on policy fit and regulation standards and boundaries.

It could be recommended to include stakeholders' and end-users' feedback at all stages of the process, from the very beginning, and also to integrate their feedback even after the solutions are fully implemented and operational for some time, to allow for evaluation based on their long-term usage.

It can also be beneficial to include more perspectives and insights during the entire co-creation process, from the very beginning. Including subjective experiences can improve the effectiveness of companies looking to integrate customers (and their employees) into their value processes, as mentioned in the literature.

Co-creation strengthened trust among stakeholders, with participants noting that being involved in the development process increased their participation and confidence in the final solutions. This collaborative approach also highlighted important governance issues, including how to raise awareness and make decisions on the management and adoption of digital tools, especially in the context of environmental challenges like water management. Ultimately, co-creation contributed not only to the success of the projects but also to the development of user-driven solutions, addressing needs and contextual challenges within a participatory framework.

Informed consent statement

This study was carried out during a meeting session with verbal informed consent from all participants. All subjects were the participants and key actors of the DWC project.

Data availability

Underlying data

Zenodo: co creation process Answers questionnaire, https://doi.org/10.5281/zenodo.10116376 (Wehbe, 2022).

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

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Open Peer Review

Current Peer Review Status: ✔ ? ? ? ?

Version 2

Reviewer Report 24 February 2025

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Love Opeyemi David
University of Johannesburg, Johannesburg, South Africa

The study has provided a comprehensive research report on utilizing co-creation and community of practices (CoP) within the EU Digital Water City (DWC) Project. However, there is room for more improvements, given the comments and insights below:

The study needs to provide a more detailed statistical account of the participants involved in the five case studies. Specifically, it should include the number of attendees at the workshops, the number of individuals interviewed, and the population and sample size for the quantitative survey, with appropriate scholarly justification. These data should be categorized per case study, following the Bowley proportional allocation system.

Furthermore, while Tables 1 to 5 highlight various digital innovations across the five case studies, the study should, perhaps in the discussion section, elaborate on how stakeholders navigated the acceptance of these technological innovations for water management in line with the Technology Acceptance Model and the principles of co-creation.

Also, following the objectives of Tables 1 to 5, the study should categorically highlight the contribution of co-creation and CoP to the technical performance of the objectives, not just the perception of working together.

Moreover, the recommendations section appears shallow, primarily reflecting stakeholder perceptions of co-creation. The recommendations should be presented as a standalone section, drawing directly from the quantitative responses. For instance, the study should offer specific recommendations to address the barriers identified in Figure 5.

Is the work clearly and accurately presented and does it engage with the current literature?
Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?
No

Are all the source data and materials underlying the results available?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: I am a Research Coordinator at the Center for Cyber-Physical Food, Energy and Water Systems, University of Johannesburg. My research publications and interests center on the Sustainable Security of Water, Energy and Food (WEF) projects, Innovation Management, Management Science and Project Management. Also, I am a management expert on the application of Emerging Technologies such as Artificial Intelligence and Blockchain Technology in WEF Resource management.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 27 December 2024

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Teresa Fidélis
Department of Environment and Planning, University of Aveiro, Aveiro, Portugal

I believe the improvements introduced in the paper were successful. The paper has clear objectives, methodological steps, and findings. A discussion of the results in the light of the literature could improve further the article. Nevertheless, the overall contents and outcomes are relevant to the scientific community and deserve to be indexed.

Is the work clearly and accurately presented and does it engage with the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

Are all the source data and materials underlying the results available?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: I am a researcher interested in policy and regulatory analysis, and the institutional arrangements for the water circular economy. I recently published an article about the institutional arrangement and water circular economy: https://doi.org/10.2166/wp.2023.155 In addition, I have had an excellent career opportunity as a researcher to work on a European project (Project Ô) focused on integrated water management and the circular economy in four pilots in four countries. Within it, I contributed to problem-solving co-creation processes. A pivotal aspect of the work was problem-solving co-creation process development that employed qualitative methods to address complex challenges (D3.4). Through this process, my colleagues and I facilitated collaborative efforts among diverse stakeholders, fostering innovative solutions that bridged the gap between theory and practice.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 27 December 2024

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Alban Kuriqi
Universidade de Lisboa, Lisbon, Lisbon, Portugal

Clarity and Focus:

1. Elaborate on the Framework:
    - Expand on what “co-creation” and “Communities of Practice” (CoPs) entail in the

context of the DWC project.
- Define key concepts earlier in the paper to aid readers unfamiliar with these terms.

2. Streamline Objectives:
   - Clarify the specific objectives of the DWC project. The goals of the co-creation process and how they align with the broader project should be explicitly stated.
3. Structure Improvements:
   - Divide the article into clearly defined sections (e.g., Introduction, Theoretical Framework, Methodology, Case Studies, Results, Discussion, Conclusion).
   - Use headings and subheadings to guide readers through the narrative.
4. Details on the Questionnaire:
   - Include more information about the questionnaire used in the study, such as:
     - Design and format.
     - Sample size and demographic details.
     - Key questions or themes addressed.
     - Statistical or qualitative analysis methods applied.

Depth of Analysis:

1. Critical Analysis of Results:
   - Discuss the results in greater depth. For example:
     - What specific needs of end-users were incorporated into digital solutions?
     - Provide examples of how stakeholders collaborated effectively or faced challenges.
2. Address Limitations:
   - Acknowledge limitations of the study (e.g., potential biases, limited generalizability of case studies, or challenges in data collection).
3. Explore Governance Issues:
   - Provide specific examples of the governance questions raised and how they were addressed or remain unresolved.

Contribution and Impact:

1. Highlight Innovations:
   - Emphasize the novel aspects of the co-creation process in DWC compared to other projects or initiatives.
   - Clearly state the added value of the co-creation process for stakeholders, particularly in terms of practical outcomes.
2. Practical Recommendations:
   - Offer actionable recommendations for future co-creation initiatives based on DWC's successes and challenges.
3. Long-term Impacts:
   - Discuss the potential long-term implications of the partnerships and governance models developed within DWC.

Presentation and Readability:

1. Use Visual Aids:
   - Add diagrams, charts, or tables to summarize the co-creation framework, key findings, or questionnaire data.
2. Improve Language and Flow:
   - Ensure the text flows smoothly by connecting sections logically.
   - Avoid repetition and use active voice where possible to enhance readability.

3. Address Audience Needs:
    - Tailor the content to the intended audience (e.g., academics, policymakers, practitioners) by emphasizing the aspects most relevant to them.

Is the work clearly and accurately presented and does it engage with the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

Are all the source data and materials underlying the results available?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Floods, Water Resources Managament, Hydraulics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Version 1

Reviewer Report 28 August 2024

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The paper presents interesting insights from the Digital Water City project. This entails the

presentation of five case studies in different European cities, namely Berlin, Paris, Milan, Copenhagen and Sofia. In these cities, so-called Communities of Practice were established to connect a variety of local stakeholders, like end-users, municipalities, tech companies, authorities, etc. The methodology being followed is based on the notion of co-creation, implemented through a variety of different exchange formats. The authors subsequently present the details of how the co-creation process in the Communities of Practice of the five case studies has been established and raise some reflective thoughts as well as achievements and derive recommendations.
Beside the very relevant and interesting content of the paper, the presentation shows some shortcomings, technical flaws and inconsistencies. The paper needs a structural and linguistic revision. In relation to this, please refer to these general comments:

- Please thoroughly go through the paper again and look for grammatical errors. Especially the omission of articles and prepositions is a prevalent mistake which influences the flow of reading. In addition, there are a lot of convoluted sentences with syntactical errors that should be restructured and can often be simplified. Examples of this are provided below in the minor comments section.
- The structure of the paper makes it hard to follow the train of thought throughout. The Methodology section should be restructured to present specifically, what data is collected, how it is synthesized and how it will serve in answering the three leading questions. With this clear structure established, the outcomes should follow the exact same structure in presenting the data gathered through this process. Subsequently, the discussion reflects upon the contents and findings and answers the leading questions. These three very distinct parts of the paper are currently scattered across these sections and are not well distinguishable.
- The results of the case studies, surveys, interviews and workshops on the different levels of the project are very intertwined, and, therefore, it is often hard to trace in the outcomes where a specific finding originates. As one example, regarding end-user needs in the Paris case study (p.18), the information seems to mainly come from the focus groups that were used, and not from the general meetings on the CoP level as is the case for the other case studies in this section. Therefore, the source of information seems quite different and is not obvious.
- Throughout the outcomes section, there are a lot of very short quotes, presumably from the survey and the interviews. The way these quotes are integrated is rather unconventional, as direct quotes are usually used for important key statements, in contrast to short notions like “took time to set up”, “more results” or “prioritizing”. Please revisit the quotes in this section and evaluate them for necessity.
- The three originally formulated leading questions are never explicitly answered or revisited in the outcomes and discussion. These leading questions could serve as a guiding structure in the composition of the outcomes and discussion which would make it a lot easier to grasp the many findings that are presented.
- The resolution of all figures should be amplified.
- It should be distinguished which (digital) solution was an outcome of the project and the CoPs work itself, and which were pre-existing and have been leveraged or enhanced in this project. As of now, it is not entirely clear, what can be attributed to the DWC project.

Furthermore, here are some detailed, minor comments:
p.1: “CoPs” is used in the abstract but has not been established as an abbreviation yet. Please spell this out in full.
p.3: The footnote on the headline of the introduction is bad form. Integrate this information in the

text itself.
p.3: “Concern [in] the water sector is all the more [...]” – “in” instead of “around”.
p.3: “They aim to improve health protection, [...]” -> Specify what/who ‘they’ is.
p.3: The third paragraph presents “Sector-specific challenges”. These could be better presented in a list or enumeration environment to make it more palpable for the reader.
p.3: “[...] EU Member States, addressing slow innovation rate as well as low awareness [...]” -> Either “[the] slow innovation rate” or “slow innovation rate[s]”
p.3: There are quite some repetitions of the same statements very close to each other, just slightly rephrased, e.g.:
"Too little or too much water can have adverse effects on water quality" vs "Both scarcity and abundance of water can have detrimental effects on water quality, [...]"
"[...] as well as low awareness and engagement of users, [...]" vs "Finally, users’ awareness and engagement are fundamental points [...]"
p.3: In the final sentence on the third paragraph, the aforementioned “challenges” are now called “processes”. This is semantically incoherent, please rephrase, e.g. like: “These challenges can be tackled/overcome by [...]”
p.3: In the fourth paragraph the “water value chain” and its different levels are mentioned. Please (briefly) introduce this concept before referring to it and/or provide citations.
p.4: “Civil society is [a] fundamental actor.”
p.5: In the caption of Figure 1, the placement of the citation in front of the actual text of the caption is very unintuitive and raises the question how it is related to the subsequent citations within the caption. Please revise.
p.5: “This can be in regard to a good understanding of the supply and sanitation services and their associated costs, and help highlight their perspectives, needs and point of views.” – What is the ‘their’ related to – the supply and sanitation services, the civil society? Please clarify. Additionally, “perspectives” and “point of views” basically means the same thing.
p.5: “In the case of DWC, collaboration was facilitated between different actors, such as academics, companies, public administration and end-users, [...]” - You can very well explicitly state that these actors were chosen based on the quadruple helix model to represent keys stakeholders; otherwise this statement and choice of actors seems decoupled from the previous explanation of the quadruple helix model.
p.5: “As mentioned in the co-creation literature, [...]” – Please provide the citation needed for this specific mention.
p.6: “[...] provide relevant solutions towards the digitization of urban water management in European cities.” – This reads more like the appropriate keyword is ‘digitalization’. Please differentiate and use the terms properly.
p.6: “They are built of public, academic and private stakeholders [...]” – What is ‘they’ referring to? Please spell this out.
p.6: “[...] solutions for water and sanitation infrastructure challenges.” – Please establish a unified wording for this specific application area of interest. Currently, version of the wording are: “water and sanitation infrastructure”, “supply and sanitation services”, “water sector”, “urban water management”, “water treatment and sanitation infrastructure”. A common choice would be to use the term “urban water management” and to establish a proper definition at the start what this term entails.
p.6: “Local CoPs (level 1), which have been operationalized in four European cities [...]” – Why only four, what about Sofia?
p.6: Figure 2: In the text, the levels are also referred to as level 1, 2, and 3. Please add these indications in the figure as well.

p.7: The third research question is shorter and differently phrased than in the introduction.
p.7: "[...] and a workshop mainly involving the pilot and city leaders." – Please elaborate on the role of the "pilot and city leaders" and what those entail, as they are not mentioned up until this point.
p.7: "DWC local COPs in action" – So far, the capitalization has always been 'CoPs' - please unify the abbreviation.
p.7: "[...] as shown in [...] Table 1, Table 2, Table 3, Table 4 and Table 5." - Please introduce more of the contents and different sections of the tables, i.e., briefly introduce what information they contain and how this relates to the project. Otherwise, these tables feel very decoupled from the rest of the paper. Also, the subsections in each table often seem to overlap conceptually and content-wise, so an elaboration on the intents of this structure might avoid confusion.
p.7: "[...] participated in a World Café exercise [...]" - For any uninformed reader, please add a citation explaining the format of such a World Café exercise.
p.8: Table 1: "Berliner Wasserbetriebe" vs. „Berlin Water Works" – Unify naming.
p.8: Table 1: „KWB" - Write this out in full.
p.8: Table 1: "The CoP worked through meetings and workshops [...] and through participatory workshops." – 'Workshops' appears twice in this list.
p.8: Table 2: "SIAAP, INRAE" - Write these out in full.
p.8: Table 2: "Expert" and "Public" vs. "expert" and "public" – Unify capitalization.
p.9: Table 3: "[...] sanitary concerns about water quality." - As phrased, this is not a goal or an ambition but a concern or challenges. Please rephrase.
p.9: Table 3: "water reuse-carbon-energy-food-climate nexus" vs. "Water-Energy-Carbon-Climatic nexus" vs. "the link between water, energy, food and climate" – Please refer to the specific nexus of domains consistently.
p.9: Table 4: "A third solution is a Decision Support System (DSS), [...]" - This builds upon the aforementioned solution for flow forecasts I assume? Please mention if so or differentiate clearly if not.
p.9: Table 4: "The Copenhagen case reunited a group of stakeholders [...]" – Reunited - so there was a group/community pre-existing to the DWC project which was reunited for this project? Please elaborate on this.
p.9: Table 4: "[...] the "Web platform for integrated sewer and wastewater treatment plant control", which is also directly related to other two DWC solutions [...]" – From the phrasing as is, this web platform is presented as something new that was not mentioned in the preceding 'Digital water innovations supported' section. Please integrate this properly in the table.
p.9: Table 4: "HOFOR" - First ever mention of HOFOR in the last section of the table. Please add information on how it relates to the DWC project, the local CoP and add it as a key stakeholder in the table, if appropriate.
p.10: Table 5: "The objective in Sofia was to create awareness in target audiences about the project objectives and progress." – This refers to the overall DWC objectives and not the objectives of the local CoP I assume. Please state this clearly.
p.10: Table 5: "The solution developed was the low-cost temperature sensors for [...], which is based on [...] low-cost temperature sensors to estimate [...]" – This reads as 'low-cost temperature sensors' are based on 'low-cost temperature sensors' - please rephrase.
p.10: Table 5: The "key challenges" in the last section of the table, based on content and phrasing, read more like goals and ambitions. Pleas rephrase or restructure.
p.10: "For some DSs, [...]" – This abbreviation has not been used before up until this point, please write out in full.
p.10: First mention of the abbreviation "ICT", please write out in full.
p.11: Figure 3: "Utility" appears twice in the diagram. Additionally, the role of "City Contact" needs

to be explained.
p.18: “More generally on communities of practice, it was said that these mutual learning spaces offered new opportunities for cooperation with other stakeholders.” – This is a repetition of what’s already written in this paragraph.
p.18: “[...] (for example some aspects were improved, and it is now possible to add new scenarios with few additional developments input).” – This is both too general (“aspects were improved”) and too detailed (“possible to add new scenarios”). Please provide context for the reader.
p.18: “In terms of expected improvements, the utilities identified several specific attributes, such as scenarios calculation and evaluation, integrated graphs, an overview of different variables, etc.” – Here, some additional details would be interesting, e.g. integrated graphs of what data, what kind of scenarios and which variables.
p.19: “DS provider” – As above, DS as an abbreviation has not been introduced.
p.19: “In Milan, the third DWC meeting of the CoP had an important focus on co-creation.” - Co-creation is described to be the focal point of the project and the meetings within the CoPs, so this raises the question, what the focus of the first two meetings was.
p.19: “For the process, co-creation has been carried out, [...]” – What process?
p.19: “ “The intervention of ‘practitioners’ [..]” – This quote starts but never ends.
p.20: “[...] the process of co-creation “takes a lot of time”. It “took time to set up” and the “co-creation process is quite time intensive”.” - This is three times the exact same information, no need to insert these quotes.
p.20: Figure 4: There are again duplicate options. As noted above, “COP” is not consistently capitalized.
p.21: Figure 5: There are options in the legend that do not appear in the chart. Either somehow signify that they account for 0% or drop them. Further, the capitalization in the legend needs to be unified.
p.21: “[...] there were some cases where co-creation mostly occurred within companies, because [...] – instead, it occurred internally within these companies [...]” - Duplicate statement within the same sentence.
p.21: “It could be recommended to add stakeholders and end-users’ feedback once the solutions are fully implemented and operational for some time.” – I very much disagree with this recommendation and do not think, the results of the project as presented support this conclusion. When a solution is already fully implemented, it is far too late to integrate stakeholders’ and end-users’ feedback.

Is the work clearly and accurately presented and does it engage with the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
No

Are all the source data and materials underlying the results available?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Not applicable

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: I have worked on research regarding various aspects of water and, especially, wastewater infrastructure for several years. In recent years, the focus has shifted to more detailed, technical aspects of wastewater systems and pumping stations. In this line of work, I have been involved in plenty of exchanges with companies in the water and wastewater sector, municipalities, local authorities as well as network and infrastructure operators. Previously, I have been involved in research projects on a European level and have contributed to and authored a variety of publications.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 09 Mar 2025

Marianne Wehbe

The paper presents a suitable concept tailored for case studies by adopting the quadruple helix approach for co-creation in the five DWC pilot cities to support the development and potential adoption of innovative digital water solutions. The concepts, including co-creation and communities of practice, are conceptualised and are highly relevant to the co-creation process. The research questions are well-designed and presented in the introduction. Therefore, the paper is well organised and conducted, conceptually guided empirical work. However, some minor revisions are strongly suggested: Thank you for your feedback on the paper. We greatly appreciate your feedback on the conceptual framework and its relevance to the co-creation process, as well as your acknowledgment of the organization and design of the research questions and all your thoughtful comments and suggestions for revisions that we tried to commit to address.

Comments Resolution Although the objective is mentioned in the abstract, “The article analyzes the ways in which they have been used and applied in DWC as well as the ways in which the project has managed to articulate them at different levels”, please add it in the introduction before the questions. Thank you for your suggestion. The objective has been added to the introduction, as requested, before the questions to provide better clarity and alignment with the abstract. What about Sofia? Local CoPs (level 1), which have been operationalized in four European cities (i.e. Berlin, Copenhagen, Milan and Paris), mainly focus on the solutions within their local contexts (page 6). Is Sofia representing another level? Thank you for your comment. Sofia was not included in the operationalization of local CoPs (level 1) because co-creation did not occur there. As noted in Table 5, the goal in Sofia was primarily to raise awareness rather than establish a full CoP as defined in the project. The CoP definition emphasizes collaborative engagement among diverse actors to build

trust, develop tailored digital solutions, and facilitate their local adoption through a dynamic learning process. Sofia's activities, while important, did not align fully with this CoP definition and focused on awareness rather than co-development initiatives present in other cities. Please mention how many stakeholders, or respondents are included in the study, in the text. Thank you for your suggestion. The information about the number of respondents has been added on page 11 following the sentence: "The survey, produced as a questionnaire, was applied to pilot leaders, consortium researchers, and stakeholders involved in the local CoPs, as well as to some innovators (see Figure 3)." A total of 13 respondents participated in the study.

Please name table 7 in a complete way, Detailed results of the survey of what and where etc,. Thank you for the suggestion. Table 7 has been renamed to: "Detailed results of the survey on the participatory approach within Communities of Practice and reflections on co-creation at Local Levels. Please revise the text of Table 7: the answer to the first question: The information is confusing. The answers section of question 1, says "Local level", does it say "Yes, Local level"? If so, please, use a unique way of presenting the answers. Thank you for your comment. The text of Table 7 has been revised for clarity. The answer to the first question now consistently states "Yes, local level", the same way as the other answers, to ensure a uniform presentation of responses. Please revise the text of Table 7: are the local level and the city level the same? If so, please, use a unique way of presenting the answers.
Yes it is the same. It has been changed. Please revise the text of Table 7: "Yes, in the city and between Paris and Berlin", can it be called Project level regarding the definition "Project CoP (level 2) provided a useful mechanism to facilitate knowledge exchange between DWC cities (mutual learning) and between DWC cities and technical partners" (page 6)."Not at local level, at project level": please clarify this, can be interpreted in many ways, for instance, "Not at the local level, but at the project level", or "Not at the local and the project level". It assumed that the answer was "at the project level". If so, please revise the answers (page 12).
Thank you for your comment. The response "Yes, in the city and between Paris and Berlin" has been clarified to indicate that it encompasses both the local and project levels. Additionally, the phrasing of the other answer has been revised to "Not at the local level, but at the project level," as suggested, for better clarity.

Please remove the reference from the conclusion section "...into their value processes, as mentioned in the literature (Galvagno & Dalli, 2014)". Considering the authors already supported the including the subjective experience of customers, on page 4. The reference to "...into their value processes, as mentioned in the literature (Galvagno & Dalli, 2014)" has been removed from the conclusion section. Data, I assume that the blank cells in the Excel file mean no answers are available, is that correct?
Thank you for your observation. Yes, the blank cells in the Excel file indicate that no answers were available for those entries. Finally, although the study includes five case studies, why the answers received are not case-based? Otherwise, it could have produced better results regarding the various goals and ambitions, innovations supported, and main challenges related to local digital water governance.
Thank you for this comment, the focus was more on capturing insights of the project about the Communities of Practice (CoPs) and reflecting on co-creation, its process and outcomes, we tried to gather feedback during the whole project and then through a survey targeted at

project and pilot leaders, rather than structuring responses on individual case studies. The survey was distributed to pilot leaders to document the co-creation activities within DWC CoPs, complemented by follow-up semi-structured interviews, aimed to provide feedback on the co-creation process across cities. The case studies were part of the broader methodology, but the survey responses reflected the general process of co-creation to capture diverse experiences on the whole process, rather than a case-by-case analysis. Reviewer 2 General comment It was a pleasure to read about the Digital Water City project and learn about the approach of co-development through communities of practice. To my knowledge, this is a novel method of improving uptake and implementation of digital technologies in water utilities. Thank you for your feedback. It was a pleasure to receive your insights, and we feel really fortunate to have benefited from your detailed comments and suggestions. Your observations have been important in refining our work, and we truly value the time and effort you dedicated to providing all this feedback. Comments Resolution There are two core ideas presented within the paper. The first is on digital water -- the development of the COPs and the digital water innovations (e.g., Berliner Wasserbetriebe is interested in AR). The second is the learning during the COP process. The first four paragraphs of the introduction made me think that the intention of the whole paper was to discuss digital water. But, as the paper evolves, it seems digital water is almost ancillary to the questions and instead the paper is really about learning. Please revise the introduction to better frame the main argument. Thank you for your comment. We have added the following sentence to the introduction to better frame the main argument: "This paper explores the learning processes of co-creation facilitated through the Communities of Practice (CoP) framework within the DWC project that developed and applied digital water innovations, emphasizing collaboration, mutual exchange, and adaptive practices." , to ensure a clearer alignment between the paper's focus and its presentation in the introduction. The methods section must be revised, removing all results and enhancing the discussion of the survey: Even if the focus is on learning, there needs to be more background information on the development and engagement of the COPs. Why were these five cities chosen? How were the key stakeholders identified? Exactly how were the COPs established? What is the make-up of the COPs (the number of the people and roles would be helpful)? Thank you for this suggestion; the methods section has been entirely revised. To answer the questions: The five cities were established during the proposal and application process for the EU-funded call as part of the consortium agreement.The key stakeholders interviewed were project leaders and actors involved throughout the project, chosen for their overview of the project, having a complete experience on the project and its inter-scale CoPs. The constitution of the CoPs, as well as the details of their establishment, are fully documented in project reports publicly accessible. These reports include all meetings, key conclusions, pictures from events, relevant materials, providing detailed insight into the whole process of each activity and COPs. The numbered lists on pages 7 and 10 should be moved to the Outcomes section. It has been moved. The "Reflecting on the process of co-creation" sub-heading is confusing. This seems like the core method for answering the research questions, but it is buried. Expand on the survey. E.g., how many people was it was distributed to? When? How were the data analyzed? Thanks for this comment. The methods section has been entirely revised, and the questions answered. The title of sub-heading has been changed. As a whole, the outcomes section has strong ideas. A challenge, however, is that many of the results are presented by city. Because there is very little discussion of the context of the different cities, it is difficult to understand the

value of interpreting the results by city. Please clarify. Thank you for this feedback. We also totally agree that the context of each city plays a crucial role. The introduction of the paper aimed to provide a general context for the project and its associated challenges, and explain the rationale behind the project, the methodology. Additionally, the case studies were intended to highlight the context of the CoPs, and some contextual factors are presented. However, the specific context of each city (including political, socio-cultural, and other local factors) was not deeply explored in this paper. We agree that this is an important point, as such factors can significantly affect how co-creation processes are facilitated and the extent to which they succeed or not. The main focus of this article was more on reflecting the value of co-creation within the CoPs, and maybe further exploration of these contextual influences could form the basis for a separate, more focused discussion in future work. In the discussion or conclusion, please reflect on the specific value of co-creation and COPs for digital water. Thanks, it has been added. In addition, following are some specific comments:
p3. The argument presented in the first paragraph could be edited to be shorter and more streamlined. Agriculture is given almost equal weight to cities, which makes it seem like the paper will be about both agriculture and urban areas. Thank you for your comment. Some adjustments have been made to improve clarity. We have kept agriculture as an important focus, as one of the case studies directly engaged with farmers and used Communities of Practice (CoPs) to foster collaboration (deployment of a reused wastewater network for agricultural irrigation, addressing both sanitary concerns and water quality, and the innovations created were key to facilitating collaboration and supporting the goals). p3. Eliminating the word “they” will help the text read more smoothly. For example, “They aim to improve health protection…” is more correctly said, “These investments aim to improve heath protection…”. “They” is also used in an uncommon way in the abstract. It has been changed. p3. Include a couple sentences explaining why or how digital technologies can help address the issues explained above. The rest of the paragraph addresses shortcomings of digital technologies. Why should digital water technologies be pursued? Thanks, a sentence has been added clarifying this point. p3. Is there a citation for “Promising solutions often do not reach real applications due to the lack of social and technical preparation, and a mismatch with expectations and needs of end-users”? It reflects more in this case common challenges faced in the DWC project and similar projects and initiatives, where the gap between technological development and real-world application often arises, also supported by observations from the project and literature on user engagement. p3. It is good that research questions are clearly stated. There needs to be more background information to understand the questions, however. Define “multi-scale” (what scales?) and “multi-actor” (what actors?). Define what is meant by a “co-creation process”. Is there another way to word question 1? Thank you for the comment. The "multi-scale" aspect refers to the involvement of different levels of Communities of Practice (CoPs) within the DWC project (including Local CoPs (Level 1): These CoPs operate at the city level, focusing on the specific contexts and challenges of cities. They aim to foster long-term collaboration, knowledge exchange, and trust-building among local actors, ensuring the relevance of digital water solutions by integrating user feedback and adapting solutions to the unique needs of each city. A Project CoP (Level 2): This level facilitates knowledge exchange between cities involved in the DWC project, allowing them to learn from each other's experiences and share insights on the adoption of new solutions. It also promotes cross-fertilization with technical partners, addressing topics like cybersecurity, interoperability,

and digital governance. And then a Trans-project CoP (Level 3): At this level, the focus is on networking and collaboration with other related projects, such as DigitalWater2020, to explore synergies and share knowledge on broader topics like data models, sensors, and market integration). Regarding the "multi-actor," this refers to the diverse range of stakeholders involved in these CoPs, including public and private entities, research organizations, technical partners, end-users, and their contribution to the development and implementation of the solutions. p4. The paragraph beginning “The concept has been used…” and the following paragraph seem tangential. Is there a way to relate both more clearly to the research questions? If not, consider considerably shortening the whole section “The concept of value cocreation” and moving this into the introduction before the research questions. Covering this material in the introduction will elevate the concept of co-creation, which is central to the paper’s objectives, and will help orient the reader to what is meant by “co-creation process” before the research questions use this term. Thanks for the suggestion; A sentence has been added to the introduction to highlight the role of value co-creation in addressing complex challenges, to make more clear with the paper’s objectives and providing context for the research questions. p6-7. How many people are involved in each COP? Can you give more description of the individuals? Thank you for your comment. The composition and size of each Community of Practice (CoP) are described in the project public reports, with detailed information on participants, roles and contributions (in general, the CoPs involved a range of stakeholders, including public and private entities, project leaders, researchers, communities, key local actors etc.). We can not provide the exact number of people involved in each CoP (there are direct role and indirect role), but numbers of participants to each event organized within the COPs process and can be found in the documented reports of the project, which include meeting summaries, key conclusions, images of events, ensuring that the CoP process and its outcomes are thoroughly documented and transparent. p7. The research questions do not need to be repeated here. Also, it is unnecessary to broadly justify the utility of a mixed methods approach. Instead, it may be useful to include a brief sentence in the introduction that the study uses a mixed methods approach and implements a survey. Thank you for the comment. We have opted to keep the research questions in this section to provide a sort of introduction to the subsequent sections. We have incorporated a brief sentence in the introduction to introduce the mixed methods approach and the survey early in the text. p7. What is a “World Café exercise”? A World Café exercise is a structured method for facilitating large group dialogue, aimed at fostering collaborative discussions, sharing knowledge, and generating actionable ideas, en general it involves multiple rounds of small-group discussions on a shared topic of interest or subject, allowing ideas from all participants (individually) to converge into a collective understanding or message, it also leverages group intelligence to enhance creativity and insight (https://mspguide.org/2022/03/18/world-cafe/) p7. The material under “Based on the discussions, a number of common points were identified…” seems to be a result, rather than a method. It would be clearer to move this from the methods section. Thanks, we moved it to the other section. Table 7. Consider rotating the table to portrait – landscape is a little more difficult to read on a screen and it seems like the table could easily be made portrait.

It has been rotated. Reviewer 3 General comment The paper presents interesting insights from the Digital Water City project. This entails the presentation of five case studies in different European cities, namely Berlin, Paris, Milan, Copenhagen and Sofia. In these

cities, so-called Communities of Practice were established to connect a variety of local stakeholders, like end-users, municipalities, tech companies, authorities, etc. The methodology being followed is based on the notion of co-creation, implemented through a variety of different exchange formats. The authors subsequently present the details of how the co-creation process in the Communities of Practice of the five case studies has been established and raise some reflective thoughts as well as achievements and derive recommendations. Beside the very relevant and interesting content of the paper, the presentation shows some shortcomings, technical flaws and inconsistencies. The paper needs a structural and linguistic revision. In relation to this, please refer to these general comments: Please thoroughly go through the paper again and look for grammatical errors. Especially the omission of articles and prepositions is a prevalent mistake which influences the flow of reading. In addition, there are a lot of convoluted sentences with syntactical errors that should be restructured and can often be simplified. Examples of this are provided below in the minor comments section. Thank you for your feedback, time and effort. We appreciate all your comments on the structure, details, presentation, content of the paper. We will carefully review the paper to address all these aspects, grammatical errors, missing articles and prepositions, and sentence clarity. We also worked on restructuring sentences to improve the readability and ensure a improved version of the text.

Comments Resolution The structure of the paper makes it hard to follow the train of thought throughout. The Methodology section should be restructured to present specifically, what data is collected, how it is synthesized and how it will serve in answering the three leading questions. With this clear structure established, the outcomes should follow the exact same structure in presenting the data gathered through this process. Subsequently, the discussion reflects upon the contents and findings and answers the leading questions. These three very distinct parts of the paper are currently scattered across these sections and are not well distinguishable. Thank you for your comment. The methodology section has been revised to provide a clearer structure and demonstrate how the data collected aligns with the three leading research questions. The five cities were chosen as pilot sites during the proposal stage of the EU-funded project, representing diverse urban and water management challenges. The survey and interviews targeted project leaders and key stakeholders with a comprehensive overview of the co-creation process. Documentation, including meeting minutes, event reports, and recorded outputs, provides detailed insights into the CoPs' establishment and operations. This revised structure explicitly connects data collection methods to the research questions and ensures that the outcomes and discussion sections follow a consistent framework for clarity. The results of the case studies, surveys, interviews and workshops on the different levels of the project are very intertwined, and, therefore, it is often hard to trace in the outcomes where a specific finding originates. As one example, regarding end-user needs in the Paris case study (p.18), the information seems to mainly come from the focus groups that were used, and not from the general meetings on the CoP level as is the case for the other case studies in this section. Therefore, the source of information seems quite different and is not obvious. Thank you for your comment. We have revised the text to improve clarification on the different events and participatory activities mentionned.

Throughout the outcomes section, there are a lot of very short quotes, presumably from the survey and the interviews. The way these quotes are integrated is rather unconventional, as direct quotes are usually used for important key statements, in contrast to short notions like “took time to set up”, “more results” or “prioritizing”. Please revisit the quotes in this section and evaluate them for necessity. Thank you for your feedback. The outcomes section has been revisted and quotes evaluated for its relevance and necessity.

The three originally formulated leading questions are never explicitly answered or revisited in the outcomes and discussion. These leading questions could serve as a guiding structure in the composition of the outcomes and discussion which would make it a lot easier to grasp the many findings that are presented. Thank you for the comment. A sentence has been added to clarify how the three research questions are addressed in the discussion section.

The resolution of all figures should be amplified. Thanks we tried to improve this. It should be distinguished which (digital) solution was an outcome of the project and the CoPs work itself, and which were pre-existing and have been leveraged or enhanced in this project. As of now, it is not entirely clear, what can be attributed to the DWC project. Thanks for the comment, we tried to make it clear in the case studies.

Furthermore, here are some detailed, minor comments:
p.1: “CoPs” is used in the abstract but has not been established as an abbreviation yet. Please spell this out in full. It has been changed.

p.3: The footnote on the headline of the introduction is bad form. Integrate this information in the text itself. It has been integrated.

p.3: “Concern [in] the water sector is all the more […]” – “in” instead of “around”. Thank you, it has been changed.

p.3: “They aim to improve health protection, […]” -> Specify what/who ‘they’ is. It has been modified.

p.3: The third paragraph presents “Sector-specific challenges”. These could be better presented in a list or enumeration environment to make it more palpable for the reader. It has been presented in a list.

p.3: “[…] EU Member States, addressing slow innovation rate as well as low awareness […]” -> Either “[the] slow innovation rate” or “slow innovation rate[s]” Thank you, it has been changed.

p.3: There are quite some repetitions of the same statements very close to each other, just slightly rephrased, e.g.:
"Too little or too much water can have adverse effects on water quality" vs "Both scarcity and abundance of water can have detrimental effects on water quality, [...]"
"[...] as well as low awareness and engagement of users, [...]" vs "Finally, users' awareness and engagement are fundamental points [...]" Thank you for the comment.

p.3: In the final sentence on the third paragraph, the aforementioned "challenges" are now called "processes". This is semantically incoherent, please rephrase, e.g. like: "These challenges can be tackled/overcome by [...]" Thank you for the comment. It has been changed.

p.3: In the fourth paragraph the "water value chain" and its different levels are mentioned. Please (briefly) introduce this concept before referring to it and/or provide citations. It has been added.

p.4: "Civil society is [a] fundamental actor." Thanks, it has been changed.

p.5: In the caption of Figure 1, the placement of the citation in front of the actual text of the caption is very unintuitive and raises the question how it is related to the subsequent citations within the caption. Please revise. It has been changed.

p.5: "This can be in regard to a good understanding of the supply and sanitation services and their associated costs, and help highlight their perspectives, needs and point of views." – What is the 'their' related to – the supply and sanitation services, the civil society? Please clarify. Additionally, "perspectives" and "point of views" basically means the same thing. Thank you for your comment. To address the first point, "their" refers to the perspectives, needs, and points of view of civil society and we removed one of the terms to avoid repetition.

p.5: "In the case of DWC, collaboration was facilitated between different actors, such as academics, companies, public administration and end-users, [...]" - You can very well explicitly state that these actors were chosen based on the quadruple helix model to represent keys stakeholders; otherwise this statement and choice of actors seems decoupled from the previous explanation of the quadruple helix model. Thank you for the suggestion. We clarified that the actors involved were chosen based on the quadruple helix model to represent key stakeholders, aligning with the explanation of the model presented.

p.5: "As mentioned in the co-creation literature, [...]" – Please provide the citation needed for this specific mention. Thanks, the citation is presented in p4. In the mention p5, the reference has been added.

p.6: "[...] provide relevant solutions towards the digitization of urban water management in European cities." – This reads more like the appropriate keyword is 'digitalization'. Please differentiate and use the terms properly. Thank you for your comment. The term has been changed.

p.6: “They are built of public, academic and private stakeholders [...]” – What is ‘they’ referring to? Please spell this out. This is refering to CoPs. Thank you for pointing this out, it has been integrated.

p.6: “[...] solutions for water and sanitation infrastructure challenges.” – Please establish a unified wording for this specific application area of interest. Currently, version of the wording are: “water and sanitation infrastructure”, “supply and sanitation services”, “water sector”, “urban water management”, “water treatment and sanitation infrastructure”. A common choice would be to use the term “urban water management” and to establish a proper definition at the start what this term entails. Thank you for pointing this out. We have unified the terminology throughout the paper to consistently use the term "urban water management", and a definition has been added at the beginning to clarify what this term entails.

p.6: “Local CoPs (level 1), which have been operationalized in four European cities [...]” – Why only four, what about Sofia? Thank you for your comment. Sofia was not included in the operationalization of local CoPs (level 1) because co-creation did not occur there. As noted in Table 5, the goal in Sofia was primarily to raise awareness rather than establish a full CoP as defined in the project. The CoP definition emphasizes collaborative engagement among diverse actors to build trust, develop tailored digital solutions, and facilitate their local adoption through a dynamic learning process. Sofia’s activities, while important, did not align fully with this CoP definition and focused on awareness rather than co-development initiatives present in other cities.

p.6: Figure 2: In the text, the levels are also referred to as level 1, 2, and 3. Please add these indications in the figure as well. These indications have been added in the figure as well.

p.7: The third research question is shorter and differently phrased than in the introduction. Thank you for the comment. We have revised the phrasing of the third research question to ensure consistency with the questions presented in the introduction.

p.7: “[...] and a workshop mainly involving the pilot and city leaders.” – Please elaborate on the role of the “pilot and city leaders” and what those entail, as they are not mentioned up until this point. Thank you for your question; Pilot leaders are responsible for overseeing the development, testing, and implementation of solutions within their respective cities. City leaders represent the team or municipal authorities, aligning the solutions with urban policies, ensuring stakeholder engagement at the local level etc. Their collaboration is essential for integrating the solutions into the context of urban water management, described in the introduction. Further details about their roles and contributions are available in the publicly accessible project reports.

p.7: “DWC local COPs in action” – So far, the capitalization has always been ‘CoPs’ - please unify the abbreviation. We have standardized the capitalization of "CoPs" throughout the paper.

p.7: “[...] as shown in [...] Table 1, Table 2, Table 3, Table 4 and Table 5.” - Please introduce more of the contents and different sections of the tables, i.e., briefly introduce what

information they contain and how this relates to the project. Otherwise, these tables feel very decoupled from the rest of the paper. Also, the subsections in each table often seem to overlap conceptually and content-wise, so an elaboration on the intents of this structure might avoid confusion. Thank you for the comment. The tables correspond to the case studies explained in the text. They represent the development of local digital solutions in five European urban and peri-urban areas, collectively covering 30 million European citizens. Given the diverse contexts and key challenges across the participating cities, the Local CoPs (CoP level 1) were structured and organized differently throughout the project, as detailed in Tables 1 through 5; this format intended to illustrate how the CoPs tried to meet specific local needs and challenges.

p.7: “[...] participated in a World Café exercise [...]” - For any uninformed reader, please add a citation explaining the format of such a World Café exercise. A World Café exercise is a structured method for facilitating large group dialogue, aimed at fostering collaborative discussions, sharing knowledge, and generating actionable ideas, en general it involves multiple rounds of small-group discussions on a shared topic of interest or subject, allowing ideas from all participants (individually) to converge into a collective understanding or message, it also leverages group intelligence to enhance creativity and insight (https://mspguide.org/2022/03/18/world-cafe/)

p.8: Table 1: “Berliner Wasserbetriebe” vs. „Berlin Water Works“ – Unify naming. Thank you for your comment, the term has been unified.

p.8: Table 1: „KWB“ - Write this out in full. Thanks, we have revised Table 1 to write out "KWB" in full as "Kompetenzzentrum Wasser Berlin

p.8: Table 1: “The CoP worked through meetings and workshops [...] and through participatory workshops.” – ‘Workshops’ appears twice in this list. The two mentions of "workshops" refer to distinct activities: the first relates to meetings and workshops focused on brainstorming and exchange, while the second specifically addresses participatory workshops utilizing a structured participatory methodology.

p.8: Table 2: “SIAAP, INRAE” - Write these out in full. Thank you for the comment, the full terms are added. p.8: Table 2: “Expert” and “Public” vs. “expert” and “public” – Unify capitalization. Unified.

p.9: Table 3: “[...] sanitary concerns about water quality.” - As phrased, this is not a goal or an ambition but a concern or challenges. Please rephrase. Thank you for the comment. We have rephrased the sentence as follows: "Deployment of a reused wastewater network for agricultural irrigation in the Milan area, addressing challenges related to water quality and sanitation"

p.9: Table 3: “water reuse-carbon-energy-food-climate nexus” vs. “Water-Energy-Carbon-Climatic nexus” vs. “the link between water, energy, food and climate” – Please refer to the specific nexus of domains consistently. Thank you for the comment, we changed to the specific nexus of domains as "Water-Energy-Food-Climate nexus" in the table.

p.9: Table 4: “A third solution is a Decision Support System (DSS), […]” - This builds upon the aforementioned solution for flow forecasts I assume? Please mention if so or differentiate clearly if not. The DSS is distinct tool, focused more on optimizing the operations of the integrated sewer network and WWTP, using flow sensors and forecast data to optimize treatment capacity and flow allocation; the sewer flow forecast toolbox is dedicated to providing accurate flow predictions and support the integrated management of the sewer network and WWTP.

p.9: Table 4: “The Copenhagen case reunited a group of stakeholders […]” – Reunited - so there was a group/community pre-existing to the DWC project which was reunited for this project? Please elaborate on this. Yes, it refers to an existing operational group for integrated water management in greater Copenhagen, involving BIOFOS and other water utilities. This group was engaged and brought together regularly within the framework of the DWC project to share expectations and support product development. The CoP process leveraged their ongoing collaboration to enhance the co-creation efforts.

p.9: Table 4: “[…] the “Web platform for integrated sewer and wastewater treatment plant control”, which is also directly related to other two DWC solutions […]” – From the phrasing as is, this web platform is presented as something new that was not mentioned in the preceding ‘Digital water innovations supported’ section. Please integrate this properly in the table. The web platform SAMDUS is already mentioned in the "Digital water innovations supported" section of Table 4, its role and functionality are described, and connected to the other two DWC solutions (sewer flow forecast toolbox and DSS) as part of the approach for managing sewer networks and wastewater treatment plants, enabling data sharing and interoperability across the tools.

p.9: Table 4: “HOFOR” - First ever mention of HOFOR in the last section of the table. Please add information on how it relates to the DWC project, the local CoP and add it as a key stakeholder in the table, if appropriate. Thank you for the comment, it has been added.

p.10: Table 5: “The objective in Sofia was to create awareness in target audiences about the project objectives and progress.” – This refers to the overall DWC objectives and not the objectives of the local CoP I assume. Please state this clearly. Thank you for your comment. The objective in Sofia indeed refers to the objectives rather than the specific objectives of the local CoPs, as Sofia's focus differed from the other cities, and this is why it is not included earlier in the text when describing the four cities involved in the local CoPs (CoP level 1).

p.10: Table 5: “The solution developed was the low-cost temperature sensors for […], which is based on […] low-cost temperature sensors to estimate […]” – This reads as ‘low-cost temperature sensors’ are based on ‘low-cost temperature sensors’ - please rephrase. Thank you, the phrasing has been revised for clarity.

p.10: Table 5: The “key challenges” in the last section of the table, based on content and phrasing, read more like goals and ambitions. Pleas rephrase or restructure. Thank you for your feedback, we revised the text, highlighting objectives rather than goals.

p.10: “For some DSs, […]” – This abbreviation has not been used before up until this point, please write out in full. It has been changed.

p.10: First mention of the abbreviation “ICT”, please write out in full. Thanks it has been changed to Information and Communication Technology

p.11: Figure 3: “Utility” appears twice in the diagram. Additionally, the role of “City Contact” needs to be explained. Thank you for the comment, there was an error while uploading the image, it has now been updated. Regarding the term 'city contact', it refers to the local contacts from each city involved in the project, as outlined in the provided information.

p.18: “More generally on communities of practice, it was said that these mutual learning spaces offered new opportunities for cooperation with other stakeholders.” – This is a repetition of what’s already written in this paragraph. Thank you for pointing that out. We have revised the sentence to avoid repetition.

p.18: “[…] (for example some aspects were improved, and it is now possible to add new scenarios with few additional developments input).” – This is both too general (“aspects were improved”) and too detailed (“possible to add new scenarios”). Please provide context for the reader. We have revised the sentence.

p.18: “In terms of expected improvements, the utilities identified several specific attributes, such as scenarios calculation and evaluation, integrated graphs, an overview of different variables, etc.” – Here, some additional details would be interesting, e.g. integrated graphs of what data, what kind of scenarios and which variables. Thank you for your comment; we refer to all the reports for further details on these topics, as they capture the full context of the improvements identified by the utilities.

p.19: “DS provider” – As above, DS as an abbreviation has not been introduced. It has now been introduced.

p.19: “In Milan, the third DWC meeting of the CoP had an important focus on co-creation.” - Co-creation is described to be the focal point of the project and the meetings within the CoPs, so this raises the question, what the focus of the first two meetings was. Thank you for your comment. The first two DWC Milan meetings focused on different aspects of the project’s development. The first meeting, held in November 2020, introduced the various digital solutions and collected initial feedback from stakeholders regarding their relevance to the Milan context. The second meeting, in March 2021, provided updates on the progress of these solutions, including the development of an integrated wastewater management system, the Early Warning System, and digital tools for wastewater treatment plants. In contrast, the third meeting in December 2021 placed a stronger emphasis on co-creation, specifically around the serious game for communicating water reuse in agriculture.

p.19: “For the process, co-creation has been carried out, […]” – What process? The word "process" refers to the entire co-creation approach, encompassing the format, activities, actors involved in the CoP meetings. To clarify, this section describes how the overall co-creation approach, including the specific format and activities, was designed and

implemented to achieve the objectives of the project.

p.19: " "The intervention of 'practitioners' [..]" – This quote starts but never ends. Thank you, we revised it.

p.20: "[...] the process of co-creation "takes a lot of time". It "took time to set up" and the "co-creation process is quite time intensive"." - This is three times the exact same information, no need to insert these quotes. Thank you for your comment. We kept the citations in this text as they provide direct feedback from participants regarding the time-intensive nature of the co-creation process and the challenges faced, but we rephrased it.

p.20: Figure 4: There are again duplicate options. As noted above, "COP" is not consistently capitalized. This has been changed.

p.21: Figure 5: There are options in the legend that do not appear in the chart. Either somehow signify that they account for 0% or drop them. Further, the capitalization in the legend needs to be unified. The options in the legend that do not appear in the chart were not selected by any respondents, which is why they are not represented.

p.21: "[...] there were some cases where co-creation mostly occurred within companies, because [...] – instead, it occurred internally within these companies [...]" - Duplicate statement within the same sentence. Thank you, this has been modified.

p.21: "It could be recommended to add stakeholders and end-users' feedback once the solutions are fully implemented and operational for some time." – I very much disagree with this recommendation and do not think, the results of the project as presented support this conclusion. When a solution is already fully implemented, it is far too late to integrate stakeholders' and end-users' feedback. Thank you for your comment. We acknowledge that the recommendation was not redacted well and clearly, and we appreciate your feedback, which helps to improve and avoid misunderstandings. The intention was, of course, to emphasize the importance of including stakeholders and end-users feedback at all stages of development. The recommendation also sought to highlight the value of continuing this involvement after the solutions have been operational for some time, to allow for evaluation and adjustments based on real-world use and long-term usage.

Competing Interests: No competing interests were disclosed.

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It was a pleasure to read about the Digital Water City project and learn about the approach of co-development through communities of practice. To my knowledge, this is a novel method of improving uptake and implementation of digital technologies in water utilities.
The following revisions will strengthen the paper:

1. There are two core ideas presented within the paper. The first is on digital water -- the development of the COPs and the digital water innovations (e.g., Berliner Wasserbetriebe is interested in AR). The second is the learning during the COP process. The first four paragraphs of the introduction made me think that the intention of the whole paper was to discuss digital water. But, as the paper evolves, it seems digital water is almost ancillary to the questions and instead the paper is really about learning. Please revise the introduction to better frame the main argument.
2. The methods section must be revised, removing all results and enhancing the discussion of the survey:
    - Even if the focus is on learning, there needs to be more background information on the development and engagement of the COPs. Why were these five cities chosen? How were the key stakeholders identified? Exactly how were the COPs established? What is the make-up of the COPs (the number of the people and roles would be helpful)?
    - The numbered lists on pages 7 and 10 should be moved to the Outcomes section.
    - The “Reflecting on the process of co-creation” sub-heading is confusing. This seems like the core method for answering the research questions, but it is buried. Expand on the survey. E.g., how many people was it was distributed to? When? How were the data analyzed?
3. As a whole, the outcomes section has strong ideas. A challenge, however, is that many of the results are presented by city. Because there is very little discussion of the context of the different cities, it is difficult to understand the value of interpreting the results by city. Please clarify.
4. In the discussion or conclusion, please reflect on the specific value of co-creation and COPs for digital water.

In addition, following are some specific comments:
p3. The argument presented in the first paragraph could be edited to be shorter and more streamlined. Agriculture is given almost equal weight to cities, which makes it seem like the paper will be about both agriculture and urban areas.
p3. Eliminating the word “they” will help the text read more smoothly. For example, “They aim to improve health protection…” is more correctly said, “These investments aim to improve heath protection…”. “They” is also used in an uncommon way in the abstract.
p3. Include a couple sentences explaining why or how digital technologies can help address the issues explained above. The rest of the paragraph addresses shortcomings of digital technologies. Why should digital water technologies be pursued?
p3. Is there a citation for “Promising solutions often do not reach real applications due to the lack of social and technical preparation, and a mismatch with expectations and needs of end-users”?
p3. It is good that research questions are clearly stated. There needs to be more background

information to understand the questions, however. Define “multi-scale” (what scales?) and “multi-actor” (what actors?). Define what is meant by a “co-creation process”. Is there another way to word question 1?
p4. The paragraph beginning “The concept has been used…” and the following paragraph seem tangential. Is there a way to relate both more clearly to the research questions? If not, consider considerably shortening the whole section “The concept of value cocreation” and moving this into the introduction before the research questions. Covering this material in the introduction will elevate the concept of co-creation, which is central to the paper’s objectives, and will help orient the reader to what is meant by “co-creation process” before the research questions use this term.
p6-7. How many people are involved in each COP? Can you give more description of the individuals?
p7. The research questions do not need to be repeated here. Also, it is unnecessary to broadly justify the utility of a mixed methods approach. Instead, it may be useful to include a brief sentence in the introduction that the study uses a mixed methods approach and implements a survey.
p7. What is a “World Café exercise”?
p7. The material under “Based on the discussions, a number of common points were identified…” seems to be a result, rather than a method. It would be clearer to move this from the methods section.
Table 7. Consider rotating the table to portrait – landscape is a little more difficult to read on a screen and it seems like the table could easily be made portrait.

Is the work clearly and accurately presented and does it engage with the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
No

Are all the source data and materials underlying the results available?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Adapting urban water systems to climate change, including evaluating and co-developing digital water solutions.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have

significant reservations, as outlined above.

Reviewer Report 08 June 2024

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Your Report
Review of the paper
Insights from the co-creation process in communities of practice for urban water management
The paper presents a suitable concept tailored for case studies by adopting the quadruple helix approach for co-creation in the five DWC pilot cities to support the development and potential adoption of innovative digital water solutions. The concepts, including co-creation and communities of practice, are conceptualised and are highly relevant to the co-creation process. The research questions are well-designed and presented in the introduction. Therefore, the paper is well organised and conducted, conceptually guided empirical work. However, some minor revisions are strongly suggested:

- Although the objective is mentioned in the abstract, "*The article analyzes the ways in which they have been used and applied in DWC as well as the ways in which the project has managed to articulate them at different levels*", please add it in the introduction before the questions.
- What about Sofia*? Local CoPs (level 1), which have been operationalized in four European cities (i.e. Berlin, Copenhagen, Milan and Paris), mainly focus on the solutions within their local contexts* (page 6). Is Sofia representing another level?
- Please mention how many stakeholders, or respondents are included in the study, in the text.
- Please name table 7 in a complete way, Detailed results of the survey of what and where etc,.
- Please revise the text of Table 7:
- the answer to the first question: The information is confusing. The answers section of question 1, says "*Local level*", does it say "Yes, Local level"? If so, please, use a unique way of presenting the answers.
- are the local level and the city level the same? If so, please, use a unique way of presenting the answers.

- *"Yes, in the city and between Paris and Berlin*", can it be called Project level regarding the definition "*Project CoP (level 2) provided a useful mechanism to facilitate knowledge exchange between DWC cities (mutual learning) and between DWC cities and technical partners*" (page 6)." *Not at local level, at project level*": please clarify this, can be interpreted in many ways, for instance, "Not at the local level, but at the project level", or "Not at the local and the project level". It assumed that the answer was "at the project level". If so, please revise the answers (page 12).

Please remove the reference from the conclusion section *"…into their value processes, as mentioned in the literature (Galvagno & Dalli, 2014)"*. Considering the authors already supported the including the subjective experience of customers, on page 4.

- Data, I assume that the blank cells in the Excel file mean no answers are available, is that correct?
- Finally, although the study includes five case studies, why the answers received are not case-based? Otherwise, it could have produced better results regarding the various goals and ambitions, innovations supported, and main challenges related to local digital water governance.

Is the work clearly and accurately presented and does it engage with the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

Are all the source data and materials underlying the results available?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: I am a researcher interested in policy and regulatory analysis, and the institutional arrangements for the water circular economy. I recently published an article about the institutional arrangement and water circular economy: https://doi.org/10.2166/wp.2023.155 In addition, I have had an excellent career opportunity as a researcher to work on a European project (Project Ô) focused on integrated water management and the circular economy in four pilots in four countries. Within it, I contributed to problem-solving co-creation processes. A pivotal aspect of the work was problem-solving co-creation process development that employed qualitative methods to address complex challenges (D3.4). Through this process, my colleagues and I facilitated collaborative efforts among diverse stakeholders, fostering innovative solutions that

bridged the gap between theory and practice.

We confirm that we have read this submission and believe that we have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however we have significant reservations, as outlined above.