Open Urban Innovation Ecosystems – Integration of Data, Services, and Stakeholders

Discussion Paper

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Abstract

This paper argues for a broader understanding of the role of integration within urban system development ranging from technical to collaboration and governance challenges. It is intended to support an evolution from specific urban data platforms to broader cross-stakeholder integrative urban innovation ecosystems. This fulfils a need arising from the design and development of complex multi-stakeholder urban transitions. These are the next steps to move from smaller demonstration projects and open data pilots to large-scale deployment. They focus on long-term impacts and sustainability of urban and governance interventions. Topics are multi-stakeholder innovation, Enterprise Architecture, Open Innovation, Living Labs, multi-stakeholder innovation, building local partnerships, developing technical expertise, rolling out infrastructure, planning support, stakeholder and citizen engagement, partnerships, contractual needs, new business models, and the challenges associated with them within sustainable city development and evolution.

CCS Concepts

• **Information systems → Spatial-temporal systems**; **Information systems applications**; • **Human-centered computing**; • **Applied computing → Enterprise architecture modeling**; **Information integration and interoperability**;

Keywords

Smart Sustainable Cities; Urban Digital Ecosystems; System of Systems, Urban Living Labs; Urban Data Platforms; Open Innovation; Multi-Stakeholder Digital Ecosystems; Positive Energy District PED

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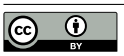

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1 Introduction

Smart cities are commonly understood as complex socio-technical systems of systems. An important perspective is that of digital ecosystems and innovation ecosystems [2, 4, 6, 16].

The main interest is often on the technical and computing solutions together with buildings and the built environment. With the raise in complexity and the need for acceptance by users and the wider ecosystem, the interest also includes non-technical solutions and aspects, urban planning, on support structures, on open innovation, multi-sector methods such as quadruple helix collaboration, and systemic change. This puts a continuing interest on innovation, on change management, and on understanding changes in their whole context when designing and developing new applications, systems, technology, or services.

Expanding the view to the wider context of the technical and computational aspects, we argue that a smart city ecosystem can be understood as a combination of built environment, structure, architecture, governance, stakeholders, and collaboration, and even the approach or "mindset" of the collaborators both as individuals and organisational entities to support the innovation ecosystem for smart cities. In this case, we understand architecture both as systems architecture, and in a wider sense as enterprise architecture of the connected and loosely coupled components, distributed over multiple (sub-)systems, organisations, and their connections as a digital ecosystem [4].

In many cases, such systems are termed urban data platforms, but in practice quite often are actually a combination of multiple systems and platforms. Therefore, we employ the ecosystem and enterprise architecture perspective, including ICT, APIs, network structure, frameworks, people, and innovation support.

The use of enterprise architecture to handle the increased complexity in a system-of-systems view needs significant adjustments to work within the Smart Cities field, which is ongoing research [8, 12, 17]. Challenges are in particular around the multi-owner, multi-platform aspects and the open ecosystem approach, which needs a different form of governance and multi-stakeholder approach.

Others term this wider development in a more ICT-centric view as city-as-a-platform or platform urbanism [18]. Further work highlights the need for technology management for inclusive development [19]. We also want to stress the importance of quality of life in cities, currently being explored as inclusive, beautiful, and sustainable cities under the New European Bauhaus principles with a specific view on stakeholder integration [21]. Smart cities as a mechanism for social transitions can also be linked to show how

social and sustainability goals are followed, for example in different platform architectures [13]. There is also a critical connection between innovation and service development for sustainability [5].

A key factor we discuss in this paper is *integration*. It is understood as a multifaceted challenge within and across not only systems, services, platforms, applications, and data, but also on wider city contexts such as infrastructure, governance, people, stakeholder, and organisational perspectives.

Many of the complex challenges within smart cities and within sustainability and climate action cannot be solved by one actor alone. The collaboration of multiple actors and multiple systems and their cross-domain integration, aggregation, or federation is a prerequisite. This integration is needed in the ideation, co-creation, development, testing, as well as in the operational phases.

1.1 Integration on a technical level

First, the technical aspects and a structural ICT view are useful since usually smart city services are inherently data-driven. Their value in many cases comes from the combination of existing and new entities. Here we discuss only such systems that need such integration, not any of the vast number of standalone applications. For many applications, an integration towards city systems, service providers, utilities, or mobility providers is vital. This goes hand in hand with how opening up systems and data can support startups and bottom-up initiatives to develop their own systems. We also include open data from municipalities or similar providers in our scope. The core technical concerns here are interconnections, interoperability, compositionality, system integration, development across organisational boundaries, interface standardisation, and Web-mediated integration through APIs.

1.2 Integration on a stakeholder and governance level

Second, the collaborative and governance aspects are especially critical in smart city developments since it is inherently a multidisciplinary and multi-stakeholder field. To a certain extent, these are already considered within perspectives of enterprise architecture as an important field, such as the integration into and between platforms, systems, and data. However, wider inclusion of integration and collaboration is critical to work towards open and collaborative ecosystems.

For example, main innovation and collaboration mechanisms are covered under the Open Innovation topic [11], such as Co-Creation and Open Innovation, Involvement and collaboration of relevant actors, Structural changes beyond any one segment, Smart city means involvement of all stakeholders and organisations in urban innovation, knowledge sharing, collaboration, such as citizens or inhabitants or communities, urban planners, academia, businesses/industry, NGOs, city operations, utilities, other stakeholders.

One of the needed context parts for the ecosystem are experimental spaces, governance approaches, and collaboration, which can for example be provided by Urban Living Labs methodologies [10]. and similar approaches for prototyping in testbeds and demonstrators.

Another important role is that of facilitation or orchestration, which can be filled by formal or informal actors. Examples are

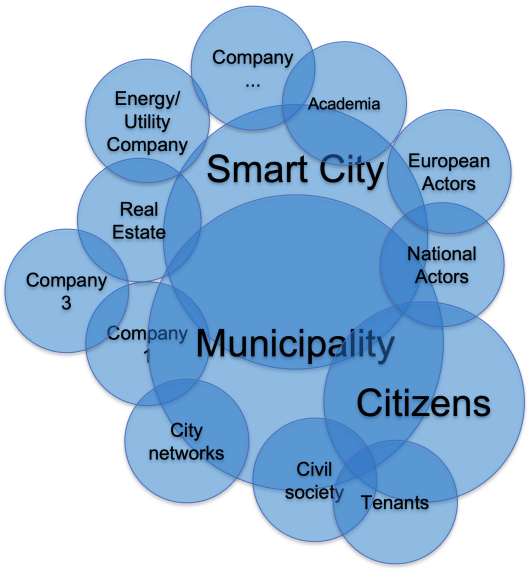

Figure 1: Smart City actors and stakeholders, partnerships, context, relations, and overlapping areas of concern

city managers, project managers, project initiators, neighbourhood representatives, citizens leading initiatives, developers, or organisational roles such as energy community operators, city project departments, etc. [7, 15, 20, 22].

In terms of roles and responsibilities, the Smart City term on the one hand describes the technical infrastructure, on the other hand it describes the urban experience of inhabitants or visitors. Parts of it come from the municipalities, or are governed or orchestrated by them, but many other aspects are provided by others or are even emergent behaviour of the interaction of players in the ecosystem. Figure 1 visualises these relations in how the Smart City as a concept is not equivalent to any one entity. It has a strong overlap with the municipality, but also with a wider range of other stakeholders and possible owners of specific systems or infrastructure.

Such a stakeholder context map will of course look differently for different actors. This particular example is developed from a municipal and academic viewpoint for service development. Depending on the complexity of any specific scenario, other actors can be varyingly involved or connected. The important aspect for integration then is to understand stakeholder responsibilities and contributions and the context and system boundaries.

2 Case Study

The smart city integration issue relates strongly to urban transitions, digitalisation, and digital support for areas such as challenges in:

- data-driven urban and municipal decision making
- sustainability, climate action support, energy transition, circularity
- urban climate mitigation and adaptation
- sustainable, inclusive, future-proof urban development and urban planning
- quality of life, quality of public space

- co-creation, stakeholder participation, inclusiveness

and on technical domains such as:

- urban planning and digital twins [9]
- building automation, built environment
- energy system integration and energy planning
- neighbourhood and district level systems
- water, green-blue infrastructure, utilities and their management
- mobility and traffic modeling, planning, management, operation
- shared mobility
- city operations
- municipal systems and services
- system and data accessibility and connectivity
- technical data integration and interoperability issues, including urban data platforms, standards, ecosystems

We had previously discussed the case of electromobility as a service (eMaaS) and its integrated development according to the principles laid out in this paper [1]. It highlighted the need for the interaction of various stakeholders in understanding the challenge, shaping the solutions, and then move towards an agreed and integrated multiple-system solution. It crossed multiple organisational and technical boundaries and could not have been built without a framework of stakeholders and joint needs around it.

In an additional case, the development of the energy and data side of an energy trading case follows similar approaches in our previous work [4, 14]. This was the development of Positive Energy District demonstrator, which aims to locally produce more energy than a district needs and combines aspects of energy production, a novel energy trading system, technical building integration, contractual issues, financial and regulatory questions, and a range of stakeholders, buildings, and projects [3]. The same principles, and especially the wider ecosystem and stakeholder collaboration considerations were core to the wider development of the complex renewable energy integration. This was also the system that integrated the mobility case as both shared mobility and using the car batteries as an additional energy asset within the PED.

In particular, these two cases covered needs of Cross-partner and cross-sector innovation; Integration and agreement between building owners, energy companies, suppliers, system developers and integrators, municipalities, tenants, citizens/inhabitants, external actors, etc.; Ambition to build scalable and replicable real-world solutions; Investment and business models; Regulatory mechanisms for sandboxes/pilots.

3 Conclusion

Smart City development and deployment seen through the lens of integration links together several open research questions and relevant Web topics:

- Web-mediated APIs
- Web intelligence and mining
- Discovering and querying/processing/analysing urban data
- Composition of Web-based applications
- Data exchange and integration
- Digital Twins and their use cases
- Augmented reality, metaverse/citiverse approaches
- Data and service standards and Open Data, especially as practical mechanisms to ease and simplify access
- AI support, including LLMs
- Responsible development, responsible AI, ethics
- Privacy and Security
- IoT, industry 4.0
- Urban data and information access
- Knowledge representation of the city, data management, semantics, interoperability
- Spatial and temporal characteristics
- Federated storage and system development
- Service and business innovation
- Community support, community/inhabitants/citizen needs, participatory approaches

We believe that this wider view of integration beyond the technical aspects is a vital approach to support development processes for Smart Cities and to make them more collaborative and human-oriented. The increasing complexity of current and future challenges and of the proposed solution need a stronger ecosystem view and a facilitation approach, to successfully address them together with all relevant actors, stakeholders, and disciplines.

Future research should focus on exploring these concepts and their role as support or barriers in innovation projects, develop a more formal understanding on how they contribute to successes or failures, and to develop practical guidance for collaboration and integration in our cities.

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