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Experimentation Platforms as Bridges to Urban Sustainability

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Abstract: Despite immense efforts to realize diverse visions of the 'smart city,' municipalities still face manifold uncertainties of how governance and the tools of governance can best support public and regional value creation for achieving urban sustainability. To this end, Urban Living Labs have become a known enabling mechanism. In this paper, we extend the lab idea and formulate the concept of Urban Experimentation Platform that focuses on developing urban innovation ecosystems for urban sustainability. We use action design research and participant observation across multiple case studies enacting Urban Experimentation Platforms in order to investigate how the tie-in between governance and the local lab's innovation process unfolds. Our analysis distills three facets that are instrumental in institutionalizing these platforms as resilient organizational models. With the help of the case studies, we illustrate the three facets, concerning issues of urban ecosystem governance, empowering co-creation, and qualifying local innovation. The facets reinforce the roles of digital instruments and digital capabilities for effective urban governance and platform management. We draw some conclusions for future research and formulate policy recommendations for implementing and operating Urban Experimentation Platforms.

Keywords: digital platform; urban development; urban ecosystem; urban experimentation; urban governance; urban living lab; urban sustainability

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1. Introduction

The global trend of urbanization reinforces the significance of cities and metropolitan regions as drivers of global change [1]. The United Nations thus recognizes them as crucial in achieving sustainable development on a global scale [1–4]. Sustainable urban development means tackling current urban challenges including rising energy and water consumption, pollution, greenhouse gas emission, growing population with a quarter of the urban population living in slums, social exclusion and discrimination, issues of managing disaster risk, and others. To this effect, we still face fundamental and insurmountable questions on how to conceive and organize evolutionary, *resilient organizational models* for cities towards a sustainable future [5–8]. Research has thus called for locally and regionally directed and enforced implementation of impactful sustainable development strategies to achieve urban sustainability in terms of ecological effectiveness, and *equitable* economic growth and social development [9]. The preeminent current perspective on urban development is thus one that focuses on urban sustainability as formulated in the *United Nations' 2030 Agenda for Sustainable Development and New Urban Agenda* [3,4].

Urban development, while existing as a social phenomenon since the Neolithic age, has seen prolific progress in lieu of the industrial revolution since at least around the 19th century. Cities turn agglomerations of people into living environments, economic and cultural centers, and accommodate businesses and public institutions that reinforce geographically concentrated clusters of industries [9]. Urban development has since been viewed as strongly linked with social, economic, and technological advancements [10,11].

It is thus not surprising that city municipalities today expressly engage in policy agendas for strategic spatial development planning in order to re-frame social, economic, intellectual, and political capital with the aims of institutional territorial integration and re-invigoration of territorial identities [12]. In this vein, cities have extended their task of urban governance related to improving urban life and policies, by city management, closely linked with sustainable development and city competitiveness [13,14]. City competitiveness aims at ensuring economic size and growth, achievable by creating attractive regulatory environments for businesses, people, culture, and the environment [14,15]. Various factors contribute to sustaining city competitiveness, such as institutional conditions, place attractiveness, branding and identity, and strength of the local innovation system [16]. In this respect, cities require *resilient organizational models* that imbue the capabilities that can attract, develop, and retain capital, businesses, and human talent, as well as continued exchange with other economic centers, and that support the goal of urban development towards urban sustainability.

Our research investigates how such resilient organizational models can be conceived and institutionalized by municipalities as a part of urban governance. In this paper, we discuss *urban experimentation culture* as a precondition for achieving locally relevant innovations that can lead to city competitiveness and urban sustainability. We highlight the roles and links between urban ecosystems, Urban Living Labs, and digital platforms. By drawing on insights from various large-scale smart city initiatives seeking to cultivate innovations that contribute towards city competitiveness and urban sustainability, we investigate how the tie-in between governance and the local lab's innovation process is accomplished, and consequently conceptualize Urban Experimentation Platforms that link city and ecosystem governance, experimentation practices, and local innovation. In Section 2, we first take a closer look at literature related to urban experimentation culture, in order to derive three facets that characterize organizational models for urban experimentation. In Section 3, we showcase insights from previous case studies on each of these facets. Section 4 formulates a concept of Urban Experimentation Platforms and Section 5 provides a short conclusion.

2. Urban Experimentation Culture

2.1. Experimental Governance

When discussing organizational models for urban sustainability, one needs to take into account that such models always originate from—and nourish on—urban business ecosystems. *Urban business ecosystems* can be considered the regional multiplicity of business ecosystems, with their ensuing networks and cooperation that offer the breeding ground to collaboratively innovate in business, culture, and policy [14,17]. Such ecosystems connect a variety of diverse stakeholder groups such as the government and utility providers (city and district government, water and transport utilities, etc.), academia (research institutes, Universities or apprenticeship programs, etc.), entrepreneurs (including co-working spaces and seed investors, etc.), and all kinds of businesses and intermediaries (job platforms, funding agencies, etc.) [14] (p. 116). In their extent and expansiveness, city ecosystems provide substantial economic development potential. Yet, conceptualizing and implementing organizational models that embrace urban ecosystems by seeding, orchestrating, and exploiting them for the goal of urban sustainability is challenging due to the ecosystems' inherently complex and elusive nature. In addition, the opportunities and authorities of stakeholders as *actors* in the wider context of addressing societal challenges are generally asymmetric, which is reinforcing the role of municipalities vis-à-vis other stakeholders because of their legitimacy as formal decision-making body [18,19].

Consequentially, municipalities with 'smart' agendas are increasingly fostering a culture of experimentation to stimulate collaborative innovation in urban ecosystems for addressing urban challenges [19–24]. The experimental approach rests on the assumption—and faith—that pressing city challenges can be tackled by paying close attention to the interdependencies of the diverse values, norms, and interests existing in our societies.

The aim is to engage in dialogues across co-existing worldviews with their divergent motivations and justifications that enable context-driven, problem-focused, and interdisciplinary knowledge production transcending spaces in science, society, business, and policy [25]. Thus, instead of waiting for supra-national or national policies to take hold, municipalities utilize diverse forms of experimental governance in order to facilitate more rapid, context-specific action at a smaller, regional scale, and to potentially arrive at more locally resilient and robust solutions[26,27].

Experimental governance as it has been conceptualized in literature can appear in different forms [23]. *Policy experiments* refer to the notion that any policy measure or intervention is to some extent fragmentary and unfinished. It is a notion often invoked on larger scales for (cross-) national initiatives that allow different degrees of influence and agency of citizens in the process of developing policy questions and related knowledge. Here, the public becomes involved with projects and initiatives with varying degrees and control over the processes; *citizen engagement* happens along with collaborative and co-created projects, and current mobile and social technologies allow for advancing citizen-generated content through practices such as data mining from public data, crowdsourcing, or citizen science [25] (p. 7). However, we might also see this type of policy in the context of *emergent developments* at a smaller scale, such as examples from the COVID-19 pandemics illustrate. Such policies might be taken as examples from *niches of innovations* in which public and private stakeholders engage in iterative feedback processes, and which potentially become drivers of change at a larger scale [28].

2.2. Urban Living Labs and Laboratories

Urban laboratories, or labs, instantiate local innovation by encouraging "urban creativity" through spaces for open and engaged learning between diverse stakeholder groups including citizens and municipalities, to support knowledge creation and sharing [29–31]. The idea is best known through the concept of Urban Living Labs (ULL), realized as public spaces allowing local authorities and citizens to interact in open innovation, experimentation, and citizen involvement towards locally oriented service design [32–36]. While municipalities are frequently acting as creators and promoters of labs, equipment, technological devices, or services to be tested, co-designed, and co-created by citizens, are often provided by participating businesses [36]. In general, labs are often implemented, coordinated, or backed up by university-led partnerships as to their authority in knowledge production, but increasingly also by private stakeholders such as business incubators [29]. Labs have been implemented in various ways such as approachable inner-city labs resembling co-working spaces, hackathons, pre-commercial procurement initiatives, digital districts, or others. They intend to "*[let] local actors test and experiment in sustainable solutions within diverse areas, ranging from technical solutions to services and policy innovations*" [37] (p. 718). This way, labs realize the 'quadruple helix' idea, i.e., collaboration among public authorities, firms, research organizations, and people in a real-life context [38] (see also [39] (p. 65)), and provide various stakeholders with the opportunity to share experiences and to facilitate broader processes of policy learning and knowledge dissemination [37,40]. In particular, labs allow municipalities to act in the rather new capacity of an *enabler* [19], extending roles such as intermediaries [41], networkers [42], or trend spotters [43]; as enumerated in [37] (p. 719).

Despite the experiences existing from numerous distinctive case studies of implemented labs around the globe, and even with the insights achieved about the role and potential benefits of experimental governance, there is still significant uncertainty with respect to how municipalities can build and sustain an experimentation culture with the help of appropriate measures. Particularly, *extending* individual initiatives, in order to *scale* beyond individual projects, and *sustaining* experimental governance initiatives by *embedding* them into existing modes of governance, constitute major challenges [24,44].

2.3. The Role of Digital Technologies in Smart Cities and Urban Experimentation

Urban development has always been strongly connected with technological development. Had it been technologies for transportation, building, and communication in the past that led to radical and breakthrough transformations of the urban landscape, today the most recent information and communication technologies (ICTs) with their capabilities and related paradigms such as Cyber-Physical Systems [45], robotics [46], or the Internet-of-Things (IoT) [47] enable the rapid and comparably silent, at times invisible but ubiquitous, realization, distribution, and integration of virtual and digital capabilities into our living environments. Within an urban context, these digital capabilities are grounded in *urban data* [48], which can be defined as "*data concerning one or more town or city spatial region(s) physical, social, cultural, political or economic environment*" [49]. Thus, urban data are about a town or city regions' citizens, its infrastructure, its businesses, government, and natural environment, etc. For example, the 'Citymapper' application system (app) acquires and exploits urban data to offer citizens the value of improved wayfinding across several European cities [50].

We largely address these ICT-driven aspects of change in urban development as some of the enablers of the "smart city" [51–53]. Research on 'smart city' has early-on characterized urban development with help of the "smartness" metaphor, which is particularly emphasizing the availability of appropriate ICTs [54] (p. 10). The smart metaphor relates to "smart . . . " economy (competitiveness), people (social and human capital), governance (participation), mobility (transport and ICT), environment (natural resources), and living (quality of life), as Giffinger et al. explain: "*A Smart City is a city well performing in a forward-looking way in these six characteristics, built on the 'smart' combination of endowments and activities of self-decisive, independent and aware citizens*" [54] (p. 11). To date, apart from specific technology implementation projects, particularly *strategic* aspects of smart city development have been discussed from various angles including quality of life, physical infrastructure, urban computing, and others more (e.g., [52,55–57]).

In this context, digital technologies do not only play a role as enablers, for instance in the form of apps that automate urban services. They increasingly play a role in managing distributed service delivery and related data management, e.g., through apps such as electric power control panels for the city utility provider [13]. Such apps also facilitate data collection in the public space, making data a resource for future service development [58,59]. Together, these diverse digital capabilities for data and information management are founded on what has been termed Urban Information Systems (UIS) [60].

In addition, digital platforms have emerged as management instruments to operate and collaborate for urban governance in the context of urban ecosystems and policy-making [61,62]. While extant research on ecosystem governance and digital platforms has primarily focused on strategic aspects [63–65], surprisingly few suggestions have been made for how *urban* ecosystems can be practically leveraged for urban governance (see e.g., [14,61,66]). Digital platforms provide for *collective resources* that can be co-created and utilized for cooperative innovation, and thus principally constitute a basis for coordination of collaborative experimentation activities—independent of the organizational form within which they are carried out [67].

In the context of urban experimentation, research has shown that digital technologies can help foster creativity and learning, and thus promote the development of knowledge through citizen engagement [68]. This effect is reinforced by the increased awareness and use of digital technologies in our daily life—thinking of the factual ubiquity of mobile and 'edge' devices such as smart speakers and sensors, or the use of social media.

In sum, we can say that research has acknowledged the diverse, yet distinct, roles digital technologies play in urban development, particularly under the lens of the 'smart city.' Yet, an integrated view of how these roles inference with each other, and specifically, how they contribute to urban governance and urban sustainability, has not been obtained [69].

Moreover, while literature studies have emphasized that research on smart cities in general "[shares] the same notion of smart cities as being urban areas in which ICTs become

a mean for supporting urban innovation and sustainable development," they have also revealed four predominant dichotomies in smart city-related publications (p. 64, [39]), [70]. These pertain to whether to take an approach that is (a) techno-led or holistic, (b) top-down or bottom-up, (c) double or triple/quadruple-helix, or (d) mono-dimensional or integrated [39] (pp. 64–65). These contradictory research lenses lead to a knowledge gap with regard to "whether the urban transformation, which smart cities develop as pathways to the future, can be mono-dimensional, vis-à-vis technical, or if they need to integrate a multitude of other human-centric and people-driven factors" [39] (p. 65). This knowledge gap characterizes urban development as complex, socio-technical transformation processes, which necessitates a holistic approach. Particularly, it represents an imperative for organizational models to become resilient, adaptive, and evolving, in order to build bridges to urban sustainability. In effect, the imperative advocates governance approaches that are open, transparent, interactive, inclusive, and participatory—intending to leverage distributed cognition and collective intelligence within the scope of urban ecosystems [71,72].

These insights lead us to discuss opportunities for how digital technologies can support the implementation of resilient organizational models for urban experimentation. In our report from various case studies, we will therefore point out distinct contributions of digital technologies and, particularly, digital platforms, for urban experimentation.

2.4. Facets of Organizational Models for Urban Experimentation

In order to play a lasting role in urban governance, Urban Living Labs as well as other forms of labs need to formalize and institutionalize 'open innovation' [32]. To this end, labs have been characterized and discussed in the literature as landscapes, real-life environments, and/or methodologies [73]. As a *methodology*, they allow to routinize practices of collaborative innovation, i.e., making co-creation and real-world experimentation actionable [21]. Viewing labs as part of a landscape, or as a meeting place within our urban real-life environment, means they need to become persistently, institutionally embedded into urban governance structures and the network of urban ecosystem stakeholders—all resonating with the citizens' engagement fostered by the practices of collaborative innovation [24].

Overall, integrating these three attributes, labs resemble an integrative *organizational model* in urban governance. As such, they raise various questions about how to make them resilient; among them is their attractiveness to citizens, municipalities, and urban ecosystem stakeholders (or 'user recruitment'), their financial and funding stability, the received policy support, and their embeddedness to urban governance, scalability, and their impact and effectiveness on local and (supra-) regional levels [24,44,73–75].

Understanding experimentation as an organizational model also involves purposeful creation of the set of actors involved in managing labs, activities such as co-design, training, transfer, etc., and the set-up of resources for experimentation (see also [24]). In this respect, labs as organizational models are enacted through their formal institution, management, value creation processes, facilitated (innovation) methodologies, and management of human, financial, technical, and spatial (e.g., workspaces) resources.

From the insights achieved by prior research, we see three interrelated facets emerge that characterize *resilient organizational models* for urban experimentation, which we refer to as facilitating urban ecosystem governance, empowering co-creation, and qualifying local innovation.

With regard to *facilitating urban ecosystem governance*, the prominent role of municipalities and public sector (city-funded) projects in the success of labs has been acknowledged in prior research, thus emphasizing the imperative for sustaining the allocation of public funding and other resources [76]. Particularly, when focusing on the long-term institutionalization of labs, a user-/citizen-driven approach to solving pressing local problems, and an embedding of the lab into regional networks of contributing organizations, is imperative [76]. These activities also strengthen the *visibility* of labs as institutions, which is

important because, often, local urban ecosystem stakeholders are not aware of the benefits of engaging through labs [44,76].

With regard to *empowering co-creation*, such visibility, as well as a focus on creativity and innovation, reinforces the potential for both, initiating new stakeholder cooperation, and safeguarding the effectiveness of innovation outcomes [77]. Experiences from past projects indicate that effective co-creation practices/mechanisms need to be implemented in order to ensure diversity in cooperation between stakeholders, raising the innovative capacity of collaborations, and warranting enduring commitment [44,77,78]. In this regard, participation in co-creation projects is higher when citizens perceive they are 'making a difference' [79].

This perception becomes a driver with regard to *qualifying local innovation*, which focuses on the scope and range of innovation outcomes possible. When insufficient resources are available or assigned to lab operations, this can hamper innovation outcomes [44]. This becomes problematic, because public funders often condition support on a 'clear return,' and private business stakeholders have been found to be particularly incentivized to participate when adequate resources are put in place, reducing perceived risk [19]. Co-creation involves individual involvement and action [80] as well as long-term relationships between municipalities and citizens or organized groups of citizens [81], which suggests *institutionalizing* experimental arrangements between stakeholders. While in the above description of facets, we have argued for relations between the first two, this latter argument links back to the first one on the level of ecosystem governance. This shows that all the three facets are closely interwoven yet persist on different *levels* of discussion and require diverse *means and instruments* to become operational.

In the next sections, we use these facets as an analysis frame for multiple case studies. Bringing together insights from these facets as perspectives on urban experimentation and looking at how digital technologies support each of them will allow us later to conceptualize Urban Experimentation Platforms as the digital foundation for organizational models of urban governance.

3. Organizing for Urban Experimentation: Case Study Insights

3.1. Method and Case Study Settings

Our research presented here is based on insights from multiple concluded case studies in which the authors were involved as researchers. Data collection as well as the authors' holistic experiences during the case studies provide a rich reserve of insights for considering the facets of organizing for urban experimentation. We particularly draw on three large-scale smart city initiatives to characterize each of the three previously identified facets of organizing for urban experimentation. These initiatives are a mobility ecosystem study for facilitating urban ecosystem governance, outlined in Section 3.2; the pan-European, EU Horizon 2020-supported collaborative research project *OrganiCity* to address the facets of empowering co-creation in Section 3.3, and the EU projects *Making Sense* and *OrganiCity* for qualifying local innovation, in Section 3.4.

Our research particularly intends to provide insights into how the tie-in between governance and the innovation process of local labs can be accomplished and sustained as part of an organizational model. To this end, the case studies provided a fertile ground for gathering experiences because each featured specific problem settings and boundary conditions for urban experimentation. As our aim is to inform both research and practice, we frame our work as *action design research* (ADR) [82–85]. Methodically, our case studies can be positioned in the ADR 'beta' research cycle of the 'building, intervention and evaluation' stage of ADR in its organization-dominant form that includes the operational system use [85].

In the case studies, ADR integrates action and design research to build and implement digital tools and related processes for the specific organizational and urban context. The authors were embedded observers, and in many cases, involved in the case studies through project planning and management, analysis of problem settings, operative imple-

mentation of digital tools and facilitation with stakeholders, revision of tool and process designs, and further activities. *Participant observation* accompanies the processes related to the design of digital tools and allowed the researchers to learn from interactions and interventions in collaboration with stakeholders. Together with ADR, this approach generates prescriptive knowledge, which is instrumental for comprehensively understanding issues and challenges related to the design and implementation of digital platforms for experimentation and lab-based innovation [86]. During the case studies, as will be detailed below, various digital tools have been designed, implemented, and iteratively refined with help of stakeholder interactions. Our further report in Section 3.2–3.4 connects to the authors' experiences from these case studies to formulate insights that become prescriptive towards policy recommendations for implementing and operating Urban Experimentation Platforms (Section 4).

3.2. Facilitating Urban Ecosystem Governance

3.2.1. Case Study: Insights from Visualizing a Mobility Business Ecosystem

In order to characterize this facet of urban experimentation, we report insights achieved as part of a smart city initiative addressing the Munich metropolitan region [59,87–89]. As part of this initiative, our research engaged in a community-based, agile approach to model and visualize the urban ecosystem related to the mobility of people in the metropolitan region, or *mobility ecosystem*. In addition, this research comprised our own software engineering design work and a field-test of the developed system prototype of a visual analytic system (VAS) in two case studies we conducted in close collaboration with industry partners [88].

The city of Munich in Germany has a population of more than 2.5 million in its urban area and more than 5.5 million in its metropolitan region. We measured the mobility ecosystem to embrace more than 3.000 firms in the automotive, traffic, and logistics sectors residing in the urban area and more than 18.000 firms in these sectors in the metropolitan region (approximate numbers base on local authorities' and chambers' of commerce publications).

We considered this mobility ecosystem 'in a nascent state,' because the majority of firms and organizations had not yet transitioned into widespread adoption of digital platforms for coordination or collaboration. The structures of this mobility ecosystem were thus emerging as affected by public authorities who re-evaluated their policy and regional development activities, and by businesses trying to co-shape the evolving mobility ecosystem.

In this process, understanding the ecosystem's evolution process is instrumental for developing public policies, for making strategic decisions about business and technology partnerships, or for identifying gaps in the service provision to consumers as extant research has shown [90]. The proactive management of the urban ecosystem is gaining relevance for firms as well as municipalities [90]. Particularly, firms have to adapt their own competencies to their specific (part of the) ecosystem to achieve complementarity [88,91]. However, surprisingly few suggestions have been made in research and practice for management instruments that help in purposely creating, managing, and governing urban ecosystems [62]. Thus, the aim of this research was to develop tools for analysis and visualization that provide ecosystem stakeholders, including public authorities as well as businesses and citizens, with information that can stimulate knowledge processes and support related decision-making.

The developed VAS software prototype, named *Business Ecosystem Explorer (BEEx, https://ecosystem-explorer.in.tum.de*, accessed on 31 March 2021), uses urban data—primarily about the ecosystem stakeholders—to create various layouts, i.e., graph representations of data, visualizing ecosystem stakeholders, their business relationships, and partially, their services. Figure 1 shows one type of layout, a chord diagram, which represents various types of stakeholder relationships. From the overall analysis of ecosystem stakeholders, we identified 16 significant stakeholder groups. These either act as service providers, such as car manufacturers, energy suppliers, insurance firms, public institutions, or transport

organizations, or as service solutions providers such as mobility service providers, mobility information providers (e.g., traffic sites), or specific mobility projects [59].

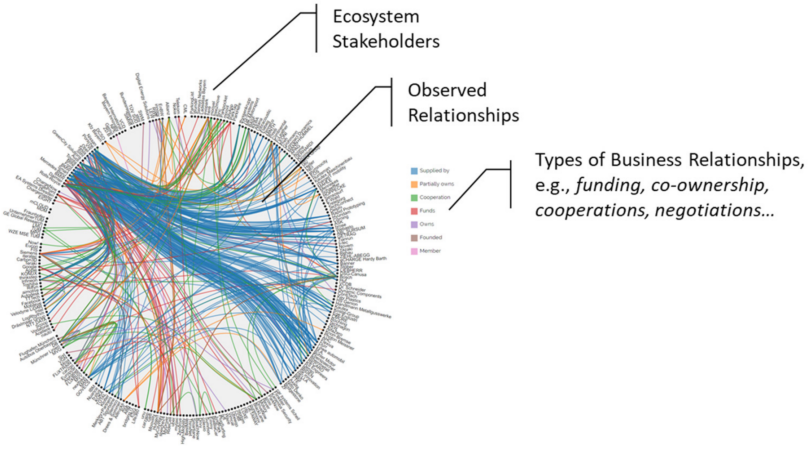

Figure 1. Structure of one visualization layout (chord diagram) to analyze urban ecosystem stakeholder relationships.

The urban ecosystem stakeholders can then tailor and use the various layouts for supporting their business- or policy-related tasks and decisions. Its implementation as a governance tool and the required data collection are supported by an agile modeling framework and project approach to ecosystem modeling, which describe how ecosystem analysts, experts, and data scientists together collect ecosystem data and evaluate and interpret visualizations [89]. A detailed overview of the software and project design is presented by [59], who also argue in which way this tool helps in responding to the challenges in ecosystem modeling.

3.2.2. Open Digital Platforms for Urban Ecosystem Governance as Governance Tool

As our case studies show, in order to be responsive to the continuous change of the urban ecosystem—and respectively, urban data—*continuity in data collection, analysis, and management* is required. We have thus argued for establishing shared urban governance boards and open digital platforms *as governance tools* that become reference points in urban governance (see Figure 2). Such digital platforms might be 'open' with respect to their users, uses, and functions, including leveraging urban data for informing and coordinating ecosystem stakeholders, and allowing to substantialize business consortia to innovate in services. Platforms might be dedicated to distinct ecosystems such as for contexts of mobility, energy, safety, and so on; each supported by distinct functionality for urban data visualization and analysis. Urban governance boards are intended to enforce participation across stakeholder groups, and eventually, involve citizens by stimulating and overseeing experimentation and crowd-based approaches. For instance, an *Ecosystem Data Editorial Office* to supervise data collection; an *Urban Data Governance Board* whose task, in contrast, is focused on data regulatory issues; and an *Urban Ecosystem Board* including citizen representatives along with experts from business, public, and academia organizations to represent various stakeholder groups in the urban ecosystem [87,89], which might again be subdivided according to required contexts as are digital platforms (e.g., as "Urban Mobility Board"). *Urban experimentation laboratories* are instrumental in achieving citizen engagement and relevant innovation outcomes, as they link citizens, service or policy experimentation, and developments with governance; accordingly, they might take various forms like living labs or group initiatives, etc.

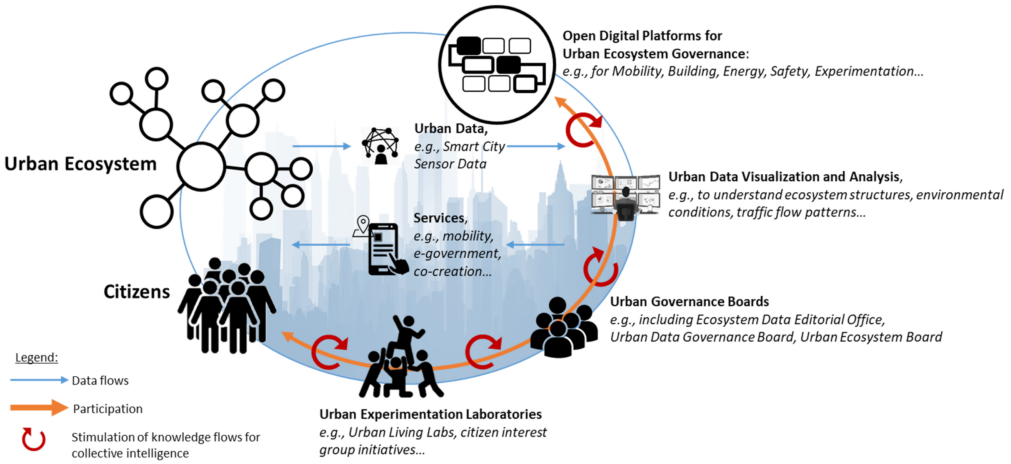

Figure 2. Open digital platforms supporting collective intelligence and organizational models for urban governance.

As we have observed in our research, visualizations constitute a data reference point for policy development for all ecosystem members. As a shared reference point, these data can become the center of open digital platforms to stimulate and fuel knowledge processes [59]. When stakeholders and municipalities engage in cooperation on the basis of the provided data and analyses together, they can thus base their decisions on a shared data basis, so that *collective intelligence* can be leveraged. Figure 2 illustrates this concept of how *open digital platforms for urban ecosystem governance* together with organizational units enable a citizen participation process to urban governance that builds on experimentation, data management, and governance of ecosystems to stimulate knowledge creation and exchange in order to leverage collective intelligence. This way, open digital platforms provide for a digital foundation of collective intelligence and for an organizational model of urban governance. Future research will need to sort out scales and scopes of data collection, functionality, and involvement of the various stakeholder groups, in order to be effective towards *experimental* governance approaches as well as into *sustained* urban governance.

Lacking long-term studies of stakeholder interactions in the context of urban governance, it is still an open question of how *continuity* in data management and citizen engagement can be achieved and organizational units such as the ones proposed above can be institutionalized. In addition, without long-term projects that feature such institutionalized tools, platforms, measures, and organizational units, it will be difficult to project what kind of data analyses are required, and hence, what kind of data cities will need to collect [62].

Our research on visualizing a mobility ecosystem as one kind of urban ecosystem showcased that collecting urban data and visualizing and analyzing them with help of specific Visual Analytic Systems helps in revealing ecosystem structures and integrating ecosystem stakeholders in city management initiatives [92,93]. However, to become institutionalized, actionable governance tools with a view towards city competitiveness and urban sustainability are required. In addition, more work is needed to illuminate how communication and knowledge exchange between ecosystem stakeholders can be persistently stimulated.

3.3. Empowering Co-Creation

3.3.1. Case Study: Insights from the *OrganiCity* Project

The EU Horizon 2020-supported collaborative research project *OrganiCity* (OC) implemented a federated network of Urban Living Labs (ULL) across multiple European cities, supported by an "Experimentation-as-a-Service" digital platform prototype, which we refer to as OC-EaaS digital platform. London (UK), Santander (Spain), and Aarhus (Denmark) were the major cities involved, ideal in their geographical, topographical, political, and

cultural differences for this project, as the project needed to evolve to suitably federate experimentation capabilities across differing city contexts. In the project, many of the principles of "smartness of government" [94] could be embedded, whilst addressing various challenges of experimentation for achieving adoption and diffusion of 'smart' technology solutions across numerous case studies.

The remit of the *OrganiCity* project was to develop and showcase a platform capable of supporting urban innovation ecosystems across Europe that address a myriad of pressing challenges to realizing urban sustainability, via the affordance of data-driven solutions. The project was timely, as the nature and potential of *data-driven* urban business ecosystems in Europe is as yet unclear, whereby this project sought to emphasis citizens and other actors in the process of defining the character or make-up of what data-driven urban innovation should look like.

The project took the shape of funding and support mechanisms for over 40 selected 'experimenters,' i.e., businesses, NGOs, etc., all seeking to develop data-driven innovations capable of addressing clear challenges to realizing urban sustainability. These innovations took the form of Internet-of-Things (IoT) systems, Artificial Intelligence (AI) techniques, smartphone applications, and digital platform interfaces, etc.

The principles at the foundation of this project related to (a) *co-creation involving quadruple-helix stakeholders*, seen as important for inclusive design, and for adoption and scalable innovation, (b) *real-world development and testing of innovations* that support their real-world use value, (c) *multiple-city experimentation* to support innovations that can be developed and tested across numerous European cities, and (d) *a 'toolkit' encouraging good practice* and diminished barriers to the innovation, within the context of urban innovation ecosystems. At the core of this toolkit was the OC-EaaS digital platform supporting the availability, interoperability, and visualization of urban data arising from the different experimenters involved, thus supporting thinking and practice oriented towards urban innovation ecosystems.

3.3.2. Implementing Co-Creation Practices

In relation to *empowering co-creation* in urban innovation ecosystems, all aspects of the *OrganiCity* project encouraged co-creation in the thinking and practices of experimenters throughout the innovation lifecycle, from problem formulation, ideation, to testing and validation of design. From an organizational and technical point of view, this centered around four major aspects: (a) City challenge co-creation, (b) systematic co-creation of experiments, (c) digital capabilities for co-creation, and (d) OC facility co-creation, where co-creation was supported with both technological and non-technical elements as discussed further below.

With regards to *(a) City challenge co-creation,* funding calls were developed to address 'cities' challenges', established through a combination of citizen and municipality co-creation activities. The OC team engaged with city officials in developing city challenges through meetings prior to open call funding launches. Activities also included an online 'scenarios' tool, where citizens and other stakeholders could submit scenario-based stories of what their future city could look like, such as transparency in spending, or high-precision indoor wayfinding for the visually impaired. These scenarios could then be rated and discussed by others. The culmination of these activities was better *clarity on key challenges of respective cities*, subsequently communicated as part of the funding open call documentation.

To achieve *(b) systematic co-creation of experiments*, OC required that experimenters implement co-creation practices in order to be funded and supported by OC. Applicants were encouraged to draw from the OC "Engagement Principles" document to aid the design of co-creation activities, as referenced in the funding "open call instructions" to applicants. Requirements took the form of evaluation criteria for funding proposals that included aspects of experimenter co-creation as a facet of scoring criteria. Funding of successful applicants was released in three stages (beginning, mid, end) of their experiment support, so as to

access and advise on aspects of their experiment, particularly the practice of co-creation, and ensure compliance. Furthermore, both online and offline networking/collaboration opportunities for experimenters to identify and share resources, learnings, and identify potential collaborations. These included an online 'Open Call Connect' tool to match-make skills, volunteer spaces/knowledge, and offline meetings/events between experimenters and other stakeholders. Thus, as can be surmised from the above, *systematic co-creation of experiments* was enhanced through *education* (e.g., engagement principles document), *requirements* (e.g., evaluation criteria and staggered fund releases), and *facilitation* (e.g., 'Open Call Connect' and OC hosted meetings/events).

From a technical perspective, *(c) digital capabilities for co-creation* were put in place. Digital capabilities included a federated digital platform and related access portals, Application Programming Interfaces (APIs), and co-creation and solution development tools. The digital platform featured an appropriate architecture for the experimenter, participant, community, and management portals. It encompassed the 'Assets Directory,' which federates all data assets, the Urban Data Observatory (UDO), and related APIs and tools. The purpose of the platform was to provide (a) a single point of access, management, storage, and sharing of relevant open data and experimenter data (from assets generating the data) accessed through the experimenter/management portal; (b) various APIs for accessing and sharing data via the platform; (c) a community portal and participant portal for experimenter engagement with stakeholders such as citizens/users; and (d) a UDO to enable exploration, visualization, and citizen/user annotation and feedback of these data. The UDO was positioned as a service for both experimenters and citizens to view and contextualize data generated via assets available. In summary, *the OC digital platform was configured to encourage the visibility and sharing of data for all involved in the experimentation and innovation process.* For example, experimenters could share data amongst each other through the 'Assets Directory', whilst the UDO online interface enabled citizens to rate and comment on the quality of data being generated.

Finally, *(d) OC facility co-creation* was seen as important to *organically* improve *OrganiCity's* offerings over time. Throughout the OC project, there was an ongoing evaluation of the *OrganiCity* project accomplishments and outputs. Including periodic surveys and interviews with experimenters, city stakeholders, ongoing technical feedback loops with experimenters on digital capabilities, and documentation of OC staff decisions and operations, the OC facility undertook a significant refresh between the two funding rounds. For example, due to engagements with experimenters in round 1, the OC team implemented a mentoring approach to experimenters in round 2, which provided a better single point of contact for experimenters with an OC team member. Overall, *supporting co-creation means iterative changes over time. Ongoing facility co-creation ensured that the organizational modelling aspects of supporting co-creation was not a static but a dynamic process.*

One of the key learnings from interviews with *OrganiCity* experimenters on how to further empower co-creation was that although credibility as an EU-funded project and the branding of *OrganiCity* provided added value to experimenters in attracting stakeholders for co-creation, it was found that *city municipalities should also play a role in assuring visibility, access, credibility, and support in attracting stakeholders for co-creation to be effective*. Throughout the various case studies, we observed that city officials often act as gate-keepers and boundary spanners for co-creation to take place, and thus empower co-creation for innovation.

3.4. Qualifying Local Innovation

Qualifying local innovation focuses on the scope and range of innovation outcomes possible. This means cultivating *local* innovations that support, directly lead to, or fit into local innovation and business ecosystems. These could range from a new technological artifact to changed mindsets or changed patterns of citizen behavior, etc. For the *OrganiCity* OC-EaaS digital platform, it also meant achieving credibility and visibility of the platform and building its ability to cultivate experimentation and innovation. In general, whilst such

platforms aim to specifically cultivate innovations with intended business application, they can also provide support, credibility, and visibility to innovations intended for specific positive local actions. The very nature of experimentation after all does not necessarily imply only commercial intent, though may lead to, or benefit, subsequent business applications down the line, nonetheless.

Below, we discuss insights from two projects, *Making Sense*, which we introduce below, and *OrganiCity* (introduced in Section 3.2.1). Whilst the objectives of these two projects differed greatly overall, both projects empowered citizens with the technological tools to innovate positive change in their communities using urban data, whilst *OrganiCity* additionally supported innovations with the intended business application. Both projects offer insights about qualifying the nature of local experimentation and innovation, and how to achieve local innovation through digital platforms for experimentation.

3.4.1. Case Study: Insights from the Making Sense Project

'Making Sense' was an EU Horizon 2020-supported collaborative research project designed to showcase how open-source software, hardware, and design, along with digital maker practices, could be effective for local communities in appropriating their own digital sensing tools to gain awareness and subsequently provoke new policies addressing current and locally relevant environmental concerns. Based on nine pilots in Amsterdam, Barcelona, and Pristina, *Making Sense* developed a toolkit for participatory sensing that enables collective awareness and understanding of local issues, and can thus support action through collective intelligence. The toolkit was developed from the experience of three pilots whereby citizens have been empowered through low-cost IoT sensors (named the 'Smart Citizen Kit,' smartcitizen.me, accessed on 31 March 2021) to visualize air quality, noise, and gamma radiation data in real time on an open platform.

3.4.2. Making Sense: How Digital Toolkits Empower Citizens

Many current smart city strategies state the priority of developing urban data and IoT use cases by leveraging urban ecosystems and drawing on urban data, serving to benefit citizens and support local enterprises (see e.g., the city of London's data strategy; [95]). However, there is groundwork to be done in preparing and transitioning to a data-driven paradigm that benefits urban sustainability. *Making Sense* helped make tangible for citizens how their generation and use of urban data can support positive change making in their community, by action, informed by supporting evidence, and credible in prompting or persuading top-down change. In other words, the project supported citizens in *recognizing the value and becoming an active part of urban data-driven experimentation and innovation*. For example, one pilot involved local citizens capturing urban data concerning late night noise pollution in a Barcelona neighborhood. As a result, new policies were introduced, such as adapting closing times of bars in the area, and new infrastructural developments, e.g., to avoid agglomeration of groups of young people. Going through cycles in policy drafting led local neighborhoods to become aware of sensing and visualizing noise pollution data, and provoked informed action. The project showed how public awareness and acceptance of urban data-driven initiatives could be aided through supporting citizen science projects via *digital toolkits* that empower citizens to design and implement innovations with targeted community actions through appropriate functionality. Urban data, technology, and skills developed through these experimentations also support outcomes with business potential, e.g., applications that leverage urban data generated by locally distributed IoT sensors**.**

The focus of *Making Sense* was on adhering to open source principles in design, software and hardware of citizen science, which was delivered as an integrated digital toolkit. This provides important insights for how digital platforms support urban experimentation, whereby providing a digital repository and following the ethos of 'open source' could add value to platform attractiveness, usability, and utility in local innovation ecosystems across different socio-technical and policy contexts.

3.4.3. OrganiCity: Raising Mindfulness for Open Urban Data and Scalability of Experiments

OrganiCity illustrated ways to make experimenters *recognize the value of urban data*. This was achieved by integrating urban data sources within the OC-EaaS platform, making this *open* urban data available to experimenters, and by supporting experiments that demonstrated the impact resulting from data use. As of today, many cities are starting to create "open datasets" to share publicly available data such as e.g., the London Data Store (LDS) and the Open Data DK (ODD) initiatives. In *OrganiCity*, in dialogue with experimenters and city stakeholders, e.g., members of the Smart London Board, voices raised the need for *mechanisms* to better exploit such open urban data. Thus, enabling the exploitation of open urban data by providing adequate mechanisms along with digital platforms surfaced as a significant aspect in achieving urban sustainability.

OC also supported *public awareness and acceptance of urban data-driven initiatives* whilst adhering to ethical and responsible use and protection of data. This was accomplished by educating experimenters and urging them to adhere to ethical principles in the collection and exploitation of urban data. Measures included 'liability and intellectual property rights' passages as well as an 'ethics and privacy checklist' to experimenter funding contracts.

In qualifying local innovation, *OrganiCity* also supported *one-off experiments where data added value in supporting future action and innovation*. For example, the grassroots-led experimenters of 'Tranquil City' collected data to identify the areas combining low noise and air pollution in London in order to provide alternative routes for travel and leisure commutes. This resulted in an open dataset of over 180 category points, potentially benefitting (1) city planners, (2) a business's commuting app offering (3) citizen housing renting/buying choices. Similarly, 'Colour in City' took a social innovation approach to ascertaining new data-driven insights related to well-being issues of parents living in overcrowded housing in parts of London. This resulted in policy recommendations for the London Economic Action Partnership (LEAP). In relation to the above, a key insight from experimenter use cases concerned the need for additional sources of data that enable or provide added value to experimenter solutions being realized. In this respect, by enabling and supporting one-off experiments to release *new forms of urban data*, in addition to supporting experiments that lead to specific innovations, a richer *data ecosystem* with which to stimulate the development of urban ecosystems can be created.

The ability for urban experimentations and innovations to scale to other cities is also an important qualifier of local innovation, as the ability to scale increases the potential impact, such as the commercial success of the local innovations, i.e., they can sustain as a business. Given a key KPI of *OrganiCity's* success was the ability to foster commercial returns—as far as local innovations could be sustained as commercial offerings—scaling is an important part of this. Scaling experimentation outcomes raises the importance of supporting multi-city experiments that deal with differing city contexts. For example, the two commercially sustained initiatives, 'LeapCraft' and 'Wastehero' developed multi-city experiments to prototyping and validating mobile air-pollution IoT sensors and IoT waste bin sensors, respectively. These experiments exposed existing *challenges to scalability* such as cooperation and coordination with city councils, access to city assets, or navigating differing city typologies during validation of use-cases**.** More generally, a critical finding from experimenter use cases was a roadblock in coordination and cooperation from city councils in enabling and supporting use cases. This points to *the important gatekeeping role municipalities play in access, co-operation, and co-ordination* of stakeholders. Urban experimentation needs to address the gatekeeping and boundary spanning role of municipalities in their organizational set-up in order to ensure clarity and function when it comes to making experimentation and innovation locally relevant.

4. Towards a Concept of Urban Experimentation Platforms

In the previous sections, we have discussed insights from various case studies using the analytic lens of three interrelated facets that characterize organizational models for ur-

ban experimentation. In all these cases, digital platforms and related tools supported these organizational facets. From the case study experiences and empirical insights achieved and described in various related publications, in this section, we derive a set of factors, including objectives, measures, and the role of municipalities, which are substantial for achieving a sustained adoption of digital platforms for urban governance. Our particular view is on urban experimentation, and we attempt to sketch an early conception of Urban Experimentation Platforms.

Prior research has emphasized that the ability of business ecosystems to evolve over time through competition and *experimentation* represents a core characteristic of business ecosystems [96]. The aspect of experimentation, however, is often overlooked in business research, and with it, the question of how to implement experimentation resiliently in light of the goal of city competitiveness and urban sustainability. Insights from our various case studies presented suggest that experimentation needs to be a feature of any initiative towards urban sustainability, yet effective experimentation is difficult to achieve. In other words, in order for organizational models to be resilient in tackling urban sustainability, experimentation needs to cope with the complexity and dynamics inherent in urban development. To achieve resilience, as a precondition for adaptation and sustainability, we believe digital platforms play a decisive role as part of the institutionalization of such models. To this end, from our studies, we can derive a set of factors, which as we believe contribute to resilient organizational models of Urban Experimentation Platforms, in order to accommodate the diversity of initiatives, experimentation outcomes, and innovations across the three discussed facets, i.e., facilitating urban ecosystem governance, empowering co-creation, and qualifying local innovation. In Table 1, we summarize findings from our case studies that speak to the features Urban Experimentation Platforms need to offer. The mentioned aspects and measures can be understood as early policy recommendations for implementing and operating Urban Experimentation Platforms.

Overall, we can identify four key interrelated *adoption challenges* to achieving the success of Urban Experimentation Platforms. Firstly, that the platform itself will be promoted by city municipalities or entitled organizations with the aim to establish an experimental culture at large. This also comprises long-term policy support for building a contributive political environment for ecosystem growth and evolution. Secondly, that experimenters, such as start-ups or organized groups of citizens, get support for adopting the platform on a continued basis. Thirdly, that the platform offers appropriate online spaces (extending the *physical* laboratory spaces), and useful methods, tools, and apps to experimenters to advance their co-creation initiatives. Fourth, that experimenters' innovations focus on local issues, because this will make it more likely for innovations (services) to be adopted by end-users—thus reinforcing the added value of the platform itself.

We also posit that these adoption challenges are interrelated and together underline the complexity and dynamics to consider when creating an urban experimentation culture. For instance, municipalities will more likely adopt the platform if its offerings are valued by potential users and experimenters' innovations are successful in terms of adoption and diffusion amongst local end-users. These outcomes resonate with the constellation of urban ecosystem stakeholders, policies, local challenges (social, environmental etc.), the implementation (look-and-feel and utility) of the platform, and the local physical arrangements such as inner-city Urban Living Labs. On the other hand, experimenters will more likely adopt the platform if there is multi-city federation and support and co-created innovations potentially reach substantial and cross-city adoption and diffusion [97]. Thus, such constellations, the intricate interactions between stakeholders in the city ecosystem, the design and implementation of the platform, and the response met with the co-created innovations in their local setting, all substantialize dynamics that will challenge the sustained adoption of Urban Experimentation Platforms.

Table 1. Aspects and measures supporting set-up of urban experimentation platforms as indicated by case studies.

	Facilitating Urban Ecosystem Governance	Empowering Co-Creation	Qualifying Local Innovation
Objectives	- Understanding the ecosystem's evolution process - Oversight of urban data generation, security, access and sharing - Setting positive conditions for ecosystem evolution - Setting and advancing policy priorities (e.g., on climate)	- Identifying gaps in service provision through urban challenge formulation - Encouraging and supporting co-creation with urban data - Ensuring long-term public value of developments - Ensuring continued participation of businesses and organized groups of citizens	- Making tangible the value of local innovation - Encouraging the mindful exploitation of local data, information and knowledge sources for innovation - Assuring visibility, access, credibility and mediation of stakeholders for co-creation to be effective - Sustaining local innovations, e.g., by attentiveness to policy and commercial returns
Measures	- Proactive governance of the city ecosystem(s) - Institutionalization of urban (and ecosystem) governance steering groups, boards, offices, committees or communities to support management of stakeholder relationships - Digital platform and apps to leverage urban data for ecosystem governance, e.g., VAS dashboards	- Proactively attracting stakeholder involvement - Accompanying and stimulating co-creation through education, requirements analysis and facilitation - Digital platform(s) to support co-creation using urban data - Building technological capacity and related skills for supporting collective intelligence, e.g., through specific tools, repositories, apps, virtual and real spaces for activities etc. - Organizational, technological and methodical support across the entire innovation lifecycle, including 'good practice' toolkits for experimentation and co-creation	- Supporting experiments that tackle local community issues with both intended and unintended business application - Creating awareness of the value of local innovation - Support 'open source' principles and tools where possible - Proactively engaging with citizens, organized groups and other stakeholders to ensure local focus, end-user adoption and appropriately broad diffusion - Providing multi-city experimentation support
Role of municipalities	- Municipalities to act as promoters, providers and sponsors	- Municipalities to act as boundary spanners; also across cities	- Municipalities to act as gatekeepers

5. Conclusions

Despite the appetite for municipalities to fund experimentation to realize the 'smart city,' experimentation approaches such as Urban Living Labs face uncertainties and challenges in demonstrating effectiveness, public value, and viability. The contribution of this paper is to draw on insights from multiple smart city case studies in considering how to develop resilient organizational models for urban experimentation platforms. Based on a review of the related literature, these considerations centered on three key facets, (1) facilitating urban ecosystem governance, (2) empowering co-creation, and (3) qualifying local innovation. Based on a discussion of case insights, along these three facets, we propose a set of objectives and measures supporting the set-up of Urban Experimentation Platforms, along with the roles municipalities could play.

As all of our cases illustrate, digital platforms can substantialize and strengthen urban experimentation in many ways. This becomes progressively more relevant as experimentation and innovation for urban sustainability increasingly take a data-driven turn and become embedded into larger urban business ecosystems. Thus, fostering an urban experimentation culture also requires supporting approaches grounded in urban data and ecosystem thinking.

In conclusion, this paper served to highlight the inherent complexity and dynamic nature and context of urban development. The resulting dynamics must be considered in the design and evolution of resilient organizational models for Urban Experimentation Platforms.

Our future research will thus use system dynamics as a simulation technique to model urban experimentation settings, to better understand what kind of dynamics result, and which constellations and policy measures promise to be fruitful for achieving a *resilient* uptake of Urban Experimentation Platforms. Overall, the rationale for the adoption of Urban Experimentation Platforms beyond the development of human and social capital is the sustainable organization of production and humane design of our urban living environments, which will resonate with the local and regional cultural and environmental

setting. The exact policy recommendations that will have the potential to improve these conditions will depend on the dynamics existing in a specific place at a certain time.

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