

Design Principles for Platform-Based Innovation in Smart Cities

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Abstract. Smart Cities represent the next big frontier for computational science. However, the real-world impacts of this transformation have been considerably slower than other domains of digital innovation. In this work, we study the interplay between the core properties of digital platforms and the urban innovation contexts that aim to promote digital transition as a means to generate value for cities and its citizens. The research methodology is based on a literature review, which aimed to characterise the key limitations preventing smart city initiatives from attaining the same level of fast paced innovation as other areas of computational science, and seek for alternative innovation practices. The results suggest that innovation practices in the context of smart city initiatives seem to be framed by a key trade-off between the idea that only global solutions may be able to capture the full benefits of digital innovation and the idea that each city is unique and must pave its own way towards digital transition. From the analysis of those results, we derive five design principles for new service-based platforms. These principles represent a new direction to address the specificities of smart cities and unleash the real-world impact of digital innovation in smart and sustainable cities.

Keywords: Smart Cities · Digital Platforms · Digital Innovation

1 Introduction

Becoming a smart city is now a common aspiration for any city aiming to provide their citizens with better services and more socioeconomic development. In recent years, many cities and urban regions have established strategies to promote the digital transformation of their territories, embracing a broad range of dimensions, such as mobility, energy, digital governance, sustainability or the entrepreneurial context. Digital technologies, in general, can have a very profound impact in addressing long-term problems of city life, and thus, there is a legitimate expectation that we may start to witness a progressive and positive impact emerging from their increasing presence in urban contexts.

However, there is also a general sense of disappointment about the real-world impacts of this transformation. While there are numerous smart cities initiatives

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aiming to leverage the disruptive potential of digital innovation to address urban problems, the results are still somewhat limited in regard to the initial expectations and the investments involved. The innovation pace seems much slower than in other areas of Computational Science and there are even growing signs of backlash against what is seen as an excessive presence of computing technology in urban settings. There is thus an increasing pressure to deliver real value and show evidences of relevant progress. In this context, it is timely and relevant for the whole field of smart cities to study the fundamental causes behind this limited progress and seek for alternative innovation directions that may offer a better fit between the unique properties of digital innovation and the concrete needs of cities.

1.1 Objectives

In this work, we seek to uncover the key limitations faced by innovation initiatives aiming to explore the application of digital technology in urban contexts. We also seek to identify novel innovation patterns that may unlock the innovation potential of computational science in smart and sustainable cities. Digital platforms and local innovation ecosystems have been at the centre of these processes of digital transformation for cities. Our study is thus focused on the interplay between the core properties of digital platforms and the urban innovation contexts that aim to promote digital transition as a medium to generate value for cities and its citizens. These broader goals can be represented by the following two research questions:

- RQ1: What are key limitations that may be preventing current smart city initiatives from attaining the same level of fast paced innovation as other areas of computational science?
- RQ2: What type of alternative innovation practices may help to unleash the real-world impact of digital platforms in smart cities?

With the first research question, we aim to contribute to the understanding of the limitations that are shaping the concrete results produced by smart city initiatives and offer a framework for the subsequent analysis of alternative paths for smart city innovation. With the second research question, we aim to inform the exploration of novel platform design approaches that are more effective at capturing the potential of digital innovation for the benefit of urban life.

In the remainder of the paper, in Sect. 2, we review prior work on platforms for smart cities, an then in Sect. 3, we describe the execution of a Systematic Literature Review on urban innovation ecosystems, from which we gathered evidences about the fundamental challenges faced by smart city innovation. In Sect. 4, we present the result of the review, which highlight the existence of a key trade-off between two quite distinct approaches to urban digital innovation. In Sect. 5, we discuss those results and their implications for platform design, resulting in the proposal of five fundamental design principles for new service-based architectures for smart cities.

2 Related Work

Platform development has been a major topic in smart cities literature, as researchers seem determined to define an explicit smart city architecture to facilitate the actual deployment of smart city applications [26]. The core motivation is strongly associated with the goals of interoperability and development optimization. As described by Santana et al. [23], most solutions focus on a specific domain, target a specific problem, and were developed from scratch, with little software reuse. Since they do not interoperate, they lead to duplication of work, incompatible solutions, and non-optimized resource use. The conclusion is the need for a Unified Reference Architecture that can offer a novel and comprehensive software platform to support application development, integration, deployment, and management.

Saborido and Alba [26], analyse several platforms and claim that most existing smart city deployments are based on closed systems that use private software systems sold by a particular vendor, who does not provide many details about its software design and architecture. As a consequence, although there is a variety of smart city software systems, their benefits and limitations are still unknown. Tsampoulatidis et al. [29] report on the inherent heterogeneity of Internet-of-Things (IoT) devices and how it leads to many different architectures and communication protocols for exchanging data streams. They conclude that this diversity disrupts the creation of smart city ecosystems and prohibits the establishment of holistic and universal access models.

Lim et al. [15] address Big Data for smart cities and propose a set of reference models, challenges, and considerations to offer a framework for data usage in smart cities. This focus on data management has led to many data-driven platforms. A common pattern is the organization of functionality across a set of layers, such as sensing, transmission, data management, and application. However, this data-centric perspective faces the lack of open data initiatives and depends on the willingness of vendors and integrators to support interoperability [25]. Singh et al. [26], claim that, while theoretically feasible, the viability of a common smart city architecture for deployment in the real world is far away from reality and general architectural guesses are limited by major changes in required functionality.

There is thus extensive work on architectures and development paradigms for Smart Cities, and there are many elements related to the design, development, deployment, and management of smart city platforms that still challenge the research community. Our work moves away from specific architectural designs and data interoperability issues, and focus instead on the fundamental properties of digital innovation as the core principles for the design of digital platforms for smart cities. To the best of our knowledge, this is a relevant and novel contribution to this field, with the capability to open fundamentally new innovation practices for smart cities.

3 Methodology

The methodology for this study is based on a Systematic Literature Review (SLR) on the topic of smart city innovation. The main advantage of a SLR is the ability to uncover common issues across a wide range of smart city initiatives. There is a considerable body of research literature reporting on the results of various types of innovation strategies. This is thus a meaningful and timely review that reflects on the limitations of the prevalent innovation paradigms. Its results should help to inform new urban innovation strategies that might be more efficient at capturing the specific sources of value offered by digital innovation.

The review protocol follows the general guidelines proposed by Kitchenham and Charters [12], and the PRISMA reporting guidance [18]. The formulation of the review protocol is centred on the two research questions defined for this study, which drive the selection of primary studies included in the review and the analytical approaches used to uncover evidences from those publications.

The eligibility criteria considers research studies, in English, published in the last 5 years and reporting findings about the creation, operation, challenges and outcomes of urban innovation ecosystems created as part of smart city initiatives. To search for the relevant bibliography, we used Scopus, a major bibliographic database, 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 [20]. It also largely overlaps with the other major bibliography indexing databases, including Web of Science (WoS) [33].

Our search strategy comprises two separate queries. Both queries included the same five years time frame and used *smart cities* as a selection keyword. The first query used the term *innovation ecosystem* and the second used the term *helix*, which is often used in the literature to describe different stakeholder combinations in local innovation ecosystems. This led to the formulation of the two complementary search strings presented 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"))

The search was performed in February 2023. The list of results was screened for a quick eligibility assessment, based only on the analysis of the title and abstract of each of the publications. All papers that seemed to match the eligibility criteria were selected. To reduce bias and clarify the selection decisions, we also used an exclusion criteria to eliminate any studies where the contribution was strongly associated with a specific technology. The results of the complete data selection process are summarized in Fig. 1.

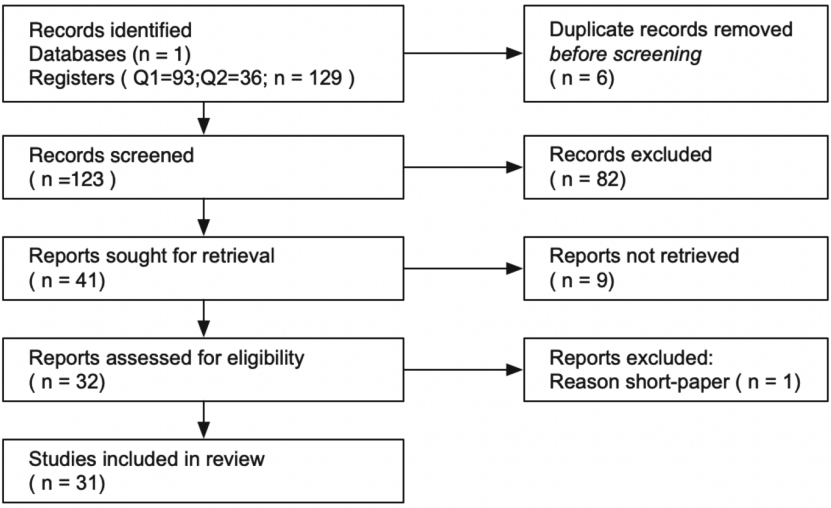

Fig. 1. Data selection process

The selected publications were then analyzed according to a semi-structure coding process, supported by a software tool for Qualitative Data Analysis. The coding was framed by the two research questions, which became the two top-level code categories, one for core challenges for smart city initiatives; and the other for novel opportunities for smart city innovation. Under these top-level codes, coding was based on an open coding process. At the end, the resulting codes were aggregated to combine similar codes and organized them under representative second-level categories. The information extracted within each category was then used to synthesize a qualitative overview of the respective topic.

4 Results

The results of this review have shown the diversity and breadth of the challenges that may be preventing current smart city platforms from attaining the same level of fast paced innovation as other areas of computational science.

The most fundamental challenges can be described as intrinsic to the depth and magnitude of the transformation process itself. The concept of smart city is a major paradigm transition, which necessarily challenges established practices and perceptions, causing imbalances of power, frustrations, organizational stress, communication difficulties. More than annoyances, these elements can become major obstacles to the transition itself, either through the inability to devise appropriate strategies, to deal with decision in a context of major uncertainty or to assume the risks associated with a profound change.

These challenges seem to be exacerbated by the strongly ambiguous nature of the concept of 'smart city' and the many unique ways in which it can be interpreted. The literature reports the existence of numerous definitions of 'smart city', but, more importantly, it clearly emphasises how despite those definition attempts, the concept remains largely ambiguous [6,14,28]. Appio et al. [2] highlight how the ambiguity generated by these many perspectives can significantly challenge policy makers in setting a proper smart cities development agenda. Other authors emphasise the inherently evolutionary nature of the process of urban transformation [4], and its need to constantly re-invent itself as it unfolds through a set of contingent and relational processes shaped by local governance practices, political priorities, political economic context and institutional settings [6]. Sarv et al. [24] suggest moving the focus to the situated interpretation of the concept within the specific context of a given territory, which means each smart city project would be made unique because of its own geographical, cultural, and economic context. This need for a local interpretation of the concept represents in itself a major challenge because it requires a strong alignment with the local reality and, ideally, a strongly participatory process. A strong strategic vision is thus essential, but is normally absent. It is extremely complex for any city to congregate the drive, the knowledge, and the collective support needed to define, plan and execute a long-term vision and corresponding strategy for its digital transition.

Even when city managers are genuinely motivated to move forward and know what they want to accomplish, they still need to face all sorts of barriers. According to Borghys [3], cities identify the lack of (sustainable) resources, experience, and capacity as the main bottleneck in addressing smart city challenges. Common examples include outmoded procurement processes and regulations [6], provision models that are optimized for predictable and well-known solutions, not for innovative solutions [8], or slow decision-making, which breaks expectations and trust from private partners [8]. 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, both financial and Human [16]. These obstacles are often underestimated, but the reality of smart city initiatives is always made of these organizational misalignments and multiple forms of resistance.

Finance is another critical issue for these local innovation ecosystems. The technological infrastructures and services promoted by smart city initiatives cannot be created or exist without adequate capital expenditures [11]. Since munic-

ipal budgets are very short, they are only able, at most, to fund ongoing tasks, not the type of strategic investment, over a period of at least several years, that is required by most smart city initiatives. Also, classical models of financing, with traditional annual budget cycles, can limit the flexible management of projects, especially in the case of unexpected business and technological opportunity that can arise [8]. According to Sarv et al. [24] many cities assess their chances of smart development as low or very low.

Digital transition is thus a major paradigm chance for cities. They miss the expertise, the tools and the forms of governance that are needed to deal with the breadth and complexity of these changes. To embrace this highly dynamic context and benefit from its many opportunities, they need to find partnerships that allow them to mitigate their limitations and accelerate their digital transition process. In our review, we have identified two major directions for the promotion of these collaborations. While not necessarily exclusive, they seem to represent two very distinct perspectives about the role of digital platforms in smart cities. The first direction is based on partnerships with technology companies, in some cases large global platforms, which can offer them the technical expertise or the services they need to develop parts of their digital agenda. The second direction involves the promotion of local innovation ecosystems to address the digital transformation of the respective territory. This section, will now describe in more detail each of these directions and their implications for urban innovation.

4.1 The Challenges of Digital Platforms

As they feel pressured to be seen as smart cities, a technology-centred partnership may seem like an easy way forward. It allows the city to draw on the competencies held within industry, which possesses sufficient expertise to guide city administrators in delivering better city services. These partnerships are often associated with a double-helix structured collaboration between a local government and an ICT company. They may emerge in the form of public-private partnerships (PPP), leasing, deregulation and market competition, or outright privatisation [6]. Considering the complex challenges associated with developing a strategic vision and the necessary capabilities, this type of collaboration may seem very attractive for cities. The collaborations are simpler than those associated with a larger ecosystem and they do not normally involve major upfront investment, which helps to address the lack of resources of local governments. It is also something that may seem less risky, as it may deliver visible results in a much shorter period of time and allow experimentation to be done within relatively controlled contexts. On top of that, cool technology can be exciting and generate positive press coverage, as most people can relate very easily with techno-utopias [10] and technology determinism [21].

However, attempting to transfer to the private sector a large share of the responsibility for developing, managing and promoting a smart city initiative, does not provide the necessary intellectual capital to drive smart city development [16]. The city benefits from the expertise, guidance and solutions of the partner companies, but in that process it may fail to address the real challenges

of the city [6]. According to Mora et al. [16], this is essentially a partnership between information technology corporations offering their technological solutions and local governments, which are persuaded to underpin smart city development by adopting such proprietary technologies. Therefore, this technology-led model may fail to cope with the complexity of smart city development, and is most likely to promote a utopian and technological deterministic interpretation of smart cities that serves nothing but the interests of companies working in the technology industry. Many cities have also expressed a specific concern about the risk of vendor lock-in [17], which they fear may hamper the necessary flexibility to deal with the natural evolution of the projects. Data interoperability seems to be the most common concern, with cities fearing the consequences of endless data formats and complementary solutions that cannot communicate between each other.

This techno-centric perspective is also at the centre of the "platformization" trend, in which services that significantly shape cities, e.g. ride-hailing, property rental, or electric scooter sharing, are delivered by major private players and are rarely co-designed with cities [3]. These smart city technologies are developed and marketed by multinational high-tech corporations as universal solutions to urban issues [6]. They address the city as a tabula rasa for innovation, layering their technology onto the city and replacing existing city systems, infrastructures, organisational structures or established modes of practice. The disruptive nature of these platforms and the ways in which they are able to generate user involvement, has propelled a very quick growth, often beyond the control of local governments, which are thus compelled to consider their role in this ecosystem. The concept of "platform urbanism" [9] has emerged to describe these dynamics and reveal a complex platform-based ecosystem encompassing organizations and citizens and challenging the smart city framework as a planning and development paradigm.

These platforms are valuable to citizens and often convenient for cities, but they can be hard to align with any local strategy for the smart city. They often operate in an uncertain regulatory state, with questions related to privacy, ethical working conditions, use of and access to data or the commodification of the public space [3]. Cities can lose control of their own strategy and platforms may reach a monopoly situation in which they will have acquired the power to shape urban policies. Among other risks, this approach may lead to a smart city, dominated by expensive technologies and capital-intensive infrastructure, and only accessible to young, healthy, and rich residents [11].

A smart city initiative is thus a very broad challenge that goes far beyond its enabling technologies. The smart city should also provide human capital development opportunities, as a way to foster knowledge and creativity; should deal with sustainability solutions, to cope with the changing urban environment; and, at the end of the day, should offer quality of life to its citizens [4]. Therefore, an approach only focusing on the technical aspects and economic possibilities is not sufficient. Truly smart cities need to employ a holistic approach and engage in a co-creative open innovation process [27].

4.2 The Challenges of Local Innovation Ecosystems

The promotion of a local innovation ecosystem has become a common practice to drive the development of smart city initiatives beyond mere technological fixes. These 'smart ecosystems' can involve a wide spectrum of stakeholders engaged in a continuous collaboration on a human-oriented knowledge and learning process toward 'intelligent' solutions to urban challenges [28]. They can combine the contributions of governments, universities and industry (triple-helix structure), along with those expressed by citizens and civil society organizations (quadruple-helix structure) [16]. The overall goal is to create an environment that is conducive to innovation, by fostering collaboration and partnerships between these different groups and providing easier access to resources, such as funding and specialized knowledge. They may help to overcome the lack of financial resources and technological capabilities of public organizations, and also to expand access to innovators, skilled human resources, and other loci of knowledge, where tacit know-how is shared and exploited [8]. Despite the widespread recognition of the role that local innovation ecosystem may play in the promotion of smart city initiatives, the review results highlight that no ecosystem can fully address all the core challenges of smart city development and that the creation and promotion of an effective ecosystem is also a challenge on its own.

The first major challenge is to bring together a set of stakeholders with the right combination of contributions to create a valuable innovation ecosystem. Key activities at this formation stage involve partner search, partner identification and value creation [17]. This is always a challenging task, but it can be particularly difficult 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 [7]. Even when those partners are available, it can be very challenging to progress from the formation stage to the coordination stage of these initiatives [17], and transform a group of partners into a thriving and effective urban innovation ecosystem. Weak interactions between partners can hamper the growth of smart city projects and lead to a misalignment between key actors [17]. A large number of heterogeneous stakeholders is also a challenge for knowledge sharing. According to Robaeyst et al. [22], an heterogeneous multi-stakeholder ecosystem corresponds to a variety of knowledge 'assets' distributed within the regional space, which can be the main driver of regional innovation, as long as there is the ability to transfer innovations and knowledge among entities. Without the ability to access and share that knowledge, innovative insights from external partners are more difficult to emerge [1].

Panori et al. [19] recognise that many smart city initiatives fail to grow beyond their initial pilot phase 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. In particular, to continuously generate, capture and protect value, it is necessary to carefully manage the trade-off between public and private value [17]. While private stakeholders may favour approaches that aim to protect their business cases, public stakeholders may seek the value emerging from scalability, openness and interoperability. According to Ferraris [8], 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.

Ecosystem governance is recognised as essential, but it often seems to be missing or to be largely misunderstood. Typical roles attributed to governance entities may include: promoting, executing, financing, warrantying and certifying projects; coordinating stakeholders (including citizens) and manage the respective information flows [2]. However, many cities seem to prefer other actors to take up this coordinating role and are still experimenting with different ways to organize, foster, and sustain these initiatives [3]. Clement et al. [5] claim that this central role of local government in managing the ecosystem is essential, but only up to a certain point, after which, diseconomies are likely to arise because the local government is unable to standardize the dynamics in the collaborative ecosystem. This suggests that collaboration with more stakeholders increases coordination costs, which ultimately leads to an optimal size that offers the best combination between the value that can be brought by the presence of more stakeholders and the added costs associated with those collaborations. This may be seen as a negative reinforcement loop that prevents urban innovation ecosystems from growing beyond an optimal number of stakeholders. This barrier often emerges when smart city initiatives attempt to expand to the regional or national level [17]. 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. [22]

5 Discussion

The insights from the review suggest that innovation practices in smart city initiatives seem to be framed by a key trade-off between the idea that only global solutions may be able to capture the full benefits of digital innovation and the idea that each city is unique and must pave its own way to digital transition.

On the one hand, it is widely recognized that the local context should play a key role when transforming broader smart city concepts into specific policy actions [13], and that the promotion of a local innovation ecosystem with multiple stakeholders can significantly increase the ability of a city to pursue its own smart city initiatives. However, this policy of many city-specific ecosystems, leads to many local solutions, all of which face many challenges in regard to their dissemination and replication, leading to an inefficient innovation context.

On the other hand, a global solution has a unique capability to congregate the multidisciplinary knowledge, the capital and the domain expertise that are required to address the growing complexity of urban information systems and

produce solutions of excellence. They may also provide a context for the emergence of large scale and distributed innovation, where multiple entities can benefit from and learn with innovation anywhere in the system. However, platforms are often conceived as universal solutions that rely on the assumption that cities can be shaped to align with the design principles embedded in the platform operation [6], when the exact opposite would be expected. This may compromise the autonomy and uniqueness of each smart city initiative.

These results suggests that the answer to our second research question, regarding alternative innovation practices for digital platforms in smart cities, may be associated with the ability to untangle this trade-off, addressing the issue of how to enable cities to leverage the transformative force of platforms while also preserving their many specificities and their own digital transformation paths.

Based on the analysis of the challenges described in Sect. 4, we elaborated five design principles for digital platforms in smart cities, which aim to align smart city development with the capabilities of digital innovation. These principles are independent of any particular platform technology, and should be applicable across a wide range of platform models.

Principle 1: A Platform of Many Independent Services. The first principle is to explore a platform design inspired by micro-service architectures. Under this principle, the digital infrastructure of the smart city, would be composed of a multitude of smaller and autonomous services. Each service is conceived as a self-contained unit of logic, with its own unique functionality, data storage, business model and interoperability mechanisms. These services should follow a service-dominant logic [31], with a profound understanding of the concrete nature of the target problem and strong insights about value co-creation [32]. They should also offer a strong solution to a specific, bounded and relevant problem that is common across many cities. The assumption is that these services would be developed independently by multiple providers to address multiple, very diverse and possibly overlapping needs, creating a heterogeneous offer that cuts across the many dimensions of urban digital transition.

By breaking down the vision of large global platform systems and focusing instead on compositions of smaller services, this principle should significantly facilitate the continuous and mutual alignment between a strategic vision for the smart city and the information infrastructures needed to pursue that vision. A strategy based on the composition of smaller services can offer a smoother development path based on the progressive, but steady integration of technology. Smart city initiatives in the early stage, would no longer be constrained by the lack of a strong strategic vision and they would no longer be pushed into large and risky investments under conditions of major uncertainty. Instead, they could start with simpler and less risky steps and, then, learn with the process to continuously realign their strategic vision and their technology infrastructure. Small services can thus offer a much-needed flexibility to allow the strategic vision and the technological infrastructure to evolve independently, and still be able to mutually adjust as needed.

A development strategy based on smaller services targeting concrete problems is also more likely to align investments with concrete value creation and, thus, reduce the risks associated with technology-centred views of smart city development. A focus on smaller, but more concrete problems, makes it easier to create offers that are much closer to concrete city needs and can thus be much more efficient at delivering real value, rather than just technological infrastructures. Technology development could follow a lean paradigm, based on smaller viable solutions that promote diversity, reduce risks, support experimentation and allow innovation to emerge from simpler and more concrete steps. Services that fail to deliver real value should be easy to identify and be discarded before becoming a waste of resources or an obstacle to better solutions.

A steady and incremental development of the technological ecosystem can also be very beneficial from the perspective of funding. Instead of complex upfront investments, funding can be transformed into a predictable budget. This may help to safeguard economic sustainability and is more aligned with the funding restrictions of many local governments. Finally, smaller service units offered by multiple independent providers can help to reduce dependencies from any single provider and thus avoid vendor lock-in. The fact that services address a smaller scope, also means they should be easier to replace by similar ones.

Principle 2: Global Solutions. The second principle is the assumption that these services will be offering globally available solutions to be used across many cities. Most urban problems are largely shared by many cities. For most cases, only a global solution will have the capability to congregate the capital, the multidisciplinary knowledge, the domain expertise and the multi-deployment insights that are required to address the growing complexity of urban information systems. These services would be much smaller than large global platforms, but within the scope of their target value proposition, they should offer the type of top-quality solution that today can only be found in larger platforms.

The vision of global services should still be compatible with the specificities of each city. Different strategic visions and development priorities should be matched by specific selections of global services. Unlike platforms that promote homogenization, this platform model would be composed of many smaller heterogeneous value propositions, allowing cities to pursue their specific strategy, without necessarily recurring to city-specific technology. This would provide a direct path to address the trade-off between the quality of technical solutions and the specificities of each smart city initiative.

These global solutions will offer an obvious channel to scale the distribution of expert knowledge across multiple cities. By being embedded with top expertise, these services can significantly reduce the expertise demand on each city and help to mitigate the lack of advanced knowledge that permeates local innovation ecosystems. This congregation of knowledge becomes seamlessly available to all the cities using the service. Services will thus become a context for the provision and scalable distribution of expertise that can help local governments to mitigate their own limitations.

As global solutions, these services should also become the enablers for specific value chains involving diverse collaboration patterns between multiple types of stakeholders. This would be very different from local innovation ecosystems where these collaborations need to be explicitly promoted and are normally limited to a small number of stakeholders. Instead, in these services, collaborations between multiple stakeholders are directly embedded into the service design, which defines its own value chain, and the roles of the various types of stakeholders involved. This should allow interactions between stakeholders to be orchestrated to optimise the value generation process and the concrete value proposition offered by the service. As a consequence, collaborations can be much more scalable, because they are based on low-cost interactions, and much more effective, because they are already part of value co-creation processes embedded in the service design. This reduces collaboration barriers and enables collaborations between large numbers of potentially very diverse stakeholders.

Principle 3: Multi-city Communities. A fundamental challenge emerging from the review is the fragmentation of urban innovation ecosystems. Each city tends to develop its own ecosystem, and collaborations between cities are far from being the rule, even when they are dealing with the exact same issues. 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 highly inefficient that each of them may operate as an isolated reality and be unable to share the innovation process with other territories.

Platform services should thus be conceived as more than global applications ready to address the similar needs of many different cities with a common solution. They should also provide a context that promotes their collaboration, either explicitly or not, as part of the solution itself. While, global solutions may offer the benefits of scale and access to advanced expertise, the shared collaborative environment of a multi-city operation should bring the benefits of connected intelligence. Services should thus be able to explore the collective wisdom and the co-creation possibilities that can emerge from the availability of data and activities that cut across all those territories.

According to Panori et al., [19] 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, such as online collaboration, data analytics, object classification or forecasting, they allow analytics and AI to further enhance human skills. A multi-city operation provides the context for these two sources of innovation, by producing crowdsourced knowledge, advanced analytics, AI, and large scale distributed learning. This is essential to unleash some of the most powerful capabilities of digital innovation that rely on the ability to connect human, collective, and machine intelligences

Despite serving as a generic solution, a service designed for many cities should be policy agnostic, avoiding any major assumptions about local urban policies.

Instead, there should be an explicit separation between service features and any parameterization that may define how those features are affected by different urban policies. This should allow cities to define their own operational settings to match their specific strategies. This is essential to preserve the uniqueness of each territory, but is also a driver for shared innovation. The diversity of strategies explored by different territories within the scope of the same service should become an important source of value, experimentation and shared innovation, allowing city-specific strategies to be combined with larger knowledge flows that can significantly expand the breath, depth and sustainability of the innovations involved.

This layer of collaboration between multiple cities is not meant to replace the role of urban innovation ecosystems, but it complements those ecosystems with the ability to trigger the explosion and multiplication of innovation actors (nodes); multiple forms of crowdsourcing and user engagement; glocalisation of knowledge and specialisation by mixing local and global competence and know-how; informed intelligence and discovery based on data [19]. These services can become the enablers for many new types of boundary-spanning collaborations that cut across multiple local ecosystems [27,30,34]. As they have the ability to frame low-cost and very scalable collaborations between many stakeholders, these services should not be bound by the constraints that normally define the maximum number of partners in an effective collaboration.

Principle 4: Service Recombinations. The downside of the division into many smaller and autonomous service units is the risk of fragmentation, with each service becoming its own data and functionality island. Despite their autonomy, these services should maintain their ability to share resources and promote collaborative innovation. These are the same motivations that are commonly used to justify the need for data-centric architectures that aim to abstract core data needs and allow services to be built on top of those common data layers. However, such data-layers are often based on strong assumptions about the nature of the data and the types of applications that will use it. Unlike data-centric architectures, we propose a mainly vertical organization of those services, where each service is focused on a specific value proposition for cities. Any data interoperability should be shaped by the needs and opportunities associated with the delivery of that value proposition. This is the opposite of common data-centric approaches where data is expected to come first, and then applications will naturally emerge.

The goal is to enable arbitrary and unexpected connections between multiple services to become a tool for open innovation. These should be loosely coupled associations, most likely based on indirect communication models in which any service can potentially be recombined with others through the exchange of specific data resources that can act as convergence points between multiple services. The use of well-know or standard data formats or APIs should offer many opportunities to promote the emergence of such convergence points. Still, these connections should never be seen as essential for the service operation, and

should only emerge as additional value generation opportunities resulting from the shared used of data produced by those services.

Principle 5: Platform Governance. Another dimension of fragmentation involves the many functional elements that may be offered with significant advantages at the platform level rather than at the service level. The first group involves features that are common across most of the services, and do not benefit from many unique implementations across the various services. These features should be identified, characterised and developed as common platforms services. Common examples may include generic horizontal services, such as identity management, service discovery and service subscriptions. Like any middleware strategy, this should reduce development effort and significantly increase the quality of those implementations. This would be more convenient for service developers and would allow turn-key solutions with reduced barriers for new ideas [2].

The other group involves coordination features that can only be addressed from a collective perspective, rather than from the perspective of a single service. For example, a service platform should offer marketplace services to create awareness about existing services. The existence of a coordination layer above the multitude of endless and diverse services offered by multiple providers, can significantly enhance the efficiency of the whole system, in a number of ways. A system-wide perspective enables new valuable perspectives that would never be possible from a single service perspective, e.g. matching problems to possible services, matching services to territories with compatible resources or matching services to convergence resources.

6 Conclusions

Digital Innovation represents a major transformation force for cities. However, cities are highly complex ecosystems where innovation relies on contextual elements that can be hard to align with the properties that can make digital innovation a source of powerful and fast paced innovation. This results in a much slower progress or even frustration with the smart city concept.

The first contribution of this work is the identification of key limitations associated with current innovation processes in smart city initiatives. Based on the results of a Systematic Literature Review, we analysed those limitations and nailed down the problem to a trade-off between the idea that only global solutions may be able to capture the full benefits of digital innovation in smart cities and the idea that each city is unique and must pave its own way towards digital transition. The second contribution is a set of five design principles that aims to address those limitations and provide new directions for the design of digital platforms for smart cities

These new directions should support the ability to pursue large scale shared innovation, without imposing any homogeneous view about smart city priorities, policies or collaboration patterns. Platforms designed under these principles should embrace the diversity of urban ecosystems as the essence of what

cities are, and never as a problem. They should also embrace this diversity as the essence of innovation itself, by offering broader innovation ecosystems where the independent experimentation of many alternative directions may become a major source of innovation. This implies that the knowledge generated by those experiments can be shared, leading to a thriving multi-city innovation ecosystem, with the capability to learn much faster and much more efficiently than what is possible today.

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