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Knowledge Management for Smart Cities—Standardization and Replication as Policy Instruments to Foster the Implementation of Smart City Solutions

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Abstract: As cities tackle a variety of recent challenges, such as climate change or resilience against natural hazards, the concept of smart cities has increasingly moved into the spotlight to provide technological solutions as appropriate countermeasures. European policymakers chose the systematic funding of smart city initiatives to incentivize and accelerate innovation and sustainability transitions by disseminating knowledge, data, and information. As this undertaking is complex, there is a pressing need to involve and engage capable stakeholders to successfully implement and operate smart city projects. To ensure the diffusion and effectiveness of these initiatives, activities towards replication and standardization as knowledge management instruments have been applied in some of these research projects. However, there is a knowledge gap on how standardization can be combined with replication efforts. As one possible answer, the lighthouse project Smarter Together has actively integrated standardization in its replication activities, resulting in the development of the CEN Workshop Agreement 17381 for describing and assessing smart city solutions. The analysis of these activities resulted in the development of 11 assumptions, which show the role of standardization as a knowledge carrier for replication activities and as a facilitator for stakeholder engagement. These findings reinforce the chosen and future policy decisions.

Keywords: smart city; standardization; replication; knowledge management; diffusion of innovation

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1. Introduction

Facing the global challenge of climate change, cities are pressured to act. Cities severely suffer from the consequences of changing climatic conditions as they struggle to provide resilient infrastructure and services. Urban areas reinforce this development since they are responsible for 75 percent of global CO_2 emissions [1]. This situation calls for multiple entrepreneurial, political, and societal actions to foster transformative change through technological innovation and a progressive urban policy mix.

As one recent policy activity, the European Commission announced its mission of leading 100 European cities to systemic transformation and climate neutrality by 2030 [2]. This measure is the logical consequence of a funding and innovation policy framework that has been present for a decade in the form of the European Innovation Partnership for Smart Cities and Communities (EIP-SCC), providing a strategic and financing framework for structural change at the regional and local level [3].

The EIP-SCC and related programs shaped the "European perspective" on smart cities, perceiving smart city concepts as an effective measure for achieving climate neutrality in urban areas where technological solutions from the ICT industry can result in relevant emission reductions. In this understanding, the development and dissemination of smart

cities directly relate to urban sustainability and the sustainable transformation of cities [4]. This is also reflected in the Sustainable Development Goals, particularly SDG 11, which targets sustainable cities and communities and highlights the importance of the topic for actors from science and practice.

In light of this policy landscape, local authorities are increasingly taking on the role of change agents in the development and delivery of sustainable urban solutions, with citizens at the center. From a pure technology- and corporate-driven approach, smart city initiatives have become an established building block in international urban development to tackle pressing challenges by providing information, increasing efficiency, and reducing the environmental impact of public operations [5].

Although smart city project implementation has increased, they lack a proper knowledge management (KM) approach to enhance dissemination and exploitation [6]. In this context, it is striking that little attention is paid to standardization activities, particularly when it comes to supporting replicating smart city initiatives. Standardization is the 'activity of establishing, with regard to actual or potential problems, provisions for common and repeated use, aimed at the achievement of the optimum degree of order in a given context' [7]. Standardization and replication are two crucial concepts that, in combination, are still unexplored in smart city research projects; thus, practical examples of implementation are lacking. However, the fact that the responsible ISO technical committee (TC) on Smart and Sustainable Cities declared replication as one of the five major priority areas already highlights the linkage of both approaches [8]. Moreover, this committee (ISO/TC 268) developed several standards to replicate smart city solutions, such as ISO 37106 'Guidance on establishing smart city operating models for sustainable communities' and ISO 37122 'Indicators for smart cities' [9]. However, most proposals for standards are driven by non-European organizations. The potential for applying these standards in European cities is limited due to different national interpretations and approaches. Assumptions that successful projects in one city can be easily transferred to other cities must be critically questioned. Standardization serves as a knowledge provider, a tool for knowledge creation and dissemination, and a way to engage stakeholders in the solution development process within a smart city project.

However, standardization is not suitable for providing local and context-specific information for implementation and application in the context of replication. The aim must be to develop and describe solutions so that they can be used and, thus, replicated by other cities. The replication and implementation of smart city measures with the support of standardization can serve as a policy for local governments to align EU goals (SDGs) with their own locally defined urban development strategies [10]. It can, therefore, be established that the interplay between standardization and replication is becoming increasingly important.

This article aims to reflect critically on these interactions. It also raises key issues important in the standardization discourse, such as the contribution and potential benefits it offers to research projects. Thus, this paper addresses the research gap between urban development and standardization and assesses the impact of standardization activities to support smart city replication within research projects and to ensure stakeholder engagement. This encourages transdisciplinary engagement and adds value for stakeholders from diverse sectors, such as researchers, businesses, policymakers, and civilian actors.

In order to reflect on these issues, the EC-SCC-H2020 lighthouse project Smarter Together is considered in more detail, as standardization has already been actively integrated into the project's replication activities, and two standards have successfully been developed out of the project activities [11]. One of these standards, the CEN Workshop Agreement (CWA) 17381 'The Description and Assessment of Good Practices for Smart City Solutions', supports the transfer of smart city solutions by providing a framework for their description and assessment [12]. Therefore, one of the guiding questions will be what can be learned from the Smarter Together project to integrate standardization in replication efforts suc-

cessfully. This has implications for local and European policymakers, researchers, and technology and solution providers in the urban domain.

The paper is structured as follows: first, the relevance of standardization and replication for innovation and knowledge management in smart city projects is outlined. Further, the methodology of this research for revising the conducted standardization activities of the case study is explained. The obtained results are summarized and discussed in subsequent sections. The Section 6 provides the conclusion.

2. State of the Art

2.1. The Relevance of Knowledge Management for Smart Cities

Cities and urban areas have always been places considered to be highly innovative. Cities are seen as incubators for new technologies, products, and processes that can lead to far-reaching societal and economic progress [13–15]. This relationship has been widely researched from different perspectives, with regard to the spatial dynamics of innovation and the interaction of local actors in the innovation process [15,16], the beneficial effects of high urban density and size [17–19] and the local availability of creative talent [20,21]. Another feature of cities that foster innovation is that they represent centers of knowledge production and information hubs [6,22]. Since innovation can be described as the creation of knowledge and ideas to facilitate new outcomes [23], cities, with their people, capital, and ideas, provide an essential source for innovation [22].

KM at the city scale is an instrument to maintain and strengthen economic competitiveness and increase the quality of life. It represents one of the most important strategies for optimizing urban systems because the effectiveness of organizations is built on individual and collective knowledge [6]. From a governance perspective, KM provides support to adequately address human development needs by understanding the environmental impact of cities and applying suitable strategies for policy implementation, city planning, and construction [24]. In this context, cities and policymakers use emerging technologies and innovative concepts that can be defined as smart city initiatives [25]. Smart city initiatives represent urban innovations introduced to improve the efficiency and effectiveness of public administrative processes, foster collaboration between stakeholders, and improve the provision of information and services [25,26]. The development of these smart city initiatives benefits from knowledge production, which involves all four parts of the quadruple helix [27]. The quadruple helix describes the network and stakeholder interactions for the co-development of knowledge and innovation modes, comprising academia, government, industry and the public [28].

Smart cities result from knowledge-intensive and creative strategies aiming to enhance cities' socioeconomic, ecological, logistic, and competitive performance [29]. The term "smart city" has emerged over time and has become established over similar concepts such as "information city", "knowledge city" and "intelligent city" [30,31]. Although knowledge can be considered one of the essential infrastructure components of a smart city [32], there is a lack of strategies to incorporate KM in developing smart cities [6].

Against this backdrop, there is a particular need for research in the following two areas:

(1) Stakeholder management for replication: One research gap refers to stakeholders' interaction in upscaling a smart city initiative. Inadequate stakeholder management impairs further engagement and prevents the successful upscaling of a smart city initiative [33]. Smart city KM involves meeting the needs of all relevant stakeholders to ensure successful outcomes [6,34]. However, as van Winden and van den Buuse put it, participants in smart city initiatives tend to share their perspectives and ambitions without building mechanisms that facilitate replication and upscaling [33].
(2) Standardization for replication and upscaling: One of these missing mechanisms for replication and upscaling can be standardization since its resulting standards represent benchmarks for functional and technical performances that are lacking [35]. Standardization represents a form of knowledge sharing and can be seen as a knowledge-creating strategy [36]. As KM in smart city development is about making tacit knowl-

edge more explicit [37] and making users become information generators and holders [38], standardization can support the diffusion of smart city initiatives. A lack of standardization can even hinder the development of smart cities [39,40]. Nevertheless, standardization is hardly implemented in practice when developing new products and services [41].

KM can contribute to resolve current problems in smart city implementation and replication: There is a knowledge gap in understanding these up-scaling concepts between practitioners (city networks and urban actors) and academic research [42]. Regarding stakeholder management, the stages at which different partners should be involved in smart city projects remain unclear. It is also unclear how to manage tensions between partners and how to align incentives and conflicting goals and interests [43]. Standardization offers tools for participation and interdisciplinary consensus building. Therefore, the notions of smart city replication and standardization are discussed in the following. This sets the foundation to explore both concepts further and obtain standardization-led replication guidelines for their integration into smart city strategies and policies.

2.2. Standardization-Led Replication as Proposed Strategy to Drive Urban Change

The concept of smart city replication, defined as the translation to another location, refers broadly to an exchange between city stakeholders about relevant information, experiences, ideas, or technical solutions [44]. Replication research shows influences from urban studies, diffusion and innovation research, transition management, management studies, and knowledge management [45]. In a broader sense, replication describes how results from one pilot case are transported or "copied" to other geographic areas, albeit under possibly different boundary conditions [46]. It is assumed that cities, albeit different in many characteristics, deal with similar challenges and can exploit the knowledge about successfully implemented practices. Given the European path that assigns smart cities the role of a vehicle to achieve decarbonization, climate neutrality, and green energy transition, replication can be seen as facilitating policy instrument [47]. According to van Winden and van den Buuse, replication is part of the scaling process [33]. It is perceived as the consequence of the initial roll-out and successful solution expansion. The roll-out refers to the first application or introduction of a solution in a given setting, while the expansion describes its quantitative, functional, or geographic extension.

After the European Commission incorporated the idea of replication into their smart city initiatives and funding schemes, the concept of replication received wider attention. More precisely, the EIP-SCC referred to replication efforts to support knowledge sharing and standardization activities to ensure, for example, interoperability of the different smart city solutions and systems [48]. The declared lighthouse projects, funded under the Smart Cities and Communities call of the European Horizon 2020 Framework Programme (EC-SCC-H2020), were required to include replication strategies and activities in their project scope to support transferring their smart city initiatives. These replication-related actions contain network activities between cities, tutoring and following approaches, and stakeholder involvement strategies in replicating cities. Table 1 gives an overview of the different approaches and perceptions of replication in current and past SCC projects. The table is based on the work of Boulanger and Nagorny [49]; see "x" in Table 1. The analysis of the seven most established replication strategies and actions was chosen and updated based on the current knowledge and project activities (see "△" in Table 1).

The analysis shows a recent shift towards more stakeholder involvement and stronger ties between the lighthouse city, where the experimental setup is tested, and the replicating city (or follower city).

Table 1. Comparison of replication activities in SCC projects.

Replicability Strategies/Actions	Projects													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
S1: Development of a replicability framework or plan	x	x	x	x	x	x	△	△	△	△	△	△	△	△
S2: Actions aimed at activating stakeholders in follower cities	x	x					△	△	△		△		△	
S3: Deep involvement of citizens and/or local authorities	x	x					△	△	△			△	△	△
S4: Implementation of studies and diagnosis in follower cities	x	x					△				△	△		
S5: Definition of milestones, targets and objectives	x	x	x		x		△	△	△	△	△	△	△	△
S6: Focus on process replication instead of action replication		x								△				△
S7: Definition of a network of cities	x	x	x	x	x	x	x	△	△	△	△	△	△	△

(1) Triangulum, (2) Remourban, (3) Grow Smarter, (4) Replicate, (5) Sharing City, (6) SmartEnCity, (7) Smarter Together [50], (8) ATELIER [46], (9) SPARCS [51], (10) ALIGHT [52], (11) MAKING-CITY [50], (12) POCITYF [53,54], (13) Response [55], (14) +CityxChange [56].

An obvious option to strengthen stakeholder engagement and knowledge sharing would be to integrate standardization activities in the replication strategies of smart city research projects. The importance of standards and standardization for all stages of research has been shown in various areas [12,57]. In this regard, standards can be considered a means to provide the interoperability of project tools and a suitable channel to disseminate, exploit and market project results.

From a European smart city perspective, standards help cities work, enable incremental improvements, and trigger citywide transformations [58]. For this, standards need to be incorporated into corresponding frameworks and conceptual approaches, as has been conducted by Mourshed et al., Exner, and Lindner et al. [58–60].

However, while standardization, with its normative and participatory nature, receives at least a little attention in academia [61], it is almost completely neglected in European smart city research projects when it comes to replication. Mendes is one of the few exceptions, referring to experiences in the EIP-SCC project Smarter Together [62].

In Smarter Together, standardization activities were part of the replication work package Smarter Together [50]. The effort resulted in the development of two standards (CWAs), which were developed with the involvement of internal and external partners. Comparing these results to other projects from the Smart Cities and Communities call (SCC1) stresses the novelty of these outcomes, since there have not been any similar efforts that have led to a deliverable standardization, such as a CWA, in a Europe-wide project in this domain [63].

Reflecting on this whole context reveals a clear research gap. While public authorities and cities are looking for scalable and replicable initiatives, the possibilities of standardization are not being used for replication in municipal practice, nor are they being addressed in academia. This is surprising for two reasons: first, as shown, the fundamental relevance of standards and standardization in the smart city context is well recognized. Second, the standardization process offers opportunities for participatory knowledge generation and dissemination. Future replication efforts could benefit from these possibilities, especially since current approaches are increasingly criticized for their lack of outcomes [10,49,64,65].

Therefore, this study addresses the following research questions using the Smarter Together project as a case study: How can standardization support replication activities in smart city-related research projects? Furthermore, what role does the engagement of stakeholders play in these standardization and replication efforts?

3. Materials and Methods

The research approach in this paper is based on a multi-method approach, which includes a preliminary case study review, interviews with selected stakeholders, and a Delphi survey to ensure a comprehensive qualitative research design. The research team chose these methods because they proved to be the most suitable for getting in touch in the given time frame with the target group of this research, which were mainly direct contacts from the case study and other smart city projects and initiatives. Furthermore, the Delphi survey was a very suitable instrument, as it enabled participants to give clear feedback in a very simple way. This feedback could be further validated and specified through further involvement in the second round. Figure 1 shows the three steps of the research methodology, which are further explained afterward.

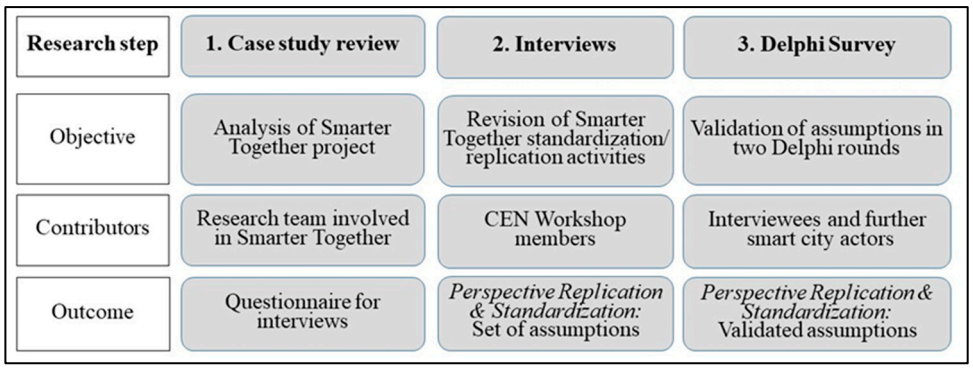

Figure 1. Research methodology.

The EIP-SCC stated that besides replication fostering a critical mass of customers for the smart city market, standardization of smart city solutions supports their implementation throughout Europe [48]. However, the comparison of replication activities in SCC projects shown above in Table 1 does not mention standardization explicitly. However, it shows a slight relationship between the standardization process and replicability strategies (e.g., replication/standardization plan, stakeholder engagement, integration of a variety of stakeholders, objective definition). Smarter Together was the only project that actively integrated standardization activities to support replication efforts.

3.1. About the Smarter Together Project

The cities of Vienna, Munich, and Lyon, as well as 30 partners from research and industry, received funding from the SCC1 call to implement smart city solutions in selected urban districts. The consortium included partners such as leading smart city providers, various Small- and Medium-sized Enterprises (SMEs), Real-Estate companies, municipal utility companies, research and standardization organizations, and the follower cities Santiago de Compostela, Sofia, and Venice. Between January 2016 and July 2021, these partners worked jointly on the project Smarter Together. The projects' main focus and implementation activities were data management, eco-refurbishment, renewable energies, e-mobility, and citizen participation. The corresponding demonstration activities and results were supported by accompanying measures to reflect on the implementation process by gathering data, evaluating financing and business models, and learning about possible replication strategies. The chosen project name, which emphasizes collaborative action and learning, was, thus, intended to represent the collective approach to engagement and progress among all partners. The concept of replication and the corresponding instruments for transferring knowledge, experience, and results were firmly embedded in the project structure [66].

One of the major issues of the project was to structure the variety of existing smart city solutions from other cities in a good practice collection. The information provided about the solutions was rarely consistent or comparable. Therefore, the project decided to develop

a Smarter Together Wiki to provide these good practices and establish a CEN Workshop that produces a CWA, which defines requirements to describe and assess good practices of smart city solutions. A CWA is a document published by the European Committee for Standardization (CEN), one of the officially recognized European Standardization Organizations, which aims to bring about consensual agreements based on open workshop deliberations with full direct representation of interested parties [67]. The CWA should support the decision making of city representatives and their advisors and provide a basis for companies to describe their smart city products and services in a standardized format [68]. A project plan for the workshop was published on the CEN/CENELEC website. The CEN workshop was attended by 14 representatives from 11 parties, including seven from the Smarter Together project, representing municipalities, research and industry. Four external partners (city, consumer organization, start-up consultancy and standardization body) also participated. After several physical and web meetings to conduct the CWA's content, a draft of the document was made available to the public. New impulses and other views from the end-user side of the envisaged standard were gathered that significantly enhanced the quality of the final document. The standard states that a description of a smart city solution should include key facts, such as a short description, solution environment, and background information, as well as its value proposition, target groups, required resources, activities and partners, financial information, and lessons learned from previous implementations. The assessment part shall include three components: information assessment, individual solution assessment, and replication assessment. The latter links the standardization content with the projects' approach of replicating smart city solutions and includes the analysis of internal and external requirements and the definition of indicators to assess the replicability of the solution described [12].

Finally, the CWA 17381 "Description and Assessment of Good Practices for Smart City Solutions" was approved by 12 CEN Workshop members, of which about one fifth were not project partners [69]. It was published in February 2019 and further promoted, among others, in European standardization committees for its potential uptake as a European standard [11]. The CWA 17381 helps to establish a common vocabulary and to make descriptions of smart city solutions more comparable and assessable [62] while also addressing the need for the standardization of smart city best practices [70].

3.2. Step 1: Case Study Review

The case study research was conducted to analyze the standardization and replication activities and their role within Smarter Together. This project was chosen as it is the only SCC1 smart city project that integrated active and formal standardization in the projects' replication efforts. Furthermore, the research team was directly involved in the project and, thus, approves the strengths of case study research [71].

Qualitative approaches, such as case study research, generally explore the meaning that individuals or groups attach to a social phenomenon or an existing problem [72]. The main activity in collecting initial empirical material in the present case study was to review the conducted standardization and replication activities of the Smarter Together project by the research team. Therefore, 10 Smarter Together deliverables that focus on replication and standardization were revised, with two being highly relevant for this research [11,50].

One of the main outcomes of the project-based standardization activities was the development of the CWA 17381, based on the Smarter Together Wiki. Therefore, the research team saw the need to interview the main CWA contributors to obtain their opinion on the standardization and replication activities within Smarter Together and their personal views on standardization and replication in general.

The corresponding questionnaire for the interviews was created based on the perspective the research team developed about the role of standardization in replication activities during their involvement in the Smarter Together project, but also supported by their participation in various smart city initiatives and the analysis of past and current SCC1 smart city projects (see Table 1).

In total, the following four thematic fields were identified during the assessment and used to set up the questionnaire for the interviews and the Delphi survey:

(1) The relevance of standardization and replication in smart city projects;
(2) The reflection on standardization activities with a specific focus on stakeholder involvement;
(3) The reflection on the developed standard;
(4) The promotion of standardization and replication activities.

3.3. Step 2: Interviews

In total, six interviews were conducted in April 2021, with 8 out of 12 municipal representatives, researchers, and consultants involved in developing the CWA 17381. The questionnaire was separated into the four building blocks mentioned above. The introduction referred to the general relevance of replication and standardization in smart city projects. The second part invited the interviewees to reflect on the CWA process with a particular focus on stakeholder involvement and the corresponding administrative procedure of the CWA. This was followed by a substantive discussion of the findings and the resulting CWA 17381 document. The fourth and final part addressed appropriate communication and promotion activities and channels for standardization and replication activities in general and for the CWA 17381.

The interview findings were further analyzed, and the research team derived several assumptions for each thematic field, which formed the foundation for the subsequent Delphi study. A total of eleven assumptions were made, of which the majority, five, came from the second thematic field related to the reflection of standardization and stakeholder involvement. In contrast, only one came from the third thematic field in which the developed CWA was reviewed. With three and two, the remaining assumptions came from the first and fourth thematic fields.

3.4. Step 3: Delphi Survey

Delphi is a method for structuring a group communication process. The process allows a group of individuals to address a complex problem as a whole [73]. In this study, the Delphi method was used to construct validity. The participants and further practitioners and experts validated previous results to provide clarity about the construct [74]. This was carried out through multi-stage repeated surveys.

In the existing literature, the Delphi method has already been used successfully within a standardization process to identify the different perceptions about smart cities [61], which confirms the chosen approach. The goal of the Delphi study was to further verify the assumptions drawn from the interviews within and beyond the scope and context of Smarter Together. Therefore, all interview partners were contacted for the Delphi study, but also further relevant smart city stakeholders with knowledge of replication and standardization activities were involved in data collection. In total, 46 potential participants were approached from May to July 2021. The Delphi study consisted of two rounds (R1 and R2). A total of 23 of the participants responded (equal to a response rate of 50%) and contributed to the first Delphi wave, while 20 participants in this group also contributed to the second round. The majority of the participants were representatives of cities (R1: 14; R2: 13), followed by researchers (R1: 5; R2: 4), businesses (R1: 3; R2: 2) and a standardization body. In terms of gender, the participants were relatively balanced. In both rounds, the participants had the option to agree, partly agree or disagree with the given statement. Furthermore, they could explain their response in a comment or add their thoughts to the respective assumption. Based on the results of each Delphi round, the research team enhanced the assumptions.

4. Results

This section provides an overview of the results from the Delphi study and shows the progress from the initially developed assumptions to validated assumptions. These are clustered according to the four thematic fields from the methodology section above.

4.1. Relevance of Standardization and Replication in Smart City Projects

The interviewees highlighted the importance of standardization and replication in smart city projects to, among others, bring relevant stakeholders together, exchange experiences and lessons learned, and compare solutions. Furthermore, they mentioned that the early consideration of both of the elements is crucial for their success. Developing standards within replication activities have been seen as beneficial to pursue common goals and harmonize project results among the different smart city projects, to reach a dedicated consensus, and build trust. Within the Delphi survey, the respondents mainly supported the initial assumptions. They suggested considering standardization and replication as knowledge-transfer tools to enable the comparability of projects and the application of solutions. Furthermore, it was mentioned that standards within replication activities should be used in specific city cases.

4.2. Reflection of Standardization Activities with a Specific Focus on Stakeholder Involvement

The interviews highlighted the importance of raising the awareness of standardization and the standards development process. In general, the involvement of, especially, the project's external stakeholders in the standards development was seen as very positive; it provided essential new impulses and views for the standard, and the open environment of the standardization process stimulated the exchange of information. However, the interviewees also stated that it was difficult to get the right stakeholders involved in the standards development and to get them on the same track if they joined at a later stage of the process, and that personal interests and resources slowed down the consensus-building process. The respondents of the Delphi survey suggested considering within the stakeholder involvement the relevance of not only a well-communicated but also a specified goal that is, additionally, aligned with the individual needs, assets, and skills of the participants. In addition, they stated the relevance of involving external project parties in the standards development to increase the (initial) user group of the standard.

4.3. Reflection of Developed Standard

The interviews concluded that standardization could be an appropriate tool to present and exploit project results like the above-mentioned Smarter Together Wiki of smart city best practices and consider the needs of cities and further relevant stakeholders. The CWA 17381 has been confirmed as a visible outcome of the Smarter Together project and is foreseen to be used in other smart city projects or related initiatives. Furthermore, as the CWA 17381 is a valuable outcome of the standardization process, which creates trust, promotional activities related to the provision of usage case descriptions are considered more legitimized. Within the two Delphi rounds, the initial assumptions were slightly adapted and, to some extent, described in more detail to increase understanding of them.

4.4. Promotion of Standardization and Replication Activities

The revision of the standardization and replication activities of Smarter Together was seen as very positive by the interviewees, as they had dedicated time to the reflection of their contribution to these activities. They promoted the standardization results to other smart city projects via different channels, showed the process of developing a standard to others, and suggested a possible uplift of the CWA 17381 as a CEN Technical Specification, confirmed and acknowledged by the respective smart city standardization committee at the European level. In addition, they suggested using city networks, overarching or umbrella organizations like the European Commission, and (scientific) articles, as well as social media and newsletters, as dissemination channels to increase the impact and visibility of

the achieved standardization and replication results. In the second round, the respondents of the Delphi survey mostly agreed with the assumptions in the first round. Thus, only minor additions, such as the consideration of networks of contributors, further smart city initiatives, and funding authority to support the promotion of the resulting standardization outcomes, were included.

Table 2 provides an overview of the progress of the 11 assumptions initially created based on the interviews and validated through the two Delphi rounds.

Table 2. Progress of the assumptions 1 to 11.

Assumption Topic	Initial Assumption	Validated Assumption
A1: General relevance of replication and standardization in smart city research projects	Integrating replication and standardization activities in research projects supports the value assessment of a given project. It promotes stakeholder exchange and enables the comparability of projects through a standardized description of solutions, methods and processes for practical use.	Integrating replication and standardization activities in (research) projects supports the value assessment and knowledge transfer of a given project and enables the comparability of projects through a jointly devised description of solutions, methods and processes for practical use.
A2: Change of perception (in relation to A1)	The perception and focus for replication and standardization in projects has changed over the last years, from: considering existing standards and a formal transfer of solutions, to supporting the development of new standards and a more informal learning approach about methods, funding models and experiences.	The perception and focus for replication in smart city projects has changed in recent years. There has been a shift from not only considering existing standards for the formal transfer of smart city solutions, to a more informal learning approach about methods, funding models, and experiences as well as the development of new standards, with the goal of knowledge transfer and application.
A3: Role of standards in smart city research projects	Developing standards for replication activities enables the comparability and dissemination of various pieces of information through a process that builds trust and consensus.	Developing standards for replication activities to be used in specific city cases enables comparability and supports the dissemination of various pieces of information through a process that builds trust and consensus.
A4: Standardization process in smart city research projects	To achieve stakeholder involvement and great(er) commitment, the standardization process within research projects should come with a flexible, adaptive and open workshop atmosphere, but should also follow a well-communicated goal that is clearly aligned with the interests and the culture of the participants.	To achieve stakeholder involvement and great(er) commitment, the standardization process within research projects should come with a flexible, adaptive and open workshop atmosphere, but should also follow a well-communicated clearly specified goal that is aligned with the interests, the needs, the assets, the skills and the culture of the participants (e.g., municipalities, other institutions and local stakeholders) and shall support future implementation.
A5: Stakeholder involvement within the standardization process	While the involvement of project external parties (organizations/individuals) provides new impulses in a standard development process and helps to verify and legitimize project results, it is also a constant challenge to involve third parties in existing project structures.	While the involvement of project external parties (organizations/individuals) provides new impulses in a standard development process, increases the (initial) user group of the standard and helps to verify and legitimize project results, it can present challenges to balance conflicting priorities and, thus, complicates the obtainment of external stakeholder commitment.

Table 2. *Cont.*

Assumption Topic	Initial Assumption	Validated Assumption
A6: Stakeholder involvement in standardization activities for replication	Stakeholder involvement in replication/standardization activities provides a valuable forum for exchange, in which participation can be partly biased by individual reservations resulting from conflicting political and personal interests, as well as time and financial constraints.	Stakeholder involvement in standardization activities within replication processes provides a valuable forum for exchange and discussion. However, the participation can be partly biased by individual reservations resulting from conflicting political and personal interests, as well as time and financial constraints.
A7: Standardization as replication process	The standardization process itself cannot be seen as a replication process, but can be seen as a starting point for replication or a means for dissemination.	The standardization process itself cannot be seen as a replication process, but can be seen as a starting point or as a building block to achieve better replication and dissemination.
A8: City needs and requirements for standardization and replication	The systematic identification of end-user (city) needs and associated individual requirements in the context of standardization and replication activities supports the translation of project results into tangible and applicable solutions for cities.	In the context of standardization and replication activities, the systematic identification of end-user (city) needs and associated individual requirements supports the translation of project results into tangible and applicable solutions for cities.
A9: Application of CWA 17381 standard on 'Good Practices'	The CWA 17381 on "Description and Assessment of Good Practices for Smart City solutions" is a standard that can be applied in (future) smart city projects, initiatives or technology developments to describe, compare and assess smart city solutions, but may also not be applicable to all cities and use cases due to the limited openness on how to describe a solution.	The CWA 17381 on "Description and Assessment of Good Practices for Smart City solutions" is a standard that can be applied in (future) smart city projects, initiatives or technology developments to describe, compare and assess smart city solutions, but further information and analysis will likely be needed where the standard does not anticipate specific circumstances.
A10: Promotion of standardization results	The CWA 17381 and possible other future standardization deliverables from research projects should be actively promoted by its contributors and their networks, which support reflecting the work conducted in the project, and legitimize their own activities when applying the standard. For this, possible strategies as well as suitable means of communication should already be developed in the standardization process.	The CWA 17381 and possible other future standardization deliverables from research projects should be actively promoted by its contributors, which support reflecting the work conducted in the project, and legitimize their own activities when applying the standard. For this, possible strategies as well as suitable means of communication should already be developed in the standardization process. Also, the contributors' and other networks as well as the funding authority should be considered for support.
A11: Dissemination channels for outcomes of replication and standardization activities	Replication and standardization results such as the CWA 17381 should be communicated to relevant stakeholders, such as overarching organizations and authorities (e.g., research institutions or the European Commission), through different channels (e.g., social media, scientific articles) to achieve dissemination beyond the duration as well as of the financial scope of a project.	Replication and standardization results such as the CWA 17381 should be communicated to relevant stakeholders, such as overarching organizations, networks and authorities (e.g., research institutions, EIP-SCC, the European Commission), through different channels (e.g., social media, scientific articles) to achieve dissemination beyond the duration as well as of the financial scope of a project.

4.5. Analysis of Answers from Delphi Rounds

The two Delphi rounds provided sufficient data for a comprehensive analysis, with 23 and 20 participants and 82 and 39 comments, respectively. This range of participants corresponded to existing surveys carried out in Delphi studies [75]. The percentage of approval for the assumptions (participants voting "yes") rose almost entirely in the second Delphi round, being in the region between 85% and 100%. Only assumption 8 (city needs and requirements) received a slightly lower confirmation rate (75%) and was the least-confirmed one in Delphi round 2. In total, a total of 40 people changed their minds to "yes". The average approval rate of the assumptions was approximately 74% in round 1. In the second round, 90% acceptance could be reached. Considering that the level of agreement for obtaining a consensus in previous Delphi studies was at least 70% [76], the two Delphi rounds can be seen as appropriate to obtain enough feedback from the participants. This was evidenced by the reduced number of comments received (see "#C" in Table 3) between the two Delphi rounds. Table 3 provides the detailed results of the two Delphi rounds.

Table 3. Analysis of Delphi Survey.

Assumption Topic	Delphi Round 1				Delphi Round 2				Change of Mind		
	Yes	Partly	No	#C	Yes	Partly	No	#C	Yes	Partly	No
A1: General relevance of replication and standardization	18 78%	5 22%	0 0%	8	17 85%	3 15%	0 0%	5	+1	+1	0
A2: Change of perception	17 74%	5 22%	1 4%	10	18 90%	1 5%	1 5%	4	+5	+1	+1
A3: Role of standards	17 74%	6 26%	0 0%	7	17 85%	3 15%	0 0%	5	+4	+2	0
A4: Standardization process	17 74%	5 22%	1 4%	11	18 90%	2 10%	0 0%	3	+3	0	0
A5: Stakeholder involvement	15 65%	8 35%	0 0%	7	17 85%	3 15%	0 0%	7	+7	+3	0
A6: Participation in replication and standardization activities	13 56%	10 44%	0 0%	11	19 95%	0 0%	1 5%	3	+8	0	+1
A7: Standardization as replication process	19 83%	4 17%	0 0%	4	19 95%	1 5%	0 0%	1	+3	+1	0
A8: City needs and requirements	18 78%	5 22%	0 0%	3	15 75%	5 25%	0 0%	5	+2	+3	0
A9: Application of CWA 17381	12 52%	9 39%	2 9%	12	18 90%	2 10%	0 0%	4	+5	+1	0
A10: Promotion of standardization Results	20 87%	3 13%	0 0%	3	20 100%	0 0%	0 0%	1	+2	0	0
A11: Dissemination channels for replication and standardization results	21 91%	2 9%	0 0%	5	19 95%	1 5%	0 0%	1	0	0	0

5. Discussion

The research approach was developed to reflect the activities and findings related to the concept of standardization in smart city replication. Therefore, the validated assumptions resulting from the research provided insights to answer the research questions posed to explore the potential contribution of standardization in replicating smart city projects and the importance of stakeholder involvement. In reviewing the replication strategies and measures in past and current SCC projects (see Table 1) and by linking them to the validated assumptions from the Delphi study, several synergies between the concept of replication

and the standardization process became apparent, contributing to enhanced knowledge management for replication activities.

5.1. The Standardization Process as Internal and External Knowledge Broker for Replication

Standardization, with its participatory nature and process-based orientation towards collective consensus, serves as a knowledge carrier and exchange format for knowledge sharing (see A1 in Table 2). Considering this aspect, standardization could be firmly anchored in future replicability frameworks or plans. This is in line with the findings of Israilidis et al., who called for embedding learning practices in smart city structures to understand the diversity and complexity of urban innovation [6].

For successful replication, relevant implementation knowledge has to be passed on to local decision-makers and operating actors. So far, these exchange formats comprise on-site visits, knowledge banks, podcasts, presentations, online courses, reports, workshops, and webinars. However, as stated earlier, there is substantial skepticism about current approaches since the impact of these networking and exchange opportunities is estimated to be low in many cases [49,65,77]. Like these formats, the CWA development included (online) workshops that established normative understanding and stimulated mutual knowledge exchange following a semi-structured process [78]. From this point of view, the standardization process can complement the methodological replication portfolio. The results show that the process provides a valuable forum for exchange (A6). This forum is open to external parties from its initiation, which makes the standardization process a gateway for conveying and receiving knowledge within a smart city project. However, standard development cannot replace all replication efforts in a smart city project because, apart from knowledge, a lack of acceptance and insufficient implementation are major hurdles [79]. Nevertheless, standardization is recognized as a starting point or as a building block to achieve better replication and dissemination (A7). Further steps are necessary to adapt a standard to specific circumstances, which can be considered the replication environment (see A9).

5.2. Standardization as an Instrument for Knowledge and Stakeholder Management

Smart cities are built by stakeholders with contrasting levels of knowledge, power and interest, which complicates the successful implementation of smart city initiatives [80]. Valdez et al. identified information gaps that need to be resolved among involved parties [38]. However, to perform this, proper KM is required to meet the needs of all relevant stakeholders in the quadruple helix [6,34]. This challenge is also apparent in the present results, as participation can be partly biased by individual reservations resulting from conflicting political and personal interests, as well as time and financial constraints (A6). Sometimes, these conflicts and constraints are artificially created by the defined hierarchy in a project. Calzada describes the challenge of overcoming the harmful hierarchical logic of the EIP-SCC structure, which classifies cities as either lighthouse or follower cities [65]. Such classifications can fuel conflict and lead to low commitment. The way to address such potential sources of conflicts in a standardization process is formulated in A4, where a flexible, adaptive, and open workshop atmosphere is proposed, including a well communicated clearly specified goal that is aligned with the interests, the needs, the assets, the skills and the culture of the participants. In this context, Macrorie et al., who also see conflicts between stakeholders as the major underlying challenge, noted that there is no common neutral approach to the management and organization of smart cities [80].

Consequently, this also applies to standardization organizations that are neither completely free of ideology nor institutional interests. However, considering these challenging stakeholder constellations, the collaborative development of a normative solution and common standpoint as part of a standardization process may already be one of the best possible approaches, as approved in, for example, the topic of city resilience [59,78].

This is, at least, true if all relevant stakeholders are involved in such a process. A remarkable aspect of smart cities is that in many cases, it is not up to citizens to decide

which applications are used. Instead, in smart city projects municipal bodies often represent gatekeepers for the introduction of these applications [45,81]. This phenomenon can also be seen when looking at standardization. Standardization brings together executing, operating, supplying, and developing entities, and does not primarily involve citizens as users and adopters. As described in A8, replication and standardization share the commonality that the systematic identification of end-user needs and associated individual requirements support the translation of project results into tangible and applicable solutions for cities. Since smart city standardization lacks, especially in Europe, broad citizen participation, their needs must be anticipated by the contributing members. To address this properly and to ensure successful replication, civic initiatives and NGOs could be involved in the standardization process to represent an urban community in its diversity.

5.3. Standardization to Generate Communicable Knowledge and Results

According to A2, replication has, more recently, been achieved through an informal learning approach about methods, funding models, and experiences, as well as the development of new standards, with the goal of knowledge transfer and application. In this environment, the question is, what are the best knowledge carriers, channels, and tools to support replication? Indeed, having a formalized deliverable such as a CWA as a result of a standardization process makes it easier to communicate findings. The CWA 17381 serves as a proof of concept for this (see A9). Its content can be spread to relevant stakeholders such as overarching organizations, networks, and authorities, such as research institutions, the EIP-SCC, and the European Commission (see A11). The established format and structure help to mediate between different domains, industries, and types of institutions. However, empirical evidence shows that replication is more than formally conveying knowledge and experience. Much of what is considered replication happens off the beaten track.

The exchange between cities often takes place in a much less systematized way. It is based on personal contacts and relationships, and sometimes projects and activities arise from casual encounters and very pragmatic reasons rather than strategic planning. This aspect should not relativize the need for the formalization and systematization of replication approaches, but it should be considered. According to Boulanger and Nagorny, practitioners in cities and authorities tend to override established project structures and look for direct contact with colleagues from other cities [49]. Wathne and Haarstad describe this phenomenon under the term "randomness" and stress the significant role of the individual in replication success stories [10]. A10 shows a way to address this during standardization. The statement proposes that possible strategies as well as suitable means of communication should already be developed in the standardization process. Also, the contributors' and other networks, and the funding authority should be considered for support. In other words, standardization is about creating commitment and engagement during the process that goes beyond the process. Contributors willing to spread and adopt the result serve as testimonials supporting further replication and strengthening the legitimacy of the developed standard.

In summary, standardization in smart city replication enables comparability and supports the dissemination of various pieces of information through a process that builds trust and consensus (see A3). As discussed, some constraints complicate the introduction of related activities and limit the impact of the results. Nevertheless, to compare standardization, which is the "process of making things of the same type have the same basic features" [82], with the concept of replication, literally referred to as the "step of making or doing something again in the same way as before" [83], seems to be obvious. Still, due to a lack of empirical data, it has not been covered extensively so far.

Table 4 summarizes the differing characteristics of both approaches, transferred from the findings obtained while conducting this study. On an operational level, the findings show relevance and value for knowledge management in smart city and public sector projects. From a more strategic and governance perspective, the results have practical implications for innovation policy design.

Table 4. Differentiation between Smart City Replication and Standardization.

Typology Item	Smart City Replication	Standardization in SC Projects
Scope	Specific	Generic
Purpose	Aims for impact	Aims for compatibility
Knowledge transfer	Requires knowledge	Provides knowledge
Main driver	Mainly result-oriented	Mainly process-oriented
Application range	Application-focused	Open-to-application
Output	Aims for adoption	Aims for consensus

6. Conclusions

For local administrations to take effective action at the local level, the idea of replicating and transferring technologies, initiatives, and solutions from and to other cities seems tempting. However, in practice, it has proved to be a very complex undertaking. The advantages of the potential knowledge advantage and supposedly faster implementation can quickly be put into perspective in the face of numerous hurdles. Against this background, it seems surprising that the synergy potential of standardization activities in smart city replication has received very little attention in scientific discourse since both concepts share common ground, as they are both based on the idea of uniformity as a guiding principle [62]. The contributions of this study can be summarized as follows:

(1) This study addresses stakeholders' perceptions of standardization activities in smart city replication. The empirical results of this paper show opportunities and roles for standardization beyond the mere consideration and integration of (technical) standards in implementation projects.
(2) It describes how standardization can be used for stakeholder involvement and engagement to support smart city replication.
(3) Based on the CWA 17381, the study shows that the outcome of a standardization process is an appropriate medium to disseminate knowledge between research and innovation projects. In addition, it shows that standardization can be used to develop bottom-up strategies to spread replication results by putting contributors in the role of ambassadors and testimonials for urban change.

While in most cases, the recent literature lacks a discussion on international standards for smart cities [35], there is even less research on standardization in smart city development. The present article can fill this gap, showing how smart city replication can benefit from standardization.

The study results indicate that policymakers should add standardization activities to the requirement catalogue of their project tenders and funding schemes. Standardization can be understood as a formalized and methodical procedure of generating, structuring, and documenting knowledge to achieve results and progress. From the replication perspective, standards that have resulted from standardization processes within smart city projects can also represent significant outcomes, as they provide a more tangible and practical result than written reports and similar deliverables.

Concerning outcomes, Kitchin [84] wonders what governance mechanisms are created by smart city standards, since they could either reinforce technocratic, instrumental, and top-down structures but could also be a means to contribute to democratizing smart city approaches. To avoid these potentially negative impacts on citizens, standardization activities in smart city projects should take place in a transparent process and with the involvement of relevant and diverse stakeholders in order to be able to create transparency and acceptance. By doing so, two major components in smart city implementation can be addressed by standard development: ICT integration and stakeholder engagement [6]. From a research point of view, the institutionalized and established link between standardization and replication will create a broader empirical base that can also be used to answer the question of how cities become aware of standards and how they adopt them, as identified as a research need by Macrorie et al. [80].

Replication aims for change and progress. More precisely, it refers to changing and renewing a social (urban) system by replicating something for a new group of users in a new context [85]. Therefore, replication always represents innovation. Considering this, standardization can also be understood as an innovation policy instrument. Voluntary and normative standards such as the CWA discussed in the case study are considered soft instruments in innovation policy [86].

This is an important aspect of elaborating on further research needs. The ongoing discourse on replicating (European) smart cities is driven by skeptical and disappointed positions fed by unfulfilled expectations and a lack of results from the EIP-SCC projects. However, many of the instruments that have been introduced also have their justification beyond the EIP-SCC framework. Even if some of the replication efforts have fallen short, the transfer of technology, knowledge, and innovation between cities remains undoubtedly a meaningful and relevant goal for achieving economic prosperity and societal progress. For standardization and other approaches, this means further research is needed to provide suitable policy framework conditions and additional empirical data outside the scope of the EIP-SCC. Following Israilidis et al., this can contribute to resolving the lack of KM strategies in smart cities [6].

Furthermore, as standardization is increasingly mentioned in EU-funded calls beyond the topic of smart cities, the outcomes of this and further related research can also be applied to other topics. Further long-term research should also assess the impact of using standards in research to support knowledge gathering and standardization to create knowledge and foster innovation.

Undisputable, the research approach reflects only one case study in-depth, and the findings are limited to some extent. The conducted Delphi method outlined in this article represents a relatively streamlined approach with its two rounds of feedback. However, there was a significant increase in the participants' acceptance beyond the actual case study at the end of the second round, which led to a high level of acceptance and validity of the developed assumptions.

Lastly, let us take another look at the bigger picture. Cities represent major hubs for economic and entrepreneurial activity. They provide the infrastructural and creative requirements for growth and long-lasting transformative change in economic and social developments [13,15]. However, urban areas consume the most significant volumes of energy and emit the highest levels of greenhouse gas emissions [47]. This means that shaping suitable framework conditions and appropriate policies foster resource-efficient processes, climate-proof infrastructure, and incentives for investment opportunities. Standards help to provide these framework conditions. As White puts it, standards have contributed significantly to improving urban living conditions in the past, "and it is not so radical to suppose that they may continue to do so." [87].

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