smart cities

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Systematic Review

A Review on Key Innovation Challenges for Smart City Initiatives

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Abstract: Smart city initiatives are being promoted across the world to address major urban challenges, and they all share a common belief in the transformative power of digital technologies. However, the pace of innovation in smart cities seems to be much slower than the rapid and profoundly disruptive transformations brought about by digital innovation in many other domains. To develop new insights about the main causes behind this relatively modest success, this study provides a Systematic Literature Review (SLR) on the connection between major smart city challenges and the essential properties of digital innovation. The review involved the qualitative analysis of 44 research papers reporting on smart city innovation practices and outcomes. The results characterize five major challenge categories for smart city innovation: Strategic vision; Organizational Capabilities and Agility; Technology Domestication; Ecosystem Development; and Transboundary Innovation. This study also explores the connections between these challenges and concrete digital innovation practices in smart city initiatives. The main conclusion is that current innovation practices in smart cities are not properly aligned with what the research literature commonly describes as core properties of digital innovation and that this might be a major cause behind the limited progress in smart city initiatives.

Keywords: smart cities; digital innovation; digital transformation; urban innovation; smart city ecosystems; helix models; distributed innovation; urban platforms

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1. Introduction

Smart city initiatives are being promoted across the world to address the complexity of long-term problems of urban environments and improve the quality of life of their residents [1]. Cities are also under pressure to play their role in addressing global emerging challenges, such as Sustainability [2,3], Decarbonization [4], or Resilience [5]. Smart city initiatives encompass multiple fields of action, such as the development of more sustainable infrastructures, new mobility paradigms [6,7], smart urbanism [8], citizen participation [9,10], city governance [11], or sustainability [3,12,13]. These initiatives can be very diverse with regard to their objectives, innovation practices, core technologies, priorities, or the properties of the urban settings where they are deployed. Still, they all share a common belief in the transformative power of digital technologies and their ability to become the core enabler for a positive, progressive, and sustainable impact in urban life [14].

However, there are also signs of disappointment about the concrete impact of smart city initiatives [15,16], or even backlash against what is increasingly perceived as an excessive control of technology by corporations in urban settings [17]. Regardless of any general political views one may have about smart cities, it seems sensible to admit that, so far, the concrete results may be seen as somewhat limited in regard to the respective investments and the proclaimed expectations. More specifically, from a digital innovation perspective, it

seems clear that the innovation pace is much slower than what happened in other domains where key digital innovation properties, such as convergence and generativity, have led to rapid and strongly disruptive transformations [18].

1.1. Understanding Smart Cities and Their Challenges

Increasing scientific studies are exploring the diverse and multidisciplinary challenges associated with the smart city vision. The objective is to provide guidance on smart city strategies and to specify responsibilities at political, legal, corporate, and societal levels, as well as to define framework conditions. Based on a bibliometric study of smart city research, Mora et al. [16] identify five development paths for interpreting– what a smart city is. They also expose a deeply rooted division, which the authors claim is leaving some fundamental unanswered questions about how to proceed and should thus be a matter of concern for the whole field. Likewise, a study by Camero and Alba [1] analyses the citation graph in this research domain and concludes that most publications do not have citations or references to the rest of the works in the same field. According to the authors, this suggests a certain lack of maturity in this research field and the need for more convergence. The diversity of definitions, technologies, and methodologies used across smart city initiatives is also reported in the studies by Sanchez-Corcuera et al. [19] and Ismagilova et al. [20].

The relationship between the concepts of smart city and sustainability is addressed by Trindade et al. [21], who claim that the smart city, as a concept and set of practices, can effectively become an enabler of urban sustainability. Bibri and Krogstie [22] highlight the need for Information and Communication Technology (ICT) development and innovation to be linked with sustainable development, so that future investment can be justified by environmental concerns and socio–economic needs, rather than technical advancement and industrial competitiveness. Yigitcanlar et al. [3] claim that cities cannot become smart without actually being sustainable. They describe a tension between the common aspirations of smart cities and the goals of sustainable urban development. Bibri [23] highlights the opportunities for the application of big data analytics to address the goals of sustainable development, but suggests that researchers should focus more on identifying real-world challenges and concrete knowledge gaps. This connection between data science and urban sustainability is also addressed by Ramaswami et al. [12], who suggest that smart city initiatives must move beyond city-level data to a higher-order understanding of cities as transboundary systems with diverse actors, priorities, and solutions. A review by Ben Letaifa [24] proposes a methodological framework for the implementation of smart cities and suggests that macro, mezzo, and micro dimensions should be considered when coming up with strategies for smart cities.

Smart city governance is addressed in the review by Meijer and Bolívar [11]. The authors identify different conceptualizations of smart city governance which differ in the level of government transformation needed to make cities smarter, from simple institutional arrangements to more radical conceptualizations where the government itself needs to be transformed to create a smart city. The review by Guedes et al. [25] identifies 20 drivers for smart city innovation and their prioritization, 15 of which are mainly focused on the governance of cities while the remaining 5 are associated with technology.

1.2. Objectives

In this study, we explore a digital innovation lens to extend the understanding of the challenges faced by smart city initiatives. We build on the fundamental properties of digital technology, as proposed by Yoo et al. [18], to analyse if smart city initiatives are actually able to provide an environment of open and flexible affordances that leads to innovations characterized by convergence and generativity. The key motivation is to comprehend to what extent the main challenges associated with smart city initiatives may all be different manifestations of a common problem originating from misalignments between smart city innovation practices and the core concepts that made digital innovation so quickly successful in other domains. This broader goal can be instantiated as two research questions:

- *RQ1: What are the main challenges blocking current smart city initiatives from attaining the same scale of disruption as other areas of digital innovation?* This first research question should provide an explicit identification of the core challenges to be faced by any city aiming to explore the opportunities of digital innovation.
- *RQ2: What type of alternative innovation practices may help to unleash the real-world impact of digital innovation in smart city initiatives?* This second question should provide insights on novel innovation paradigms for smart cities that might be more suitable for fully exploring the key properties of digital innovation.

To gather the evidences needed to answer these questions, we reviewed the research literature on smart city innovation. While there are many literature reviews addressing smart city definitions, dimensions, and challenges, to the best of our knowledge, this is the first study that specifically takes a digital innovation perspective and aims to understand the relationship between smart city challenges and the core drivers of digital innovation. The answers to our two research questions should help smart city initiatives to become more effective at capturing the value of digital innovation, improve the return from smart city investments, and scale their ability to co-create value with citizens. This seems to be a very timely issue for the whole field of smart cities, which is under increasing pressure to deliver real value and show evidence of relevant progress.

2. Materials and Methods

This study is based on a Systematic Literature Review (SLR) on smart city innovation practices. There is already a significant body of research literature reporting on the successes and limitations of various types of innovation strategies applied across numerous smart city initiatives. A systematic literature review of those research results may help us to uncover core limitations associated with the prevalent innovation paradigms for smart cities and inform new innovation strategies that might be more effective at capturing the specific sources of value offered by digital innovation.

The review protocol follows the general guidelines proposed by Kitchenham and Charters [26], as well as the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) [27]. In the planning stage, a review protocol was created with the specifications of the study goals, the research questions, the bibliography sources, the search keywords, the set of inclusion and exclusion criteria, and the overall procedures. The formulation of the review protocol is centred on our two research questions, which shaped the selection of primary studies included in the review and the analytical approaches used to uncover evidences from those publications.

The eligibility criteria for this survey includes peer-reviewed research articles in the English language, published in the last 5 years, with the full text available online and reporting findings about the creation, operation, challenges, and outcomes of urban innovation ecosystems created as part of smart city initiatives. We excluded articles where the contribution was mainly about specific technologies, and not about the process of bringing technology into an urban context. We also excluded other sources, such as authored books, journal editorials, or industry reports.

To consider different terminologies used in smart city research, we developed two complementary search strings. The first query was centred around the keywords *innovation ecosystem* and the second was centred on a combination of the keyword *helix* with keywords *urban* or *city*. This *helix* keyword is often used in the literature to describe different stakeholder arrangements for smart city ecosystems. Both queries included the same five-year (2019–2023) time frame and used *smart cities* as an additional selection keyword. All these keywords were directed only to the title of the articles. The resulting search strings are represented in Table 1.

Table 1. Search string for the two scopus queries.

Query 1 "Innovation ecosystem": TITLE-ABS-KEY (innovation AND ecosystem) AND LANGUAGE (english) AND (LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019)) AND (LIMIT-TO (EXACTKEYWORD, "Smart City"))
Query 2 "helix": (TITLE-ABS-KEY (helix) AND (TITLE-ABS-KEY (city) OR TITLE-ABS-KEY (urban))) AND LANGUAGE (english) AND (LIMIT-TO (PUBYEAR, 2023) OR LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019)) AND (LIMIT-TO (EXACTKEYWORD, "Smart City"))

To support our selection of primary sources, we used Scopus. This comprehensive database of scholarly literature is recognized as suitable for a variety of tasks, from journal and literature selection or personal career tracking to large-scale bibliometric analyses and research evaluation practices [28]. It also largely overlaps with the other major bibliography indexing databases, including Web of Science (WoS) [29]. The complete source selection process is represented in Figure 1.

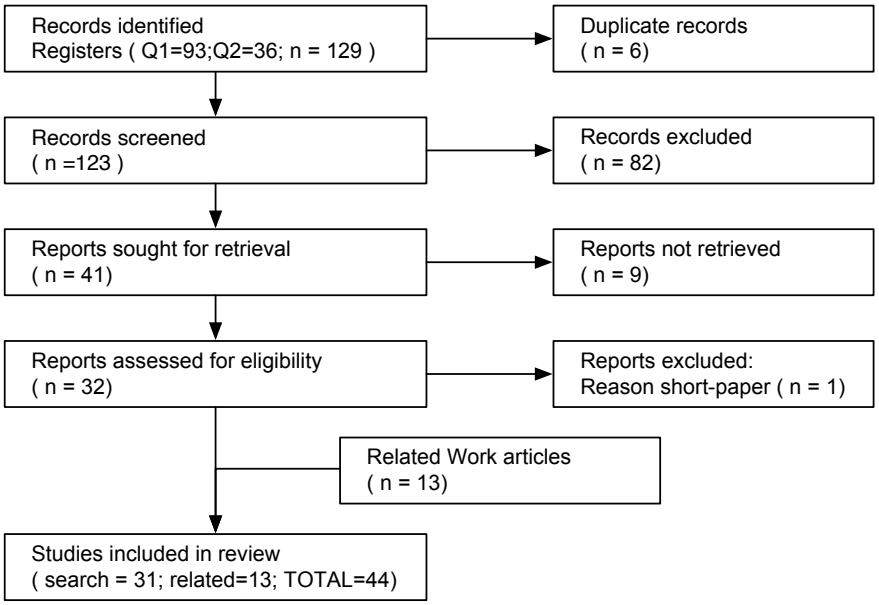

Figure 1. Data selection process.

The execution of the two search queries produced a set of 129 sources, which were reduced to 123 after checking for duplicates. The titles and the abstracts of these articles were then screened for a quick eligibility assessment. Only 41 articles matched our eligibility criteria. Most excluded articles were focused on specific smart city technologies and, therefore, did not directly address any of the innovation strategy issues in our research questions. We then proceed to obtain the full texts of those articles, resulting in a list of 32 articles that were read against the research aim. After the removal of one short article, we arrived to a selection of 31 articles. To provide additional context for the review, the references used as related works in Section 1.1, which describe previous reviews on smart city initiatives, were also integrated as sources for this study to be reviewed under the same criteria. With these additional articles, we arrived at a total of 44 articles to be reviewed as part of this study. The selected publications were then analyzed to produce evidence related with the research questions. The process followed a semi-structure coding process and was supported by a software tool for Qualitative Data Analysis.

3. Results

In this section, we address the first research question of our study about the key barriers that may be preventing smart cities from attaining the same level of fast-paced innovation as other domains of digital transformation. The results of the literature review uncovered a broad range of evidence about the diversity and breadth of those challenges. More specifically, the qualitative analysis of the 44 selected sources produced 696 coded segments referencing some type of challenge in the development of smart city initiatives. These codes were progressively arranged under multiple emerging themes which were subsequently aggregated under five top-level categories, as shown in Table 2.

Table 2. Top-level categories for smart city challenges.

Top-Level Categories for Challenges	Documents	Codes	Segments
1. Strategic vision	19	12	64
2. Organizational Capabilities and Agility	13	11	38
3. Technology Domestication	14	5	45
4. Ecosystem Development	31	60	424
5. Transboundary Innovation	19	18	125
Total		106	696

The names of these five challenge categories do not directly represent any particular challenge, but they were chosen because they seem to represent major thematic clusters for the set of challenges emerging from the survey. To some extent, these can also be seen as subsequent phases of a digital transition process. Even if these are not strictly sequential steps, they still correspond to different stages of smart city initiatives, which can help to frame the context of the respective challenges. The set of coded segments under each topic were then used to synthesize a qualitative overview of the challenges relating to that topic. A brief description of these top-level challenges and their key questions is represented in Figure 2.

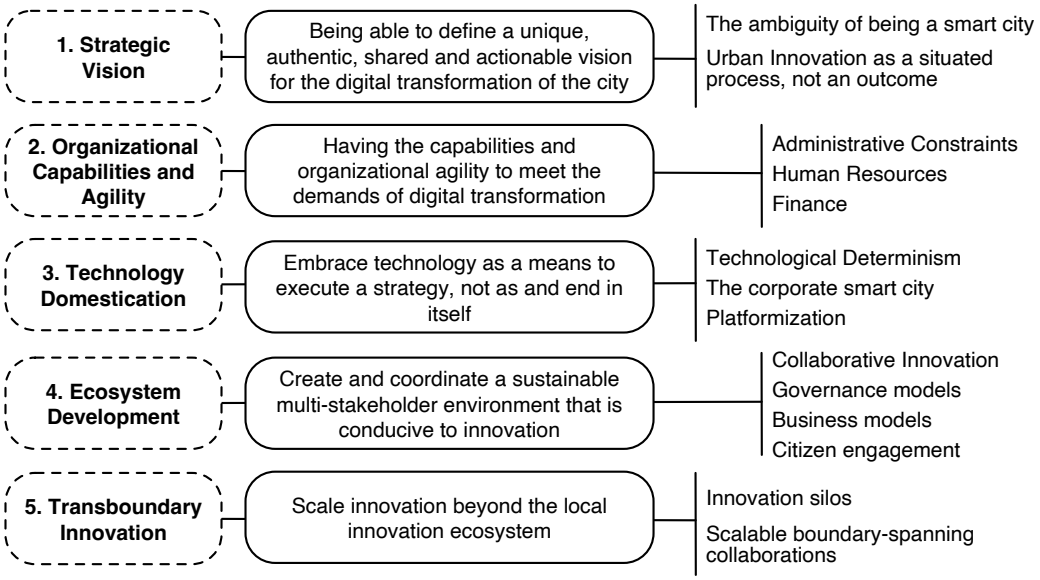

Figure 2. Key challenge categories for smart city initiatives.

The first two categories may be described as intrinsic to the transformation process. The first group involves the challenges of building a strong vision for the city and defining a suitable strategy, even in the face of major risks, resistances, and uncertainties. The second group is related to the resources and novel capabilities that cities will need to support the new demands of digital transition. The third group addresses the delicate balance between

leveraging technology and being driven by technology. The fourth category includes the many challenges associated with the promotion, coordination, and sustainable operation of local innovation ecosystems. The much larger number of codes in this category can be explained by the focus of our search queries on innovation ecosystems, which was based on the expectation that this would be where we would find most of the sources that actually study innovation practices related with smart cities. Finally, focusing on a local innovation ecosystem may lead to a strong fragmentation of the global innovation ecosystem, which needs to be mitigated with new forms of transboundary collaborations. This section, will now describe in more detail each of these five challenges and their respective evidences from the research literature.

3.1. Challenge 1: Strategic Vision

A strong strategic vision is widely recognised as an essential element in smart city initiatives. Sánchez-Corcuera et al. [19] claim that moving forward with just a set of potentially interesting initiatives does not lead to long-term goals and does not promote collaboration between the different groups that should be involved. However, the ambiguity, technological uncertainties, and disruptive effects associated with this major paradigm change can make it extremely complex for any city to congregate the drive, the knowledge, and the collective support that are needed to consolidate a participatory, situated, and informed vision for its own digital transition. A strategic vision needs to be built on top of significant ambiguity or even opposing views about what a smart city should be, and yet it also needs to represent a consensual perspective of the priorities, convey a strong political leadership, and be based on a thorough understanding of the local community [24]. There are many sources of uncertainty, very few references of proven and replicable results, and many complex interdependencies between technology, politics, funding, businesses, and social development. This calls for high-risk decisions in a context of fast-paced changes that challenge established practices and perceptions.

3.1.1. The Ambiguity of Being a Smart City

The magnitude of this challenge is exacerbated by the ambiguity of the concept of a 'smart city' itself, and the many unique ways in which it can be interpreted. Appio et al. [30] highlight how the ambiguity generated by these many perspectives can significantly challenge policy makers in setting a proper smart city development agenda. This ambiguity is not just about the existence of numerous definitions of 'smart city'. It is mostly about a greater divide regarding the intended outcomes of smart city initiatives. Mora et al. [16] describe a deeply entrenched division in smart city research, with a lack of intellectual exchange among researchers, and little agreement about the concept itself or about what needs to be done in order to make a city smart.

While the idea of embedding digital technologies in urban infrastructures is common across smart city initiatives [31], more specific perspectives may suggest that being a smart city is about increasing the competitiveness of local communities through innovation while also increasing the quality of life for its citizens through better public services and a cleaner environment [30], or that a smart city goes beyond the operations of local government and should emerge from the actions of many individuals with access to smart services, both public and private [31]. Taratori et al. [32] identify three main types of definitions for smart cities: those exploiting smart technologies for their smart transition, those focusing on human-oriented innovations for their smart transition, and lastly, those perpetually striving to update their governance towards a more ecosystemic approach. The 3RC framework [33] describes four schools of thought: the Restrictive school, primarily focused on ICT, connectivity and data; the Reflective school, primarily focused on communities, creativity, innovation, and entrepreneurship; the Rationalistic school, primarily focused on the role of human capital; and the Critical school, primarily focused on a critique of the whole concept of Smart Cities. These many subjective and isolated interpretations fail to

provide the understanding and scientific knowledge that policy makers and practitioners would need to guide them in the development of their own initiatives.

3.1.2. Urban Innovation as a Situated Process, Not an Outcome

Urban innovation is inherently evolutionary, rather than stable and linear. Camboin et al. [34] dismiss the relevance of discussions about smart city definitions and claim instead that more attention should be paid to the ways in which innovation, as an integral component of smart cities initiatives, is constantly re-inventing itself. This would justify why the concept of a smart city is always changing and, correspondingly, the lack of consensus on the main factors that can make a city smarter and sustainable. A similar argument is presented by Coletta et al. [31], who consider that the development of a smart city is far from stable and linear in nature, but rather unfolds through a set of contingent and relational processes shaped by local governance practices, political priorities, political economic context, and institutional settings.

Sarv et al. [35] suggest that the focus should be on the situated interpretation of the concept within the specific context of a given territory. Each smart city project would thus be made unique because of its own geographical, cultural, and economic context, which should shape the selection of the specific development pathways and determine the priority application domains. Likewise, Guedes et al. [25] argue that the perception of urban problems is different between different societies, and therefore the main drivers for smart city initiatives should always be considered in relation to the reality of the respective territory. This need for a local interpretation of the concept reinforces the need for a strategic vision that is informed by global shared knowledge, but is developed locally and is strongly aligned with the local reality and, ideally, co-created with the local community.

3.2. Challenge 2: Organizational Capabilities and Agility

The digital transition represents a fundamental paradigm shift in city management, necessitating the development of new capabilities—analytical, administrative, and political—as well as a more transparent infrastructure governance across various sectors and scales [12]. Even if a city has successfully formulated a robust strategic vision, pursuing that vision requires a significant adaptation of its governance processes to this new reality. While some of these challenges may be underestimated, the reality often consists of organizational misalignments, various forms of resistance, and unmet expectations.

3.2.1. Administrative Constraints

The rigidity of administrative procedures and regulations is described as a strong inhibitor of urban innovation efforts. Most city governments are not well equipped to explore digital technologies as a solution to urban challenges due to rigid management structures and limited resources [36]. In particular, technology acquisition is often a critical bureaucratic challenge. Procurement processes and regulations are described as being outmoded and something that actively blocks progress [31]. Ferraris et al. [37] suggest that they are based on provision models that are optimized for predictable and well-known solutions, but are largely incompatible with innovative solutions.

The limitations of administrative processes is also reflected in very slow decision-making processes. Local governments do not have the same economic pressure as companies, and they need to deal with too much internal bureaucracy, are subjected to multiple external authorities, and may have to conduct formal consultations with key city stakeholders [37]. This can undermine collaboration with private companies, which work on a very different time frame and mindset. Slow and complex administrative procedures can break expectations and become detrimental to the city's ability to promote entrepreneurial initiatives within its territory [38].

Meijer and Bolívar [11] propose four conceptualizations for the level of government transformation that may be needed to make cities smarter: (1) government of a smart city, (2) smart decision-making, (3) smart administration, and (4) smart urban collaboration.

While more conservative approaches may suggest that simple institutional arrangements might be enough, more radical conceptualizations suggest that government itself needs to be transformed to create a smart city.

3.2.2. Human Resources

Local governments often lack the core skills, competencies and capacities they would need to develop a smart city initiative. According to Borghys [39], cities identify the lack of resources, experience, and capacity as the main bottleneck in addressing smart city challenges. These human resource limitations can significantly reduce the effectiveness of a smart city initiative, as many of the people involved may not understand how the new technological solutions work, may find it difficult to learn about a new technology, or may fail to grasp its potential impact [37].

Even when those human resources exist, they often lack the work context they would need to become agents of change. According to Sarv et al. [35], city governments with limited or no innovation units can find it very hard to have city officials with the appropriate knowledge and enough time left from their other duties. They are often addressing pressing urban issues or maintaining critical services and infrastructures, which are, themselves, becoming more socially and technically complex and requiring multi-tiered specialist interventions [31]. They can also be too isolated as the result of insularity, which describes the lack of inter-departmental coordination and communication, as many smart city projects are managed by vertically structured departments (silos) with little horizontal co-operation and reduced knowledge sharing [35].

3.2.3. Finance

Technological infrastructures and services associated with smart city initiatives cannot be created or exist without adequate capital expenditures [38]. However, local government budgets are only able, at most, to fund ongoing tasks, not the type of strategic investment, over a period of several years, that is required by most smart city initiatives. As city budgets are strongly correlated with their size and economic development, there might be strong disparities between cities, with cities in countries or regions with a higher level of prosperity being more able to allocate funds to their digital transition [38].

Funding limitations are also about flexibility. Classical models of financing, with traditional annual budget cycles, can limit the flexible management of projects, especially when unexpected business or technological opportunities happen to arise [37]. There is thus a need for new and more agile financing modes that can ensure not only the planned long-term investments, but also the flexibility that is needed to deal with the demands of a dynamic innovation environment.

3.3. Challenge 3: Technology Domestication

The idea that ICT will become increasingly central to city operations and to the many dimensions of urban life is at the core of the smart city concept. However, the concrete ways in which these myriad technologies will consolidate into new sources of value for cities can be very vague and or even misunderstood. There is often too much focus on the technology itself, and too little on managing the assimilation of technology into the fabric of the city. The real challenge seems to be how to find the right balance between technological possibilities and the real value that can be created from their concrete usage.

3.3.1. Technological Determinism

Technological determinism embraces technology as the main driver for societal change [40]. Technology is portrayed as a fascinating sign of progress, normally receiving positive press coverage and widespread support from a society in which most people can easily identify with techno-utopias [41]. This type of techno-centric discourse is strongly embedded in the smart city agenda. It places a monocentric focus on technology and promises a new and sustainable urban future, providing technological solutions to our

urban challenges and major changes to how we live in cities [34]. Under this "diffusionist" view of innovation, technology is perceived to be developed independently of society, having a subsequent impact on societal change [42]. According to Bibri [23], most smart city initiatives end up being driven by the exploration of the newly open possibilities associated with emerging technologies, rather than being directed at the most pressing urban issues and challenges. Referring to the Korean vision of the smart city, Yigitcanlar et al. [3] describe these cities as being driven by techno-centric practices that carry the risk of leading to a long-term trend towards increasing dependency on technology and negligence of socio-spatial issues. These signs of techno-centricity can also be found in the dominant rhetoric about data-driven urbanism, which feeds a widespread belief in data as a key ingredient to urban policy, from competitiveness, to good governance, accountability, and transparency [43].

To counter technologically deterministic perspectives, numerous authors are advocating for more comprehensive viewpoints. Camboim et al. [34] claim that the smart city is about humans and their use of technology, and therefore, it must provide human capital development opportunities; deal with sustainability solutions; and, at the end of the day, offer quality of life to its citizens. Suzic et al. [44] claim that smart cities need to employ a holistic approach that engages citizens with a co-creative open innovation process. Mora et al. [36] report how several cities recognise the need to embrace a more holistic vision of smart cities as socio-technical systems, in which technological development is aligned with human, social, cultural, economic, and environmental factors. Yigitcanlar et al. [3] remind us that urban technology does not necessarily need to be new to be effective, and that the most effective solutions may often involve retrofitting as well as innovative uses of existing and relatively inexpensive technology. The challenge is therefore to identify the most appropriate and simple technologies that allow cities to capture most of the benefits of digital innovation without becoming obsessed with the technology itself or losing sight of its many limitations.

3.3.2. The Corporate Smart City

Regardless of any consideration about the risks of technologically deterministic views, the fact remains that technology is indeed a core element of any smart city initiative and requires advanced technical expertise. As described in Section 3.2, we cannot expect local governments to have the capabilities to fully understand the possibilities and the conceptual challenges associated with the myriad technologies that may eventually be valuable to address urban challenges. Therefore, a significant involvement of technical partners from the private sector is often seen as highly desirable or even inevitable [12]. This has led to many smart city initiatives that are firmly rooted in partnerships with a strong technical partner. These partnerships, involving a local government and an ICT company, commonly described as double-helix structured collaborations, may take many forms, such as public–private partnerships (PPP), leasing, deregulation and market competition, or outright privatisation [31]. The technological partner can offer technical expertise, deployment experience, or specific information technology infrastructures, e.g. data centers or IoT. For local governments, this type of partnerships offer the opportunity to overcome the strategic and operational challenges they face when trying to promote these initiatives on their own. They allow cities to avoid significant upfront investment, helping them to address the lack of funding and resources associated with the instrumentation and interconnection of large numbers of urban devices [16].

However, there are also many long-term risks involved. Many cities have expressed a specific concern about the risk of vendor lock-in [45], which they fear may hamper the necessary flexibility to deal with the natural evolution of the projects. According to Bodum and Moreno [46], different technical options across various platforms end up impeding interoperability and make it difficult to implement solutions serving multiple domains and business areas. This can lead to many independent technological silos and can become a major obstacle for small and medium-sized cities to invest in the right infrastructure.

Yigitcanlara et al. [3] highlight how local policymakers are reluctant to implement large-scale smart city projects because of their concern about the future update and upgrade requirements of those infrastructures, and how they might make them dependent on the technology solution company for a very long time. Attempts to prevent lock-in have led to significant interest in open solutions, but the many specificities associated with each city and fast-paced innovation have been detrimental to the emergence of widely used standards that could promote interoperability between offers from many independent providers [19].

A more complex issue is the implicit attempt to transfer to the private sector a large share of the responsibility for managing and promoting a smart city initiative. The city benefits from the expertise, guidance, solutions, or even the vision of partner companies. However, this raises a conflict of interest situation because these companies will be in a dual role of shaping the local smart city policy and providing the services that are needed for the implementation of that policy. According to Noy and Givoni [6], the problem is not that private companies are concerned about their own commercial goals and profitability, as this is expected, or even required. The problem is when these same actors are the ones who set the agenda and largely determine public policy and planning. Mora et al. [36] describe these collaborations as essentially partnerships between information technology corporations, offering their technological solutions, and local governments, who are persuaded to underpin smart city development by adopting such proprietary technologies. These technology-led innovation strategies are more likely to promote a utopian and technologically deterministic interpretation of smart cities that mainly serves the interests of the companies involved [36]. They may very well fail to address the real challenges of the city [31] or fail to develop the intellectual capital which is necessary to drive this profound smart city transformation [36]. Yigitcanlar et al. [15] refer to these risks as the darker side of smart cities, associating them with an extreme dependency on technology. Ramaswami reports on the growing concern about the issues of ownership, equity, governance, and data sovereignty associated with these partnership model [12]. Increasing awareness about these risks is leading to growing signs of backlash against what is seen as the excessive power of information technology companies in urban settings [17].

3.3.3. Platformization

The platform-based model of competition is now a common trend in contemporary growth [47]. It involves the creation and delivery of services and products in the city and the public domain, normally developed and offered by private players [39]. Typical examples include ride-hailing (Uber), journey planning (CityMapper), property rental (AirBnB), or electric scooter sharing (Bird). These platform-based ecosystems have quickly evolved from "disruptive innovations" to an essential feature of smart places, including smart cities and regions [48]. They are now significantly shaping many dimensions of urban life [31], affecting the local economy, everyday life, utilities, and governance [48]. Their very fast growth and strong level of user engagement represents a major contrast with quadruple helix approaches promoted by local governments [39], where governments struggle to involve their own citizens in the services they promote (c.f. Section 3.4.4).

While valuable to citizens and often convenient to cities, these platform-based services are not always easy to align with local government strategies. They are developed and marketed as universal solutions to urban issues, and tend to address the city as a tabula rasa for innovation, layering their technology onto the city and replacing existing city systems, infrastructures, organizational structures, or established practices [31]. Cities are rarely involved in the respective innovation process, with the few forms of collaboration normally emerging only in a post factum, regulatory (or, at times, usage) capacity [39]. Borghys et al. [39] suggest that such collaborations will always be hard to achieve due to limited government capacity, experience, and resources.

Cities are thus confronted with the practices of these "platform industries" and the uncertain regulatory status in which they often operate, with frequent questions being raised

about privacy, ethical working conditions, use of and access to data, or the commodification of the public space [39]. Among other risks, cities may lose control of their own strategy, especially if platforms reach a monopoly situation where they will have a "de facto" power to shape many urban policies. This may lead to a smart city dominated by expensive technologies and capital-intensive infrastructure, and only accessible to young, healthy, and rich residents [38]. Overall, this represents a major challenge to some of the core assumptions about smart city planning and might be illustrative of how local authorities are being compelled to reconsider their role in these urban innovation ecosystems [39].

3.4. Challenge 4: Ecosystem Development

A common strategy in smart city initiatives is the development of a local innovation ecosystem. This can help a local government to expand access to financial resources, innovators, skilled human resources, and other loci of knowledge, where tacit know-how is shared and exploited [37]. By fostering collaboration and partnerships between different stakeholder groups, an ecosystem lens can offer a context that is more conducive to innovation, and creates value from the new connections between research, communities, businesses, and technologies [49]. Despite widespread recognition of the value of local innovation ecosystems, our results highlight not only that no ecosystem can fully address all the core challenges of smart city development, but also that the creation and promotion of an effective ecosystem is also a challenge on its own. We have arranged these broader challenges of local innovation ecosystems into four major topics: collaborative innovation, governance models, business models, and citizen engagement.

3.4.1. Collaborative Innovation

An urban innovation ecosystem can be described as involving a wide spectrum of stakeholders engaged in continuous collaboration on a human-oriented knowledge and learning process toward 'intelligent' solutions to urban challenges [32]. Mora et al. [36] call for collaborative ecosystems in which the interests of governments, universities, and industry are combined (triple-helix structure), along with those expressed by citizens and civil society organizations (quadruple-helix structure). This is suggested as essential for addressing the city as a complex socio-technical system in which technological development is aligned with human, social, cultural, economic, and environmental factors.

However, it can be very hard to bring together the right combination of partners to create a valuable innovation ecosystem. Key activities at this formation stage involve partner search, partner identification, and value creation [45], which require access to a relevant network of potential partners and the ability to attract the best ones. This will always be a challenging process, but it can be much harder for smaller cities or villages, either because of the lack of resources of the local government or the lack of relevant partners in the respective territory. As pointed out by Doering [50], not every city can have the same resources and capabilities as a modern metropolis like Singapore.

To progress from the formation stage to the coordination stage of these initiatives, it becomes crucial to promote the right type of interactions to align a group of partners into a thriving innovation ecosystem [45]. These alignment issues are often neglected when partnerships are being established, but effective collaborations need to be driven by a shared strategy, need to anticipate how the collaboration patterns may unfold, and need to offer real value to all the partners involved. Weak interactions between partners can hamper growth, as they lead to a misalignment in terms of the goals and intentions of key actors [45]. According to Ferraris [37], public actors represent one of the main drivers of "cooperation failure" because they have weak absorptive capacities and innovation capabilities; low pressure to innovate; poor technological knowledge; short-term pressures associated with politics and re-election cycles; insufficient funding; and risk-aversion. These elements create a significant distance between public and private partners and may significantly impact the ability to successfully manage a cooperative behaviour.

The existence of a strong strategic vision stands as the most important driver for collaboration [51] and a key enabler for a stakeholder alignment that is consistent with the needs and visions of individual partners [37]. In each city, the respective stakeholders (municipality, businesses, and academia) should not only decide on a common vision for the city and its digital transformation, but also turn it into a strategy, including a roadmap of actions that would be implemented in a short or long-term horizon by all partners [47]. During the smart city initiative, the relationships between the different stakeholders may change, the vision may need to be evaluated and adjusted, and an internal realignment may become necessary [45].

The success of a collaborative innovation ecosystem also depends on the ability to explicitly promote the exchange of knowledge between heterogeneous partners. Without this capability, innovative insights from external partners are more difficult to emerge [43]. Robaeyst et al. [52], describe these multi-stakeholder ecosystems as being composed of a variety of knowledge 'assets' distributed within the regional space and they are ready to become key drivers of regional innovation, as long as there is the ability to transfer innovations and knowledge among entities. Ardito et al. [53] call for recombination activities that can congregate tacit knowledge from different partners or transform it into more explicit knowledge. Steils et al. [54] call for dynamic knowledge flows in which not only knowledge can be acquired and accessed at the same time, but also that every stakeholder can actively be involved at any relevant stage. Breytenbach et al. [55] highlight how knowledge loss can hinder the operations and innovation of a community.

3.4.2. Governance Models

Effective ecosystem governance is recognized as essential, but it often seems to be missing, fragile, or largely misunderstood, with important consequences in regard to the efficiency, inclusiveness, or scalability of the collaborations. Nguyen et al. [9] conceptualise smart city collaborative ecosystems as a set of arrangements among quadruple helix actors, with various sources of power. From this power perspective, governments are seen as the strongest formal authority, with regulatory support and the power to offer or withhold critical resources. The power of private companies relies mainly on the resource advantages associated with specialised technologies and their authority as creators of economic value for society. Universities and innovation agencies base their power on the access to key resources, such as human capital and research expertise. Citizens can exert power through their discursive legitimacy. In general, strong power imbalances between the various partners are commonly associated with low-quality collaborations. On the contrary, a balanced power relation is expected to offer all partners equal possibilities to contribute and thus leads to deeper collaboration. However, it also poses new risks related to inaction and a sense of 'no-one-in-charge' [9].

Borghys et al. [39] call for a critical (self-)reflection on how local governments position themselves in such ecosystems. A common perspective is that the public body should act as a strategic leader and orchestrator of relations within the entrepreneurial ecosystem [37]. Within this mindset, the place of the public sector is to challenge companies to offer solutions to a set of problems, and foster innovation and entrepreneurship with an open data policy and new ways of tendering [31]. Private companies seem to expect a public government that offers a strong governance and acts as an intermediary and orchestrator of all relations within the smart city, setting objectives and monitoring the progress of activities. According to Appio et al. [30], typical roles attributed to governance entities may include promoting, executing, financing, warrantying, and certifying projects; coordinating stakeholders and managing the respective information flows; assuring the transparency, accountability, communication, and participation among all organizations involved; and generating both internal and external awareness about smart city initiatives.

However, many cities seem to prefer other actors to take up this coordinating role and are still experimenting with different approaches and methods for organizing, fostering, and sustaining these initiatives [39]. Weak governance is often reported as being associated

with the excessively informal nature of some of these ecosystems. Ferraris [37] found that they often rely on the voluntary work and personal dedication of individuals, rather than on functional governance models. According to the authors, this lack of formalized rules committing all the stakeholders to concrete outcomes highlights the fragility of existing governance models in sustaining innovation processes and may limit the development of steady and impactful partnerships. When associated with a strategic plan, the creation of a governance agency involving public and private stakeholders is reported as potentially easing the decision-making process in regard to shared investment decisions [34]. Likewise, the existence of a smart city manager dedicated to project management and acting as a point of reference is suggested as being a key element for the success of these initiatives [19,37]. Especially in larger cities, a smart city manager or a dedicated smart city department, with the capacity to focus on the collaboration itself, promoting communication between all the stakeholders and cross-domain initiatives is seen as very relevant.

These governance debates are strongly related to the debate on whether the most effective approach for smart city initiatives should be top-down or bottom-up [35]. Top-down approaches are more associated with a long-term vision and a strategic framework generating from the city government. According to Mora et al. [36], a top-down approach is associated with a stronger focus on fulfilling market expectations and meeting the interests of major corporate suppliers rather than society at large. Bottom-up approaches are more deregulated and self-organization processes or even grassroots movements generating from civil society [36]. Colleta et al. [31] project this debate as a confrontation between the "accidental" city, unfolding through a diverse set of initiatives driven by varying actors and stakeholders pursuing different interests, and the articulated city, with an overarching, coordinated, strategic, and branded narrative, integrated control rooms, and smart city standards initiatives. The right mix between top-down and bottom-up approaches might be the most suitable way to tackle strategic, innovation, and participation challenges. City governments should offer a long-term vision while also encouraging the establishment of an open, inclusive, and cohesive collaborative ecosystem that guides diverse initiatives towards shared strategic goals.

Governance models can also affect the scalability of these innovation ecosystems. Clement et al. [51] claim that the role of local government can only be effective up to a certain point, after which diseconomies are likely to arise because local government is unable to standardize the dynamics in the collaborative ecosystem. This suggests that collaboration with more stakeholders increases coordination costs. The optimal size will offer the best combination between the value that can be brought by the presence of more stakeholders and the marginal costs of managing those collaborations. This negative reinforcement loop may prevent urban innovation ecosystems from growing beyond an optimal number of stakeholders, a barrier that often emerges when smart city initiatives attempt to expand to the regional or national level [45]. Indirectly, this natural limitation in the number of stakeholders can also limit the range of domains in which any ecosystem is able to produce significant innovation, as each problem domain requires different types of knowledge assets, which necessitates many theme-specific stakeholders [52].

3.4.3. Business Models

In general, private funding is seen as essential for smart city initiatives. Firstly, this is because local governments, alone, are not able to make the type of investment associated with digital transition. Secondly, this is because private funding can be essential for the long-term success of smart city initiatives. Even though subsidies are recognised as crucial at the formation stage, projects that are just subsidy-driven will normally end once the subsidy is gone. They end up as a showcase or a demo, without a revenue model and without any scalability perspectives [48]. Still, the combination of public and private funding sources can raise opposing priorities and various legal and ethical problems [38]. While public finance aims to address public and social needs, usually for free or only

partially for a fee, private stakeholders aim to protect their business cases, and will mostly seek to meet individual needs and maximise financial profit.

Addressing these diverse priorities in a collaborative ecosystem requires the coordination of value creation and value capture activities. In particular, to continuously generate, capture, and protect value, it is necessary to carefully manage the trade-off between public and private values [45]. Panori et al. [48] highlight that many smart city initiatives fail to grow beyond the initial formation (pilot) phase of the initiative and suggest that internal adjustment between stakeholders to coordinate value creation and value capture activities can be the key to foster growth in smart city initiatives. Very often, pilot projects are started with the expectation that, later, they might deliver a business case, but this is seldom the case and that is not a successful outcome for private partners. Without validated business models they will not be able to scale their solutions to other territories.

Local governments also need to be aware that, even though private funding can significantly expand the scale and impact of what can be done, these collaborations still need the commitment of public funding. It would be a mistake for local governments to see these ecosystems as a strategy to avoid expenditure in the digital transition of the city. In fact, the lack of resources on the public side is seen as an issue by private partners who feel there is a lack of support and people to interact with and manage the activities [37]. At its core, finance is likely to be the most crucial, sensitive, and complex challenge to be addressed by smart city initiatives. Failing to acknowledge and deal with these conflicting views seems to be a common cause for disappointment in these public–private collaborations.

3.4.4. Citizen Engagement

Citizen participation is often suggested as essential for the success of smart city initiatives, leading to the quadruple helix model, where the industry–academia–government system is joined by the urban community co-deciding on the directions of smart city development [38]. A variety of techniques have been explored for citizen engagement, such as focus groups, user tests, participating in monthly resident meetings, citizen consultations via surveys, hackathons, gathering data via citizen science, online citizen platforms, or citizen advisory boards [39]. Despite widespread recognition that citizens must be involved in the co-creation of their smart city, this still seems to be exceedingly challenging for local governments. They struggle with the complexity of the processes, with the time needed to invest in such processes, with the diverging interests at play in complex value networks or with the, often unclear, goals of the interactions [9]. Borghys et al. [39] report how these processes often fail due to the lack of co-creation and engagement practices as well as capacity and resources to organize them. The authors suggest that cities often prefer to work within the more comfortable and less risky context of relationships with companies and academia, rather than "forcing" themselves into quadruple helix constructs.

There is also a strong power imbalance between government and citizens, which is a hindrance to effective citizen inclusion in solving urban problems [9]. Users provide their knowledge to innovators, who use that knowledge to develop better products that benefit citizens, but if citizens withhold their knowledge to create leverage, then they suffer by receiving less useful solutions to their problems. As a consequence, smart cities may be failing to ensure that the voices of different citizen groups are heard, which reduces smart cities' capacity to better align services and infrastructure with what citizens want and need [9]. This also suggests the need to educate public authorities and citizens on better cooperation for experimenting and leveraging common opportunities in urban areas [44].

3.5. Challenge 5: Transboundary Innovation

The previous section has extensively discussed the key role of local ecosystems in transforming abstract smart city concepts into specific policy actions [47]. However, the survey results also suggest that an excessive focus on local innovation contexts can lead to a deeply fragmented urban innovation landscape [56]. This dispersion of the innovation

effort across a myriad of city-specific ecosystems, largely isolated from each other, all of which seeking their own local solutions to very much the same challenges, results in a very inefficient innovation ecosystem that fails to congregate the knowledge and the capabilities that would be needed to produce real impact. The final challenge for smart city initiatives is thus how to engage in new collaboration patterns that allow them to reach the type of combinatorial innovation and shared learning that is essential for the consolidation of successful practices and for the acceleration of the innovation process.

3.5.1. Innovation Silos

Smart city innovation practices are characterised by the existence of many autonomous smart city initiatives, all of which concurrently explore different directions and strategies. This should not be a problem in itself. Firstly, smart city strategies are expected to be aligned with the development goals and specificities of each local ecosystem and therefore a huge diversity of approaches is what is naturally expected. Secondly, this distribution of the innovation effort should actually become a fundamental enabler for fast-paced innovation, with progressive innovation evolving very quickly in the form of multiple small concurrent iterations, occurring anywhere across the whole ecosystem. The problem, therefore, is not the overlapping of independent efforts. The key issue is the lack of efficient mechanisms to systematically identify and replicate the most successful results so that the following iterations may start from a higher ground, and not as if they were the first ones trying to reach those same goals.

As a whole, there are numerous projects, test-beds, and pilots producing valuable new knowledge about the digital transition of cities, but they all do it in terms of small-scale atomised innovation, becoming largely independent knowledge silos or "little pockets of innovation" [31]. This isolationism may even develop into a resistance to external solutions. The so-called 'not-invented-here syndrome' [57] reflects cases where new innovations can even be rejected based on a sense of lack of ownership associated with the lack of involvement in the early stages of the development of a new product [52]. The existence of many vertical markets for the various domains of the city (energy, transportation, health, safety, governance, air pollution) is also described as another source of fragmentation in smart city solutions [47], as these strictly vertical solutions, with little interoperability or common elements, will fail to create multiplying effects to the wider urban economy. Despite their many specificities in terms of strategy, stakeholder composition, and territories, urban innovation systems will always share many similar problems, challenges, and even solutions. It is thus highly inefficient to have these many separate smart city initiatives repeatedly addressing the same challenges without significantly building on each other's previous efforts. As claimed by Komninos et al. [47], it is neither functional nor effective to deploy one hundred digital transformation strategies for one hundred city ecosystems.

Fragmentation is also associated with the lack of benchmark metrics for assessing similar solutions developed across multiple cities, which in turn is an obstacle for successive iterations based on the most successful ideas. In recent years, the performance of smart city programs has become a concern for both researchers and government [58], and many performance indicators have been proposed to evaluate the real effectiveness of smart city initiatives [59]. These assessment frameworks lean towards questions of accountability and effectiveness in meeting the original policy objectives, but they are not very effective at measuring concrete impacts on people and places or capture bottom-up learning from the smart city projects [58]. Metrics that can work across multiple territories would be able to support the assessment of alternative designs, allowing cities to learn from each other in regard to concrete problem-solving contexts.

3.5.2. Scalable Boundary-Spanning Collaborations

Growing awareness about the limitations of fragmented innovation has led to calls for new forms of collaboration across different urban ecosystems. Acuto et al. [43] call for more "permeable" cities and knowledge circulation within and between cities, with

at least four dimensions of knowledge flows: within local governments; within cities; between local government and other levels of government; and between cities via translocal exchange mechanisms. The authors also point out the role of "boundary-spanning organisations" that may act as facilitators of knowledge sharing. There are also calls for the recognition of the "transboundary" nature of smart city projects [30], and a pressing demand for sounder conceptual perspectives to understand and examine smart city initiatives from a managerial point of view [53], including from regional and national perspectives. Ramaswami et al. [12] highlight the role of a transboundary perspective in addressing the environmental impacts of cities and understanding their urban supply-chain carbon footprinting. Wang [56] claims that the concept of an ecosystem can be applied to multiple levels of the digital innovation landscape, linking diverse entities such as processes, products, services, organizations, industries, and communities to create and realize the value of digital innovations. Vallence et al. [60] acknowledge the relevance of brokerage activities that allow urban ecosystems to engage a wider range of stakeholders within the region (and beyond) who can be brought together in different combinations for individual projects.

A wide range of regional, national, and international programs has been created to bridge across these disparate ecosystems and promote the exchange of findings, experiences, and practices between cities. Many local governments have recognized the hindrances associated with lack of scale and that smart city initiatives could be better handled at the regional government and not the local level [39]. They started pushing for a conceptual transition from smart cities to smart city-regions [44]. Referring to the work by Carayannis et al. [61], Panori et al. [48] claim that glocalization involves a shift from innovation processes that are often enclosed within a single urban ecosystem to systemic and network-based innovation. Suzic et al. [44] describe how the connection of local ecosystems with national programs may help to improve visibility of networks and their outputs. In Europe, smart city promotion policies have defined a strong focus on impact and replication of results, such as the European Innovation Partnership on Smart Cities and Communities (EIP-SCC) [45]. Public funding programs are also designed around the principle that all practices, experiences, and results from these projects are shared among consortium cities and the validated smart city solutions should be implemented across different European cities [34]. These programs aim to address fragmentation issues by promoting knowledge sharing and co-creation. However, they are not designed to be generic and systematic processes for large scale collaboration across many local innovation ecosystems. They are still based on the same type of costly and formal partnership that can be found in local innovation ecosystem and they will suffer from the same scalability issues. If the collaboration costs are very high, they will limit the number of participants that can be involved in a single collaborative process and the number of collaborative processes in which a single entity can participate. These scalability barriers are extensive to every level of governance, including when these initiatives attempt to expand to the regional or national level [45].

4. Discussion

The results obtained from the literature review provide a wide range of evidence about the broad range of challenges associated with smart city initiatives. In this discussion section, we build on those challenges to analyse the alignment between common smart city innovation practices and the key defining properties of digital innovation. The goal is to address our second research question which aims to uncover new innovation practices towards socially and environmentally sustainable smart city initiatives that might be more effective at unleashing the real-world impact of digital innovation across cities. If we accept digital innovation as a unique, unprecedented, coherent, and dynamic phenomenon [62], then we must also acknowledge the need to seriously reconsider established practices. In this discussion, we explore the idea that the obstacles identified in this study may somehow be linked to significant gaps between smart city innovation and the fundamental properties of digital innovation. To structure our discussion on this topic, we will consider

the three traits of digital innovations proposed by Yoo [18]: (1) the importance of digital technology platforms, (2) the emergence of distributed innovations, and (3) the prevalence of combinatorial innovation.

4.1. The Importance of Digital Technology Platforms

The platform-based model of competition is a major trend in digital innovation [47]. Platforms provide a foundation upon which many other entities can develop their complementary offerings, leading to extended ecosystems where a network of heterogeneous actors can harness the convergence and generativity made possible by digital technology. Convergence refers to the ability to bring together user experiences that were previously separate and required separate products or tools [18]. Generativity refers to the capacity of a digital system to produce unprompted change driven by large, varied, and uncoordinated audiences [63]. It generates a continuous flow of augmentations and integrations of new digital technologies into broader ecosystems, with the key consequence being that the outcomes of digital innovation may not be fully known or knowable a priori [62].

Platforms have become very common in smart cities and smart regions [48], but existing platforms still seem very far from reaching the scale of convergence and generativity that we can witness in other domains. We can observe the existence of two major strategies. On the one hand, we have the platformization strategy with major corporation offering their services directly to citizens, and then possibly also some verticals to cities. These are proprietary and highly controlled services created to address specific application domains. They are not open in the sense that they would consider providing a context for large scale co-creation, making them ill-suited to address the many specificities of each city and its respective digital transformation trajectory.

On the other hand, we have many systems being proposed as solutions for the city platform, often presented as the so-called brain of the city, with its many extensions and ramifications. These technological frameworks often need considerable customisation work before they can be used for any specific city, but they have the capability to offer very targeted services. Even though some of these platforms are open source, they all raise obvious concerns about vendor lock-in [45], as well as openness, ownership, equity, governance, and data sovereignty [12]. None of them has managed to congregate enough engagement to become a real source of convergence and generativity. They can promote convergence, and some of them have developed substantial communities, e.g., FIWARE, from which some level of generativity can also be achieved. Still, this generativity is mostly focused on software components, which is valuable to promote code reusage across multiple cities, but is not something that can immediately open many co-creation opportunities. In the end, the idea of a centralised platform augmented with compatible extensions creates an obvious dependence on the platform provider, leading to a potentially monopolistic perspective, which in the long-term will hamper innovation.

It thus remains very hard to identify any meaningful and concrete examples of smart city platforms that are showing the capability to produce large-scale convergence and generativity across multiple urban innovation ecosystems. This gap seems to suggest the need for new types of digital platforms that can congregate technical solutions readily available to many cities with the ability to promote technology neutrality and data interoperability. In a companion study, we outline five design principles that may help urban services to move towards new platform models [64].

4.2. The Emergence of Distributed Innovations

The second major trait of digital innovation is the distributed nature of the innovation process. Convergence on common digital tools, data formats, or mediating services can substantially reduce traditional collaboration barriers and facilitate the participation of distributed actors across organizational boundaries. This "democratization" of the innovation process pushes the locus of innovation activities towards the periphery of organizations, leading to the distributed and horizontal coordination of value creation.

Innovation emerges from these flows shared between heterogeneous actors in complex socio-technical networks where ambiguous ideas, representations, and material artefacts can be assembled into new knowledge combinations [65].

The results described in Section 3.5 describe how the fragmentation of the innovation ecosystem is a major obstacle for shared learning across current smart city initiatives. Komninos et al. [47] call for new strategies shaped by common elements that remain stable over the diversity and fluidity of the various ecosystems. There are many attempts to promote knowledge exchanges between cities, but they are mostly focused on creating other scopes of collaborative innovation on top of the city level. They are not based on global knowledge exchanges and they are no more scalable in regard to the number of stakeholders involved than any local innovation ecosystem.

A distributed innovation perspective should focus on new collaborative innovation models that can scale the systematic exchange of results between stakeholders anywhere across the global ecosystem of smart city initiatives. This type of loosely coupled engagement could unlock endless new sources of innovation to complement the specific innovation work being done within each urban context. It would unleash some of the most powerful capabilities of digital innovation that rely on the ability to connect human, collective, and machine intelligence. According to Panori et al. [48], there are two ways in which digital technologies and digital platforms can become the enabler for connected intelligence: on the one hand, by bringing many people together they allow collective intelligence to appear, and on the other, by using machine competences, they allow analytics and AI to further enhance human skills.

This ability to scale transboundary collaborations across smart city initiatives will be largely determined by the ability to make it efficiently enough to avoid the costs of cooperation and collaboration that are currently involved. This may involve eliminating common barriers, such as lack of shared understanding about common problems, many different terminologies for the same types of solution, lack of mutual knowledge, and especially the exclusive focus on direct interaction between the parts involved. The assumption of formal partnerships with only a few stakeholders would be extended with new types of weak links with a very large and potentially unknown set of other innovation actors. The huge diversity of a global ecosystem composed of many cities across the world should be strongly explored as the essence of distributed innovation itself. Ideally, it should offer a context for the independent experimentation of many alternative directions. This integration between local and global can trigger major transformations, such as the multiplication of innovation actors; multiple forms of crowdsourcing and user engagement; glocalisation of knowledge; informed intelligence and discovery based on data; and skills improvement [48]. However, for this to work, it would be essential for the knowledge generated by those experimentations to be shared, leading to a thriving multi-city innovation ecosystem, with the capability to learn much faster and much more efficiently than today.

4.3. The Prevalence of Combinatorial Innovation

The third trait of digital innovation is combinatorial innovation, where shared standards, digital modules, and objects can be combined between each other to produce new creations, products, or services. A product or service has no stable and fixed boundary and essentially remains incomplete throughout its entire lifetime, with users being expected to continuously extend it with new recombinations. The nearly limitless recombination of digital artifacts becomes the main source of innovation.

A crucial precondition for combinatorial innovation is the existence of some sort of module that can be combined with others [18]. This is something that is clearly missing in smart city innovation. There are currently no modules, services, or objects that are widely available to support this level of seamless recombination. Despite the efforts made by many open smart city initiatives, there is not really a market where multiple independent entities are continuously producing modules that can later be recombined to actually provide real-world solutions across many contexts. This is a major gap that can

be addressed by increasing data portability and other technologically neutral concepts to facilitate interoperability and create the expectation of systematic resource recombinations.

5. Conclusions

Digital innovation represents a major transformative force for cities. However, cities are highly complex ecosystems where innovation relies on many contextual elements. The key properties that made digital innovation a source of powerful and fast paced innovation in many other domains seem to be harder to align with the specificities of urban innovation ecosystems, resulting in slower progress and even frustration with the smart city concept.

In this study, we collected evidence by reviewing the literature on innovation practices for smart cities. The new findings answer our first research question (RQ1) about the most fundamental challenges that may be preventing current smart city initiatives from attaining the same level of disruption as other areas of digital innovation. Our first contribution is the identification of a broad range of innovation challenges faced by smart city initiatives, and their aggregation into five major categories: Strategic Vision; Organizational Capabilities and Agility; Technology Domestication; Ecosystem Development; and Transboundary Innovation. This is a novel and relevant contribution in the way it directly addresses the design and assumptions of the innovation process itself. This contribution does not provide any direct guidelines on how to proceed, but it may offer cities a deeper sense of the unwritten rules of this transformation and a meaningful perspective of where they stand in their initiatives and what might be the broader challenges ahead.

The second contribution of this study addresses our second research question (RQ2) about alternative innovation practices for smart city initiatives. We started with the elicitation of the key defining properties of digital innovation and assessed current gaps in the alignment between those properties and the reality of smart city innovation practices, as represented by the five challenge categories from RQ1. This should provide a new perspective to discuss alternative innovation practices for smart city initiatives that may help to unleash the capabilities of digital innovation.

One limitation of our study is the potential publication bias. The selection of the research literature was largely based on reports addressing urban innovation ecosystems. While we believe this to be the most relevant context for valuable insights about innovation processes related with smart city initiatives, we do acknowledge that there might be other relevant perspectives. It is also important to note that studies addressing urban innovation ecosystems tend to report on findings from larger cities, where those innovation ecosystems are more structured. While this diversity of urban realities should not have much of an impact on the whole structure of the challenge categories, it may significantly affect the relevance that each particular challenge may actually have across different cities. Overall, this contribution should help the whole field to reflect on some of its most inner assumptions and begin exploring new innovation practices that might be more successful at unlocking the unique capabilities of digital innovation in the context of cities.

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