Review

The Importance of Collaborative Ecosystems to Boost 'Smartness' in Cities

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Abstract: Despite the increasing interest in 'smart city' initiatives worldwide, current literature still lacks the approaches and models that address challenges in organization and collaboration, which boost sustainability and 'smartness' in modern cities. This paper provides an overview of 'smart city' ecosystems as a mechanism to promote the expected outcomes of their sustainable development, and highlights the importance of conceptualizing cities from organizational and managerial perspectives. Representative exploratory models of 'city organization', which emphasize on the role of 'governance' and synergies, are presented to 'decode' complex city mechanisms and to determine key components that lead to 'smart' initiatives. Interesting case studies and applications are then analysed to examine the practical dimension of these approaches. As a review paper, this article lays out a general framework on the importance of 'collaboration', 'governance', 'management', and 'ecosystem'. However, 'planning smartly' and achieving 'sustainability' at the level of city 'organization' remain as challenges in this pioneering study of smart cities.

Keywords: Case study; Collaborative ecosystem; Governance; Smart city; Sustainability

1. Introduction

At present, cities comprise about 50% of the world's population, and this number is expected to rise up to 80% in the coming years [1]. On the same note, contemporary 'megacities' are responsible for the rising demand on natural resources, which are critical to local and global sustainability. The definition of 'sustainability' is often referenced to the Brundtland Report (1987) [2], specifically to the famous quote by G. Harlem: *'Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs'*. This leads to the ultimate questions of how to 'urbanize in harmony with society and economy protecting simultaneously the environment' and how to balance both short- and long-term needs to guarantee liveable conditions for future generations.

Sustainable urbanization has become a primary concern in modern societies in terms of environmental efficiency and the intelligent employment of resources. Hence, the notion of 'a technologically interconnected city', or IoT using Big Data, is being promoted to achieve the efficiency and intelligence in the management of cities and their resources. 'Smart cities' are often associated with the use of technology and ICT and the digital 'city image'. Undeniably, they have become a global phenomenon with an ambition to increase the competitiveness of local communities through innovations that improve the QoL of its citizens, thus offering a unique opportunity to drive the local economy [3].

ITU [4] defines a 'smart sustainable city' as *'an innovative city, which uses information and communication technologies and other means to improve the QoL of its citizens and the efficiency of its urban*

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operations and services', while the British Standards Institution [5] describes it as *'an effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens'.*

This paper aims to investigate the link between smart cities and urban sustainability through collaborative ecosystems. Achieving 'smartness' in cities consists of a wide spectrum of initiatives and interventions, but the challenges to achieve 'sustainable' and long-term solutions remain unresolved. The 'smartness' of a city is usually translated into projects that concentrate on the development of the technology and ICT sector, while the consideration of its 'sustainability' is often forgotten, if not neglected**.** ***Can we ensure the liveability of modern smart cities without being 'sustainable' and how does the collaboration of different 'ecosystems' enable their 'smartness' and sustainability?*** This study examines the determinant role of collaborations to boost 'sustainability' and to promote 'smart' initiatives.

To cover the multidisciplinary nature of 'smart cities' and the role of 'ecosystems' to boost 'smartness' in modern cities, the first part of this paper retrieves a set of related articles and database (Section 2). The second part proceeds to emphasize on the concept of 'ecosystems' and their relation to city 'smartness' that leads to innovative initiatives (Section 3). The third part then provides an overview of representative models and their successful applications (Section 4). Finally, the paper concludes with the main findings and critical aspects of the studied topic (Section 5).

2. Literature review: The 'smart city' concept and previous works

The word 'smart' is treated in literature as an adjective or as a normative concept [6]. Its definition as an 'adjective' has several meanings in the dictionary [7] such as 'mentally alert', 'very good at learning or thinking', 'intelligent', 'knowledgeable', etc. applied to persons, objects, places, etc., while as an instrumental concept it implies the creation of 'products, services, infrastructure, etc.', in which ICT play an important role [6]. On the other hand, a 'smart place', a city/district/building, is usually described as being able to manage its resources 'smartly', basically connected to technologies [8].

The concept is usually focused on the 'city' and is rapidly gaining attention as a promising response to city challenges [9]. Nonetheless, the concept of 'smartness' in cities is not new. As early as the mid-1800s, Eger et al. [10] focused their works on efficient and self-governed cities of the American West. In the 1960s, Gabrys [11] mentioned the idea of 'cybernetically planned cities'. During the 1990s, the term 'smart' referred to the integration of ICT in city infrastructures.

Recent advances in technology have enabled innovative digital scenarios that provide citizens and communities with cohesive and tailored solutions for their urban life. Synchronously, these advancements have also improved methods and tools to manage cities from the standpoint of different urban stakeholders. Following this direction, an innovative vision of a 'clever and integrated' city has emerged under the name of 'smart city'. Zuccalà and Verga [12] introduce the 'smart city' as a sustainable area, where every aspect is efficiently supported by ICT.

Table 1 provides a list of the most relevant definitions of a 'smart city' available in literature according to Anthopoulos [13]:

Table 1. Definitions of 'Smart City' Most Cited in the Literature Review.

Reference	Definition	Citations
(Caragliu, Del Bo & Nijkamp, 2011)	'We believe a city to be smart when investments in human and social capital and traditional (transport) and modern communication infrastructure fuel sustainable economic growth and a high quality of life with a wise management of natural resources through participatory governance'.	358
(Komninos, 2011)	'The Smart Cities concept (…) is connected to notions of global competitiveness, sustainability, empowerment and quality of life, enabled by broadband networks and modern ICTs'.	291
(Giffinger, Fertner, Milanovic & Meijers, 2007)	'A Smart City is a city well-performing in a forward looking way in six characteristics built on 'smart' combination of endowments and activities of self-decisive, independent and aware citizens'.	207

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Reference	Definition	Citations
(Nam & Pardo, 2011)	'Smart City integrates technologies, systems, infrastructures, services and capabilities into an organic network that is sufficiently complex for unexpected emergent properties to develop'.	103
(Batty, 2013)	'A Smart City is a city in which ICT is merged with traditional infrastructure, coordinated and integrated using new digital technologies. Smart cities are also instrumenting for improving competitiveness in such a way that community and the QoL are enhanced'.	87

Giffinger et al. [16] identify 'smart cities' with its six dimensions (**Error! Reference source not found.**).

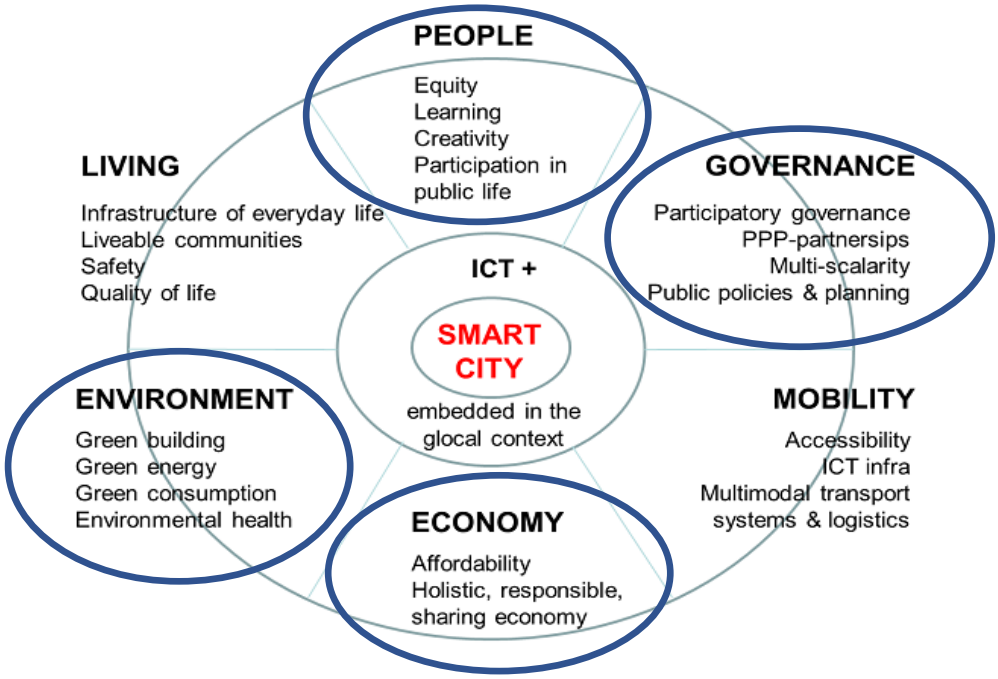

Figure 1. Six dimensions of the 'smart cities' proposed by Giffinger et al.

The 'lighthouse' of 'smart cities' finds its origins in the concept of 'smart growth' [19] during the 1990s. 'Smart growth,' which advocates for new policies in urban planning, has been adopted by a number of companies (Cisco, Siemens, et al.) since 2005 in an attempt to apply complex information systems to the integration of infrastructure and services. Since then, it has evolved to mean any form of technologically-based innovation in the planning and development of cities. Historically, however, the first concept of a 'smart city' can be traced to the 'intelligent city,' which relies on top-down approaches while focusing on technologies and ICT. Pierce et al. [20] argue that the 'smart idea' has much in common with the 'sustainable city movement' but that the former is characterized by a particular focus on technology-enabled **innovation** to achieve sustainability. This pertains to a context characterized by strong interconnection between city actors, citizens, and ecosystems. Based on available literature on smart cities, there are three different types of ideal-typical definitions: smart cities as cities using smart technologies (technological focus), smart cities as cities with smart people (human resource focus) and smart cities as cities with smart collaboration (governance focus) [21].

Since the early 2000s, many cities around the world have undertaken initiatives to position themselves and be labelled as 'smart'. In the post-industrialized era, the smart concept is highly recognized as a means to increase the attractiveness of cities, endure the local economy, and improve the citizens' QoL, as well as a promise to fight against climate change impacts [22]. The following are some definitions available in existing literature that describe 'smart cities' as those that require a hybrid framework to achieve collaborative innovation ecosystems that lead to higher QoL [3]:

Toppeta [23] defines 'smart cities' as those that combine ICT and technology with other organization, design, and planning efforts to speed up bureaucratic and administrative processes in

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an attempt to identify innovative solutions for the complexity of managing a city and to improve sustainability and liveability. Similarly, a prominent yet sophisticated definition has been developed by Caragliu et al. [14]: *'We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance.'*

'Smart cities' are rapidly gaining interest [24] as they are seen as a means to facilitate and improve citizens' life by integrating ICT. In a comprehensive study, Lee et al. [25] propose six dimensions to analyse the 'smart city' concept: (1) urban openness, (2) service innovation, (3) partnership and collaboration, (4) proactiveness, (5) infrastructure integration, and (6) **governance**, which is considered as a key driving force in enabling smart city **development.** Nam and Pardo [17] discuss the fundamental factors that make a city 'smart' and have identified three 'core categories': (1) technology, (2) people, and (3) institutions (governance). Given the connections between these factors, *a city is **smart** when investments in human capital and IT enhance the QoL through participatory governance* (**Error! Reference source not found.**).

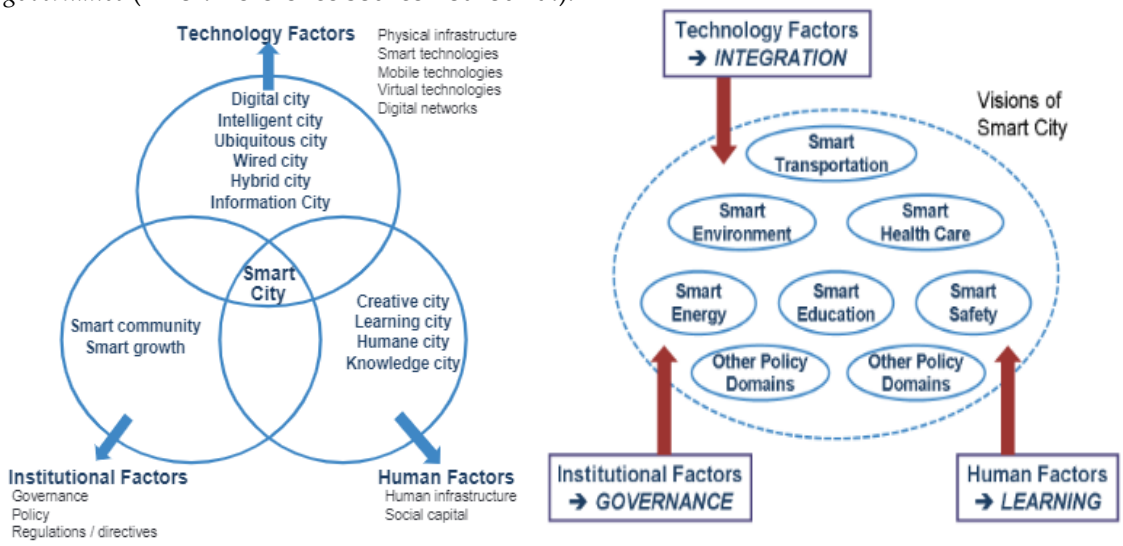

Figure 2. The role of 'governance' in the smart city model proposed by Nam and Pardo (2011).

2.1. The role of 'governance' in 'smart cities'

Of particular interest in contemporary literature is the role of 'governance' as a driving force in achieving 'smartness' in cities. *"Governance refers to all of processes of governing, whether undertaken by a government, market or network, whether over a family, tribe, formal or informal organization or territory and whether through the laws, norms, power or language"* [26]. It contributes to the successful implementation of projects that proactively engage citizens by enhancing and empowering end-user participation.

Tomor et al. [27] examine four components of governance in line with the 'smartness' in cities (**Error! Reference source not found.**):

- ✓ *Governmental organization*, which entails **commitment** of local stakeholders to implement 'smart' initiatives through ICT support and their operational management; this process includes a range of sub-facets (i.e. motivation, strategies, decision-making, coordination, etc.)
- ✓ *Citizen participation*, which concerns empowerment of citizen involvement in policy decision-making and project implementation. Another relevant component is the degree to which participation is interactive [28].
- ✓ *Use of technology*, where digital technologies are mapped out for the applications of participatory processes, such as discussion forums and meetings, platforms, etc.

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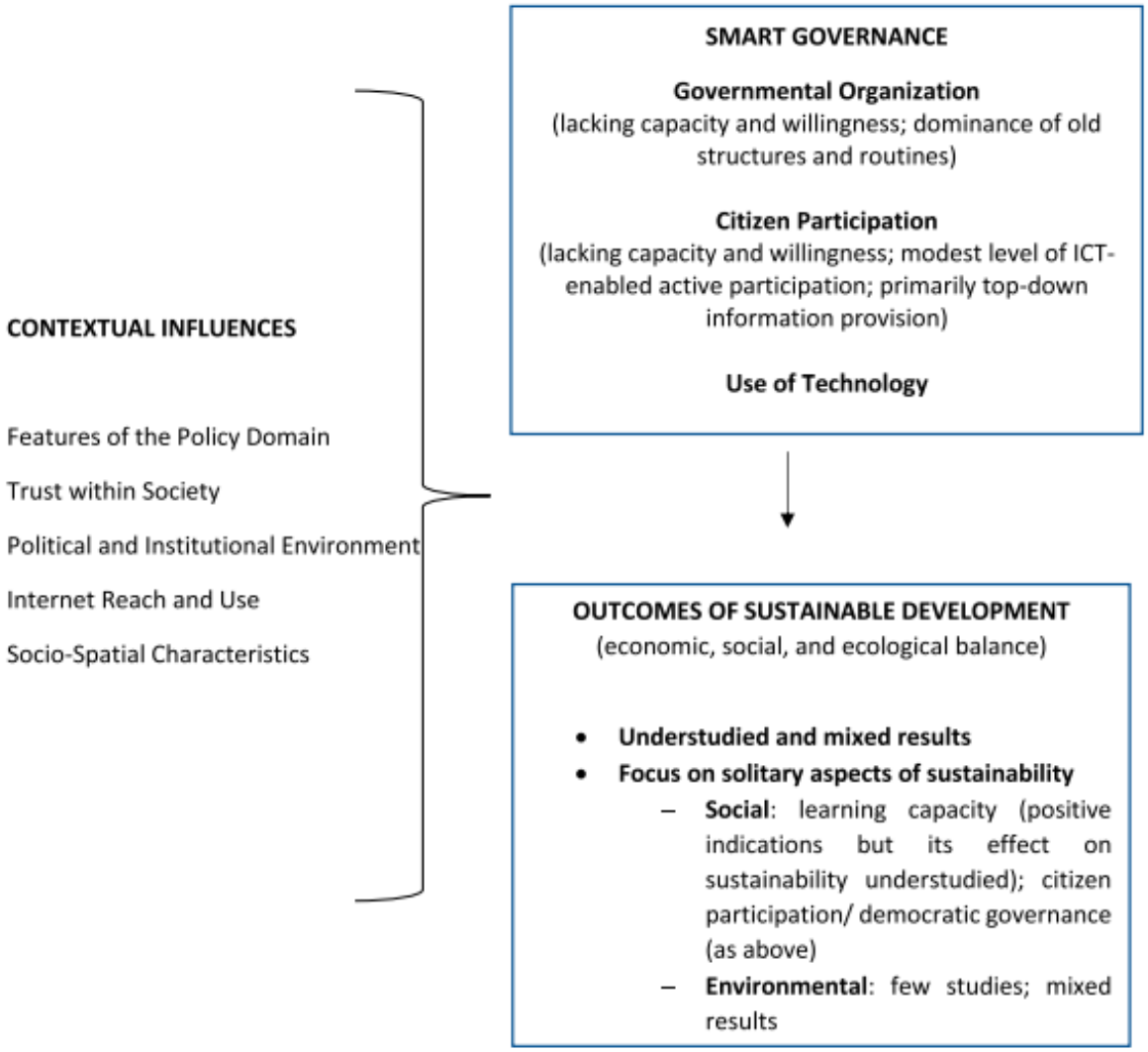

Figure 3. Key variables of the 'smart governance' and 'sustainable development'.

Ooms et al. [29] state the need for complex forms of governance to enable 'smartness' in cities where a great variety of actors are involved. Governance, however, is not merely one of a market economy; it includes processes at different levels, such as national and local policies that incorporate various strategies and initiatives [30]. Exploring the importance of 'governance' in smart cities, some studies focus on the role of specific city actors and stakeholders [31], while others [32] highlight the role of human capital. Nevertheless, there remains a knowledge gap between the role of 'governance' and its interaction with 'smartness'.

Deakin [30] states that, in terms of policies, corporate strategies and academic leadership relate 'governance' with participatory processes: *'the capacity to process the transition reflexively from creative to intelligent and as part of the cities' "smartness".'* It plays an important role in the successful collaboration of all parties involved in 'smart city ecosystems', which eventually leads to attainment of goals and urban 'innovation'. Schaffers et al. [33] highlight the significance of synergies and partnership in sharing research and resources (e.g. know-how, ICT tools, etc.) to create cooperation models. Researches and experiments contribute to urban innovation ecosystems; city and urban policies concretize solutions and stimulate citizen participation; open, user-driver innovation ecosystems promote technological experimentation. Participatory governance and citizen involvement are, in any case, key components in the 'smart city' framework and are at the core of 'smart' initiatives ([14],[35]). These two keep decision-making active and ensure the cooperation of multi-stakeholders throughout a project [35].

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An interesting observation carried out by the existing literature is that the effects of 'smart governance' on sustainable and 'smart' planning are remaining quite understudied and the largely unknown ([36], [37]); nonetheless, practitioners usually associate the 'smart governance' with more sustainable, equitable and 'intelligent' communities [38]. Some papers note the intentions to examine the contribution of the 'smart governance' and the use of ICT [39].

3. 'Smart cities' as 'ecosystems'

From a pure engineering perspective, the city represents a unique ecosystem for testing and assessing new services and technologies, particularly ICT. 'Smart cities' are perceived as 'Intelligent Communities' where 'collaborative ecosystems' facilitate social and technological innovation by creating connections and engagements among citizens city actors and stakeholders (e.g. government, businesses, educational institutions, etc.) [3]. Pierce et al. [20] posit that smart city initiatives depend on the collaboration and the dynamics of a wide range of actors far beyond traditional boundaries and relations.

'Ecosystem' literature is usually studied to analyse the 'smartness' in cities ([26]-[27]) as 'smart cities' resemble different kinds of 'ecosystems'. For instance, innovation or knowledge, which range from knowledge-related ambitions to economic, social or territorial ones, [42] requires a more holistic approach to provide insight on how ecosystems enable the smart city development [43]. Ooms et al. [29] examine the use of governance factors to stimulate 'city smartness' and how they have evolved through the time.

A city can best be viewed and understood as an ecosystem with three elements [44]: (1) the physical structure (geographic setting of the city including the natural environment), (2) the living entities that it contains, and (3) the flow of their interactions, which include four layers: the functions, the economy, the society, and the information.

In an effort to become 'smart', cities are searching for more innovative dynamics that can drive the development of products and services through technological achievements. This also includes the changes in their organizational dynamics that create a culture of innovation among various stakeholders [45]. It appears, then, that the ***main challenge for smart cities today is to develop and implement models of collaboration between different stakeholders***. Undoubtedly, the success of a 'smart city development' depends on the degree to which technological, governmental, institutional and other components are collectively integrated [46], while noting the significance of participatory design-making processes [47].

The **smart city** is a 'complex **ecosystem'** of people, processes, policies, technology and other enablers working together to deliver outcomes to specific 'smart' objectives, where ensuring QoL is an important concern as cities and urban environments are facing challenges to establish efficient, effective, open and participative processes to jointly create applications that meet the citizens' demands [48]. These 'ecosystems' consist of different organizations and institutions that collaborate to contribute to the 'smartness' of a city, along with the interrelations of infrastructure, society and institutions with different forms of 'collaboration' (for instance, smart city ecosystems typically introduce the role of citizens, etc.) [49].

In smart city projects, the term 'ecosystem' has a wide spectrum of meanings that does not only include technical systems but also human capital. The smart city ecosystem, however, has more to do with the entire living standards and is comprised of open and driven innovation settings that promise opportunities towards a 'smart' urban transformation [50].A 'smart city' is a 'well-defined geographical area where high technologies, such as ICT, logistics, energy production and so on, collaborate to create advantages for citizens in terms of well-being, QoL, intelligent development, etc. [51]. To visualize how to design, implement, and measure the 'smartness' in cities, Appio et al. [3] organized Giffinger's classic model of the six (6) pillars according to Hutchinson's pyramid (

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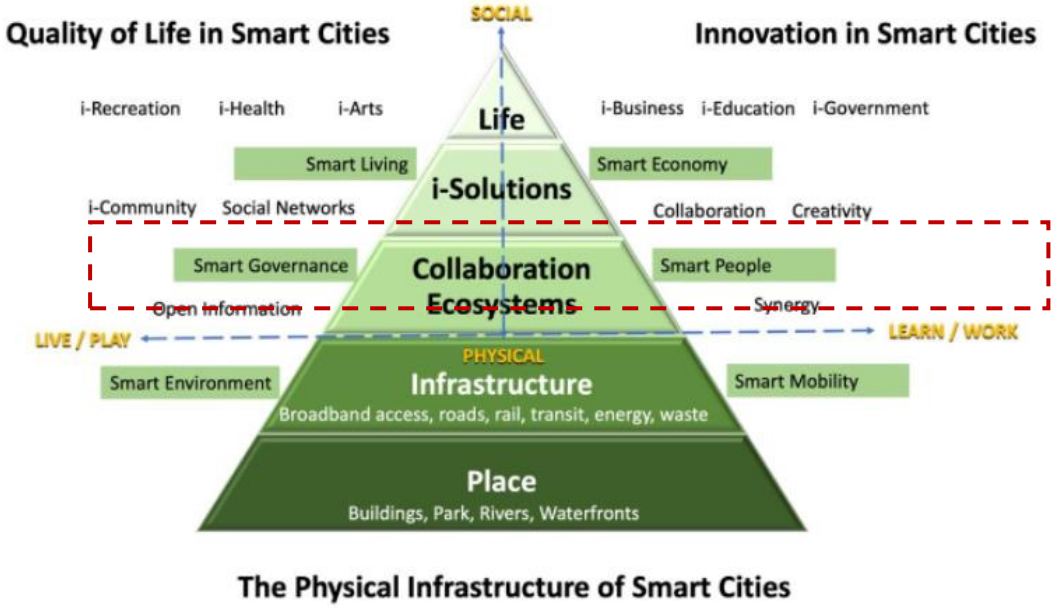

Figure 4. An adaptation of Hutchison's framework highlighting Giffinger's smart city elements.

The 'smart city ecosystem' is an interesting example of a mode of innovation that develops institutional collaborations and adapts different organizational structures at the city scale. Nam and Prado [17] consider a 'smart city' to revolve around technological, human, and institutional dimensions, thereby enforcing the idea that smart city projects stimulate learning and innovation. Meanwhile, Dameri [52] argues that economic growth requires the stakeholders of a smart city to review its practices and applications. To provide value to users and citizens, 'smart needs' also form the organizational structure of an 'ecosystem'.

Van den Bergh et al. [53] introduce the idea of 'ecosystem' in smart cities to explain future urban challenges that involve a wide spectrum of players. As such, the smart city ecosystem is identified through understanding, scoping, activating, managing, and servicing. Abella et al. [54] state that the concept of 'ecosystem' provides additional value by enabling target groups to adapt through the direct integration of external digital assets or through the provision of new ways to process information. Moreover, society, which consumes these services, also demands new features from the ecosystem that might produce several effects.

In addition to contemporary smart city literature, Ooms et al. [29] use the term 'ecosystem' to analyse smart cities for three reasons: (1) a smart city resembles different kinds of ecosystems (e.g. innovation, knowledge, etc.) in many of its attributes, such as the diversity of actors involved, the economic or social goals, etc.; (2) it holds findings on ***governance*** and (3) on the needs of policy makers and city stakeholders to develop sustainable, long-run projects.

Chan [55] describes the SSC as an ecosystem comprised of people, organizations, policies and processes geared towards desired outcomes—a city adaptive to its environment and responsive to technological evolution to accelerate and to facilitate its actions. Chan describes a smart city 'ecosystem' as one that is built on layers, where 'sustainability' is a principle target (**Error! Reference source not found.**). Its priority lies in the unification of collaboration between city actors (municipalities, businesses, planners, etc.) and residents to 'co-create' the city. A smart city is not only focused on technology, but also on the use of ICT. It aims to define and conceptualize the needs of its users and to engage communities in innovative and 'smart' solutions to improve their QoL. Furthermore, 'smart city ecosystems' are designed to enable data and information sharing by 'smartly' managing connectivity while upholding confidentiality and protecting user privacy.

The 'smart' model of cities is built on 'capability layers' (**Error! Reference source not found.**). No capability is more important than the rest but each has a unique role to fulfil in the 'smart' model that attempts to integrate technology in accelerating, facilitating, and transforming the ecosystem.

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This supports the significance of unifying and supporting synergies between different 'services' and actors.

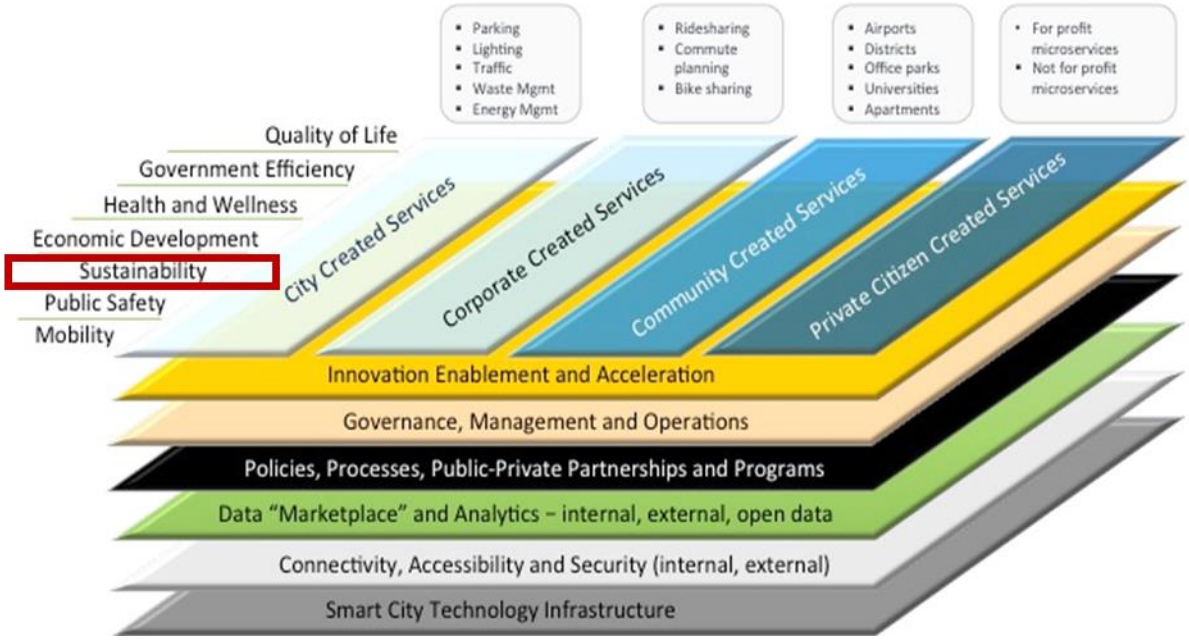

Figure 5. 'Smart cities' as 'ecosystems' are built on layers.

Schaffers et al. [43] cite the importance of **synergies** among main stakeholders in smart city 'ecosystems' to share resources (e.g. tools, know-how, etc.) and to experiment on technologies and applications that enable smart objectives 'on-site'. They propose three perspectives to explore this challenge (**Error! Reference source not found.**). The first perspective (Internet and Research) represents a technology-oriented contribution to the smart city ecosystem, where a gap exists between the various technologies to be employed and the ambitions of modern cities. The second one mainly concerns policies in city development, while the third focuses on developing concrete, innovative solutions that stimulate social participation.

Table 2. Three perspectives shaping the synergies in a smart city ecosystem.

	Internet & Research	**Urban development**	**Innovation eco-systems**
Actors	Researchers ICT companies City and EU actors	City policy actors Citizen platforms Associations	Living Lab managers Citizens Government Research Institutions
Priorities	Technical and other challenges	Infrastructure and other services	User-driven open innovation Citizen engagement
Resources	Experimental facilities and pilot projects	Development plans	Methodologies and tools
Policies	Experimental research	Policies to stimulate innovation, business and procurement	Innovation projects, open and collaborative sharing data

To better understand the idea of an 'ecosystem' and its connection to the 'smart city', Stam [56] introduces a model (Figure 6) that considers 'governance' as the 'systemic conditions' wherein the creation of value (e.g. local demand, shared culture, physical infrastructure, etc.) is empowered in an ecosystem. Simply put, it is only with 'governance' that opportunities to create value in an ecosystem are made possible.

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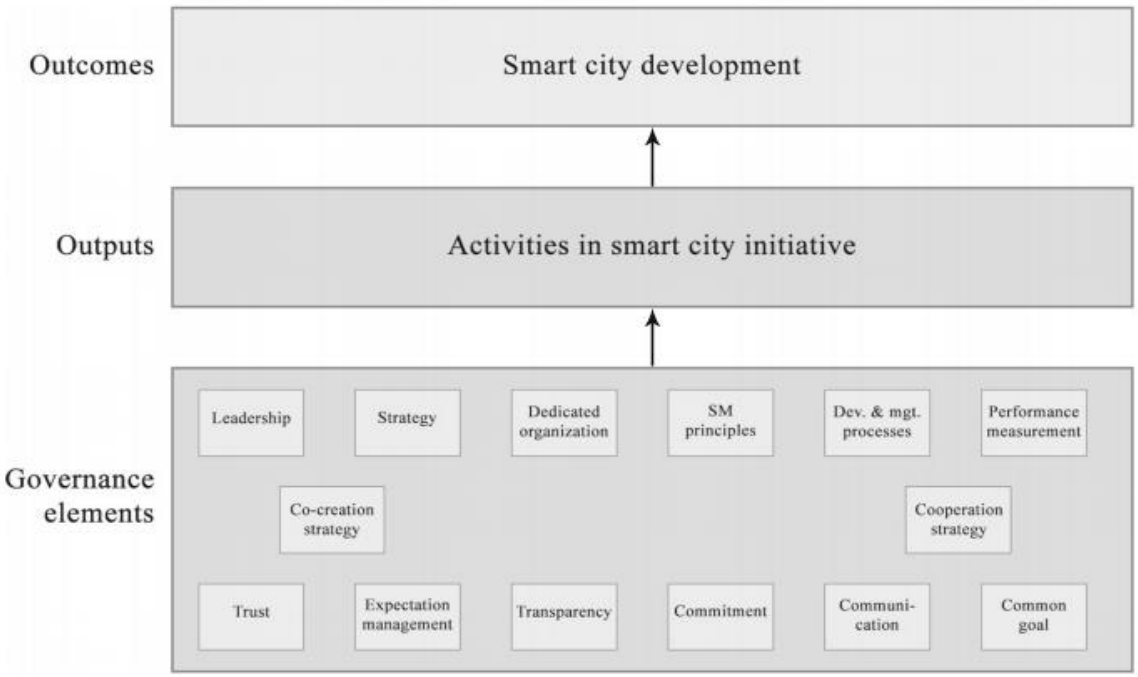

Figure 6. Governance affecting outputs and outcomes of smart cities.

Following its definition in the scientific field, an ecosystem is considered as a community made of different entities that tend to adapt to changes in the environment. It is regarded as a 'network of relationships linked together by interconnected practices.' Under this lens, collaborative relationships in 'smart city projects' supersede traditional partnerships between public and private organizations [57].

4. Collaborative 'smart' city ecosystems and applications

This section presents an overview and analyses of representative 'collaborative' ecosystems available in existing literature that highlight their most notable characteristics.

4.1. City Protocol

The 'City Protocol' is an open, global and progressive working framework for cities worldwide aiming to assess and improve the environmental sustainability, the economic competitiveness, the QoL, the city infrastructure and services, etc. by innovating and demonstrating models to engage society and its actors by leveraging the Information and Communication Technologies [58].

The City Protocol is a collaborative innovation framework, which addresses cities under a systemic approach (**Error! Reference source not found.**) to explain their complex systems and their interactions [59] and fosters city-centric solutions to benefit citizens and their QoL. The City Protocol defines an interoperable platform to communication and operate across communities, spawning an ecosystem and its innovative development and aims to embrace protocols [60].

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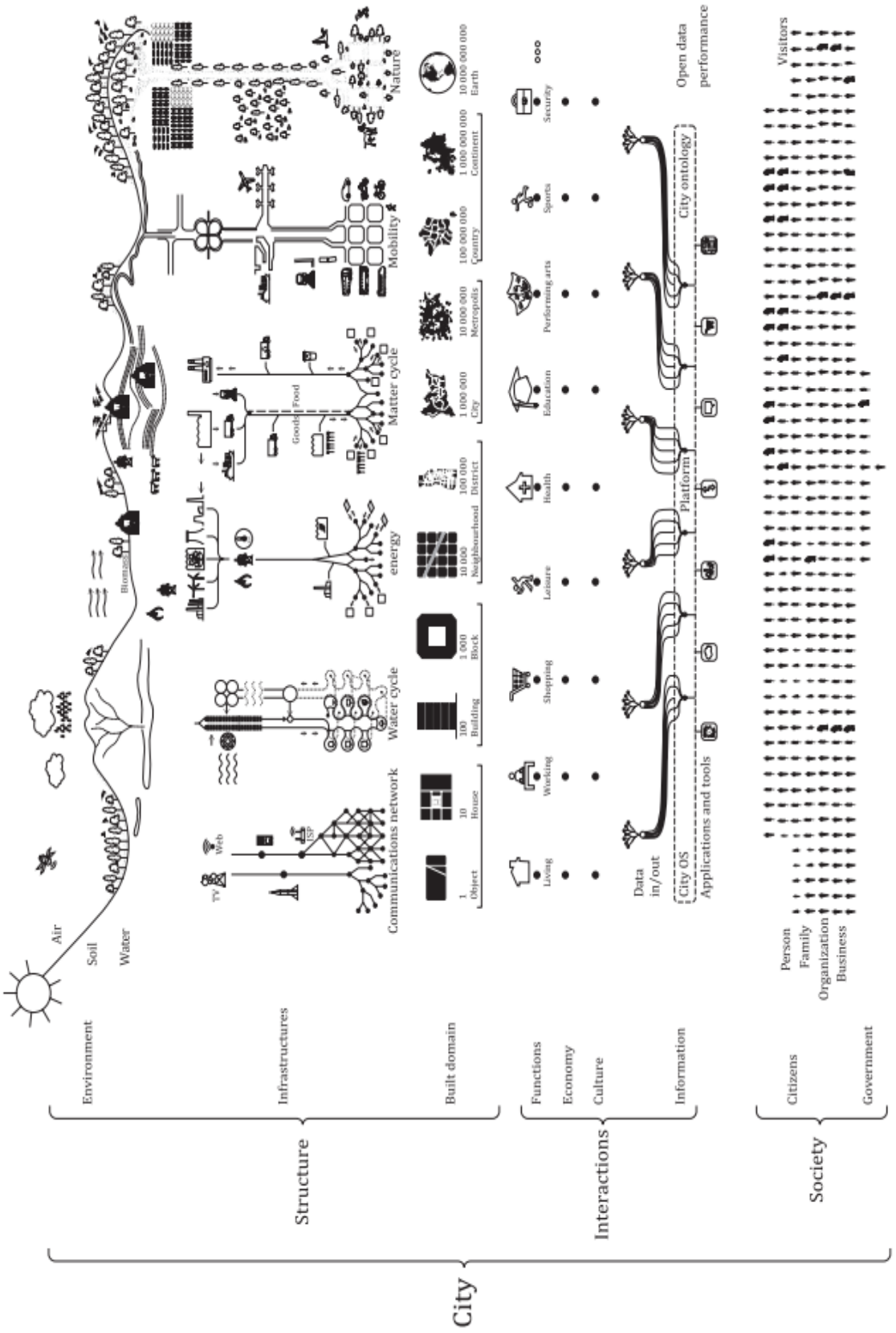

Figure 7. The City Protocol and its components.

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4.1.1 The paradigm of the city of Barcelona

The contribution of Barcelona towards the sustainable transformation of cities via the deployment of appropriate models, frameworks and tools, has been extensively discussed and recognised by authors, scholars and organisations over the last decades ([61]–[63]). Some key credentials for the above statement include, yet are not limited to, Barcelona's placement as the leading city of 'City Protocol Society', its award as the European Capital of Innovation (iCapital) by the European Commission at 2014 and its participation at the Polis network (a European scheme that aims at developing pioneering policies and technological tools for local transportation needs)[64].

In order to achieve advanced sustainable growth, Barcelona city engaged with the Smart City movement. The basic principle is to integrate innovative technological advancements into addressing city-scale challenges, whilst creating an appropriate and dynamic strategic framework as well as an open and comprehensive environment of collaboration that is capable of boosting the successful development of the relevant technological schemes[65]. A vision like this yield for the adoption of a holistic socio technical approach, that exploits ICT for achieving sustainable goals aligned with the City Protocol core ideals, via the deployment of models, tools and frameworks that ameliorate the QoL, promote social cohesion, equity and participation, secure the space for open innovation, boost communication and multi-stakeholder collaboration, disseminate information whilst securing transparency and improving public services [62].

Capdevila and Zarlenga [66] analyze the case of Barcelona city as a 'successful ecosystem', where urban development, business opportunities and quality of life have improved in the last decades. Schaffers et al. [43] refer to the case of Barcelona city to explicit how urban policies and reforms aim to lead towards becoming 'smart'. Actually, Barcelona aimed to provide an environment to generate the 'smart' idea in an open environment through fostering open data, while at the same time it reinforced the citizen involvement and the co-creation processes. A representative characteristic of Barcelona city is the approach to the urban governance, including collaboration and linkages between the city actors, the academic institutions and residents to develop smart projects for the city and to foster the city competitiveness, promote innovative actions and create new channels of communication to facilitate the access to information and data both locally an internationally.

The main elements of Barcelona's strategy are presented below [43], [62]:

- 'Smart districts' (the case of the 22@ Barcelona): an urban transformation project with the aim of creating a new innovation district. Developed as a new place for urban, economic and social innovation. This global vision has been implemented through the concentration of knowledge-based activities, as well as a strong involvement of new technologies. Urban planning was guided by the 'compact city' principle, which links higher-density planning to environmental efficiency and improved life-quality [67].
- Open data: involving territory, population, management, urban environment and other indicators for creating new services, increasing social value and perhaps also commercial value, as well.
- Infrastructure: the traditional infrastructure is redesigned to ease the ICT integration at all its levels and new services for citizens.
- Living Labs Initiatives (multiple cases such as yet not restricted to 22@Urban Lab, LIVE, BDigital Custer TIC Living Lab): exploited as dynamic tools that have the potential of revealing innovative solutions (services or products) in real-life and large-scale cooperative environments, via their development, testing, analysis and final optimization for the market's needs. Living labs offer the space for improvement for a plethora of fields (urban planning, education, health, mobility, governance, etc.) and by a variety of stakeholders (citizens, companies, academia, government), whilst their great contribution lies under the economic competitiveness and the QoL amelioration that they are capable of offering.
- New Services for the Citizen: The Smart City transformation in Barcelona has led to a number of important and useful smart services for the citizens, which greatly contribute towards the improvement of the QoL and efficient management of the city. Those

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services fall under 3 basic categories in regards to the producer-target duo; a. internal government services (improved and more efficient city management), b. government to Citizen/Business services (citizens' participation is entailed), c. Citizen to Citizen services (based on Open data and Open cooperative innovation).

Barcelona's smart city knowledge is built along with an industrial network and clusters creating interconnections and interactions of its users with city stakeholders and other institutions creating a 'knowledge society'. Ferrer [68] explains in detail the 'governance model' of Barcelona's 'smartness' in an attempt to integrate all the key stakeholders. Identifying all stakeholders concerned by the implementation of the smart city policy's programs – be they public or private – and defining a model that integrates all of them, from citizens and other external stakeholders, to the different municipal management layers (strategic, tactical and operational) (**Error! Reference source not found.**). Identifying all stakeholders concerned by the implementation of the smart city policy's programs and defining a model that integrates all of them, from citizens to city (local) stakeholders, will result in a more efficient governance model and, in the end, in the generation of synergies and a dynamic ecosystem of collaborations leading to 'smartness' and long-term projects but also to the involvement of other 'players' of the city planning initiatives and to structure the priorities to integrate future perspectives and action plans.

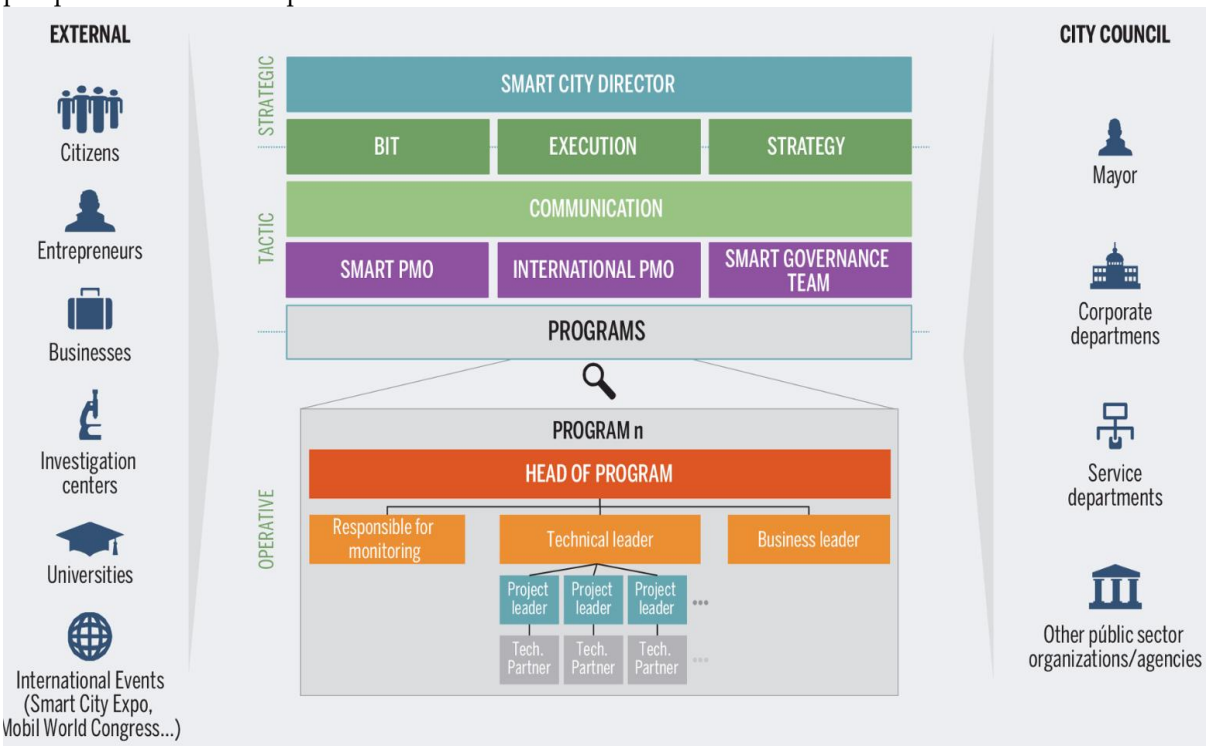

Figure 8. Barcelona Smart City's governance model.

For additional reference and in relation to the 'City Protocol', the example of Barcelona's Digital city lab (BIT Habitat – i.lab) will be presented. This lab is used as a collaborative tool to deploy sustainable and social urban innovation[69]. Its operation is based on a quadruple helix model (model to be explained in detail in the next section), as it is to be analysed on the next paragraph, and aims to the productive collaboration between citizens, companies, universities/research centers and public governments. The goals of this initiative are to efficiently address the demanding challenges that emerge at complex and multicultural environments of quickly transformative cities, like Barcelona. To do so, some key components and principles must be met to ensure the smooth and optimized transition per each case, such as the dissemination of information, technological advancements and data with a responsible and ethical way. Furthermore, the core of this initiative is the acceleration of sustainability with approaches that secure the general wellbeing of the involved populations and organisations. Another vital goal of this vision is the promoting of open and collaborative innovations, that can be achieved via quadruple helix model solutions. Lastly, another significant

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factor on a wider global scale is the dissemination of the acquired knowledge and of the lessons-learnt through the different projects realised; something to be achieved via open exchange of software, research, lessons-learnt and technologies[69].

It should not be dismissed that even the identification of challenges is not done solely from the public authorities; on the contrary a combination of various stakeholders is participating at the identification of the challenges, while most of the times the City Council initiates the conversations for a specific topic that requires solutions, however citizens, organisations and research institutions may also engage into a healthy conversation via available appropriate forms. Afterwards, the partnerships required to address each project are also defined in a collaborative way from the Council and the various stakeholders to be affected by it. The laboratory is then responsible to launch a call for participation (targeted to relevant stakeholders and the public with distributed with effective online/offline channels, while the next phases include the assessment of solutions (held by teams of multidisciplinary experts), the announcement of the winners (transparent presentation o the winners along with their proposed solutions to more widely spread the project to be realised), and finally realization of pilots that will decide the furthermore exploitation of the projects on the real market[69].

The benefits of i.lab are many and differentiate from the target user as presented at the Table 3 below [69]:

Table 3. Benefits of the i.lab per target user.

Citizens	Companies	Academia	Public Authorities
Ameliorated satisfaction of their genuine needs	Enhanced collaboration possibilities with an innovative ecosystem	Possibilities of participation at the project definition stage	Aligning innovation with techno-economic efficiency
Enhanced public services, via a. multi-stakeholders and experts' inclusion and participation b. technological and social innovation schemes	Multiple opportunities for experimentation, development and testing of solutions	Promoting technological advancement to improve the general wellbeing and QoL of city residents	Promoting and securing innovation based on social, technological, economic and environmental sustainability
	Opportunities to design and realise city and international-scale projects	Enabling collaboration with a variety of stakeholders	Enabling an internal cultural transformation

Additionally, it should be mentioned that the aforementioned lab is only one of the frameworks/tools of the city of Barcelona to apply the 'City Protocol' principles, and that it has launched multiple likewise initiatives to accelerate its sustainable development via the exploitation of smart collaborative ecosystems, as it can be seen from the multiple existing living labs and the majority of the Barcelona Digital City projects [70].

4.2. Helix Models of Innovation

As explained previously, 'governance' is required to face urban challenges by using the 'smart city' concept. On other side, the structure of 'smart cities' goes beyond the creation of collaborative ecosystems, in which citizens, enterprises, city actors and academic vectors develop innovation (products, services and finally solutions); thus, a 'smart city' ecosystem involves a multiple spectrum of actors engaged in public and private institutions, while this collaboration requires high level of both human and social capital ('smart people') based on knowledge and learning. Appio et al. [3] explain that in places, where the 'triple helix' is developed (knowledge creation and application –

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creativity and innovation), the environment is more competitive and economically attractive ('smart economy'). Both the 'Triple' and the 'Quadruple' Helix approaches are grounded on the concept that the 'innovation' in cities is a continuous and interactive process involving different actors and stakeholders (**Error! Reference source not found.**).

In 1995, Etzkowitz and Leydesdorff introduced the ***Triple Helix*** model. The traditional actors in charge of creating innovation, in the Industry sphere, and the traditional actors in charge of creating knowledge, in the academia interact with the political and city stakeholders to 'create' innovative systems and transfer the knowledge in terms of 'economic growth' through top-down approaches. This model stresses the 'helices' to generate 'innovation' in different systems: academia/industry/government placing an emphasis on the 'tri-lateral' interconnections; indeed, the 'Triple Helix' is considered as the 'core model' for innovation, resulting from different interactions in knowledge referring to academia/industries and government and it is contextualized by the broader innovation model of the Quadruple Helix ([71];[72]).

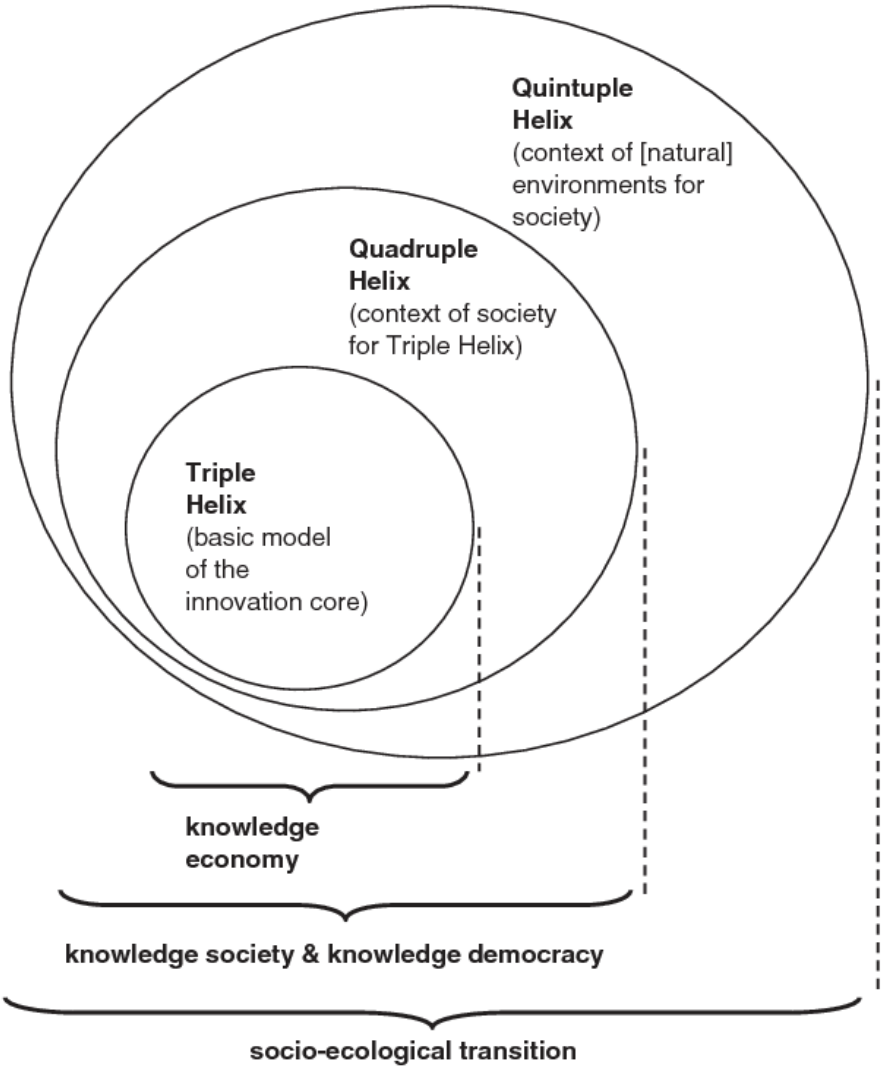

Figure 9. Knowledge, production and innovation model.

At its evolution, Schütz et al. [73] proposed the 'Quadruple Helix Model' (**Error! Reference source not found.**) (originally conceptualized by E. Carayiannis and D. Campbell as a spiral along with four branches focusing on the core components of 'innovation' (including academia, industry, government and society) in multi-layered interactions emphasizing on the importance of society and to integrate the public into innovation projects. The model clearly demonstrates that the four core components of an innovation system—academia, industry, government, and society—are not involved in unidirectional push-pull relationships, but rather in multi-layered, dynamic, bi-

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directional interactions. This highlights the role of society as a major actor in national innovation systems as well as the importance of actively integrating the public into innovation projects.

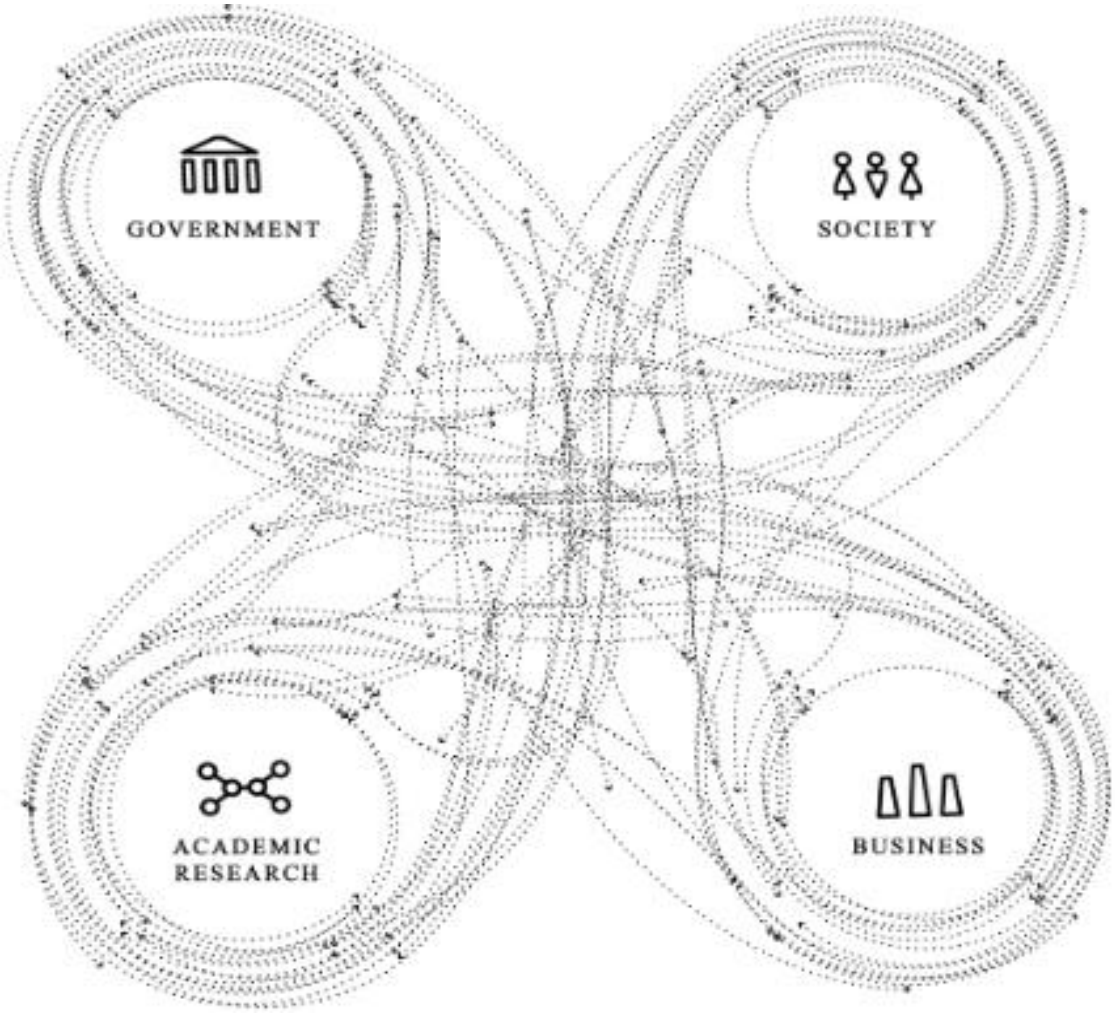

Figure 10. The Quadruple Helix Model.

Carayiannis et al. [74] explain the ***Quintuple Helix model*** as an interdisciplinary and transdisciplinary at the same time: the complexity of the five-helix structure implies that a full analytical understanding of all helices requires the continuous involvement of the whole disciplinary spectrum, ranging from the natural to the social sciences and humanities. The most important constituent element of the Quintuple Helix - apart from the active *'human agents'* – is the resource of '**knowledge'**, which, through a circulation between social (societal) subsystems, changes to innovation and knowhow in a society and for the economy. Thereby, the Quintuple Helix model visualizes the collective interaction and exchange of knowledge in a state (nation-state) by means of the following five subsystems (i.e., helices): (1) education system, (2) economic system, (3) natural environment, (4) media-based and culture-based public (also civil society), (5) and the political system (**Error! Reference source not found.**).

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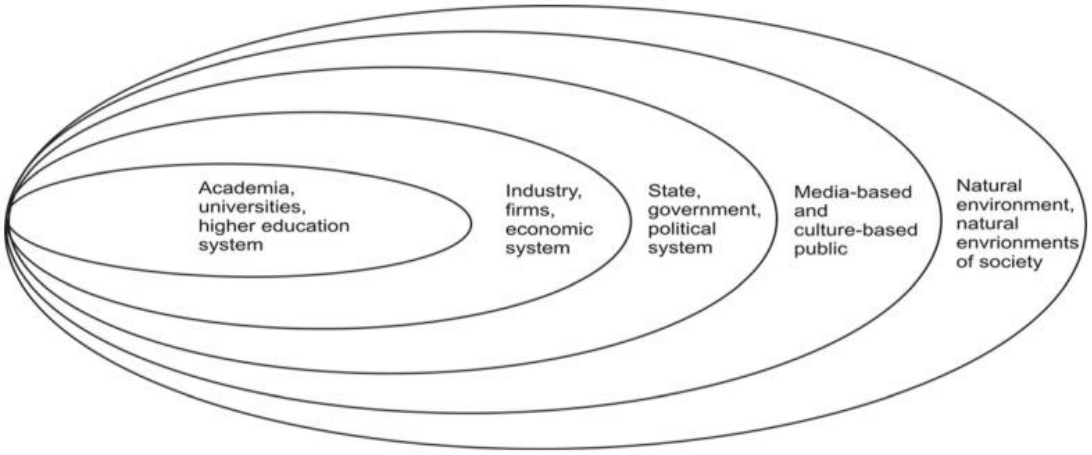

Figure 11. The sub-systems of the Quintuple Helix model.

4.2.1. Applications of the models in the cities of Amsterdam and Vienna

Amsterdam was one of the early adopters of the smart city concept in Europe adopting a bottom-up methodology based on social inclusion and QoL and one of the initiators of the City Protocol movement [59]. With the aim of enabling various initiatives, the actors of Amsterdam developed an open and collaborative platform ('Amsterdam City Platform') for an ecosystem of 'smart city solutions'. Further encouraging engagement and the connection of multiple stakeholders are initiatives like *StartupAmsterdam*, the city's portal connecting startups with the tools, talent and corporate backing they need to support them and strengthen Amsterdam's economy as well as the city's startup ecosystem, the *Amsterdam Smart Citizens Lab* (**Error! Reference source not found.**), which seeks to engage people in scientific discussion and the monitoring of their environment, and *Smart Kids Lab*, which helps kids leverage open source software and hardware to build their own monitoring systems, contributing to the city's future by equipping its children to become a central resource ([75]-[76]).

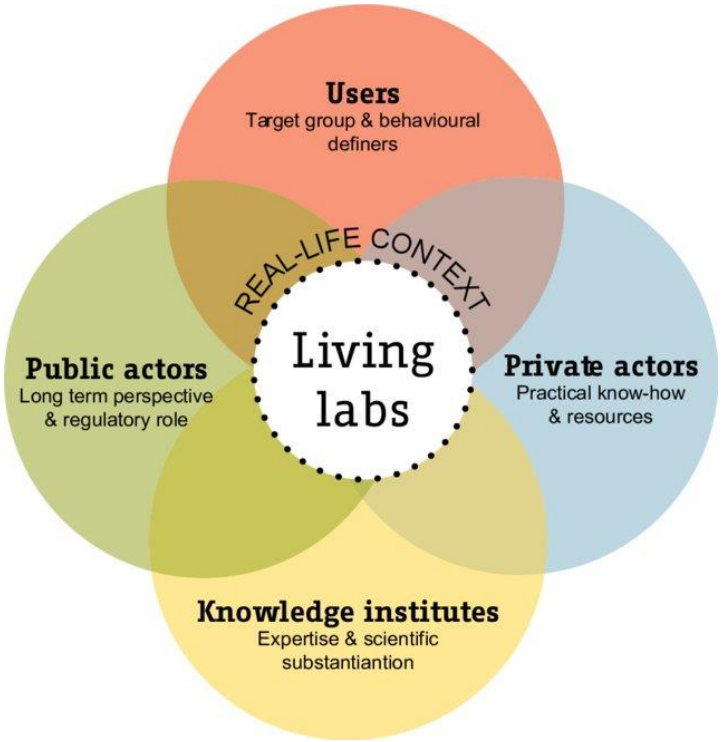

Figure 12. The stakeholders involved in the 'Amsterdam Smart City' living lab.

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The 'Amsterdam Smart City Platform' is 'the heart of Amsterdam's smart city ecosystem' [77] and it is an open web-based platform developed to increase the collaboration between the public and private actors in generating solutions across the diverse urban challenges (i.e. climate change impact mitigation, etc.) [78]. At present, the platform is an avenue for exchanging ideas for smart city projects under the following key areas: technology and infrastructure, energy, mobility, circular economy, governance and education, and citizen and living; nonetheless, Van Winden et al. [77] argue that the ASC concentrates its efforts on energy, mobility, and circular economy.

With sustainability as the main driving force of its smart city actions, Amsterdam Smart City ultimately aims to increase the QoL of its citizens by future-proofing the city based on a circular economy, which translates to a city *'ready to respond to all kinds of disruptions and changes whilst remaining attractive and competitive in innovation, which is the core element of the process'* [79]. As such, the open web-based platform acts as the principal urban innovation system of Amsterdam, which facilitates the fair and transparent distribution of information among actors, as well as the dynamic interactions between them, to achieve this goal. Noori et al. [79] point out that developing and testing urban solutions in a real-life context (urban living labs) is the dominant approach to managing innovation within Amsterdam, with the living labs mapped in the middle of the stakeholder's collaboration.

Analyzing the city of Amsterdam from a managerial perspective, Van Winden et al. [77] identified six partners involved in smart city projects: private companies, public organizations, knowledge institute, NGOs, citizens, and utilities. **Error! Reference source not found.** visualizes the types of partnership that have emerged from stakeholder collaboration and the general, relative degree of involvement of each stakeholder; however, the smart city 'ecosystem' seems to follow the *Quintuple Helix model* and 'sustainability' is the main motivation to 'boost' smartness. At the same study, Van Winden et al. [77] argue that the 'success' of smartness is Amsterdam is related to the effective synergies (collaborations with businesses and public sector, etc.) and characterized by: 1) precision in project scope and focus, 2) clarity in ownership, and 3) committed project leadership.

Figure 13. Types of partnership in the ASC living lab according to van Winden et al.

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On the other hand, Vienna's strategy was developed through multi-stakeholder processes that city administration; research institutions, private sector and civil society discussed about what city they want for the future [80]. This strategy has three pillars: "Quality of living", "Resources" and "Innovation", which organizes specific associated topics and goals (**Error! Reference source not found.**). Smart City Wien is developing new perspectives for the liveable city of tomorrow under the slogan: *'High quality of life for everyone in Vienna through social and technical innovation in all areas, while maximizing conservation of resources'* [81].

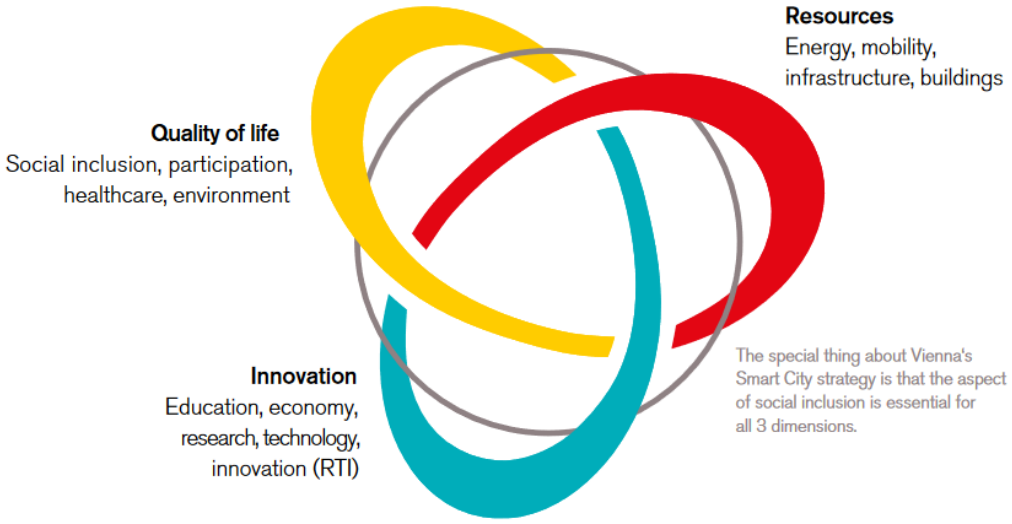

Figure 14. The Smart City Wien principle.

The principle of the Framework Strategy lies in its holistic collaborative ecosystem to ensure Vienna's future sustainability in comprehensive approach. This means new forms of action and co-ordination for politics and administration. Moreover, the scope of codetermination for the citizens of Vienna is expanded as well [81]. Nowadays, the Smart City Wien Agency is the coordinator between main initiatives and programs of the City of Vienna that enhances new methods of collaboration in order to implement the Smart City Wien framework strategy. For the second year in a row, Vienna ranked first in the Smart City Strategy Index 2019 by Roland Berger [82] and a major contributor to Vienna's position in the raking is the central Smart City Wien Agency. This approach has resulted in highly integrated solutions for mobility, the environment, education, healthcare and public administration. Some of the examples of the roles of the Smart City Agency are: communication with stakeholders and other actors, coordination and strategy, consultation on funding and project development, and project implementation [83].

Vienna collaborative ecosystem is an approach which appropriates and adjusts the model of Garcia et al. [54], which understand the importance of the 'smart city ecosystem' as a 'data-driven' services. For managing one of the biggest challenges for smart cities, big data, Vienna developed the VeroCity Platform. Vienna was the first city in the German-speaking world to publish open government data already in 2011, but the platform takes open data to a whole new level; its data aggregation and analysis capabilities are based on the European Commission's Context Broker building block, which can sort through data of all sorts and sources from all across the city [84].

Through low-threshold access to open data, start-ups and companies, as well as research, can create innovative and cost-effective solutions without risk. They also enable an open culture of sharing and cooperation. With Vienna's open data, more than 200 applications have already been developed, ranging from apps for the use of the public transportation system or parking, visualizations of statistical and georeferenced data and creative designs, to useful helpers in everyday life and for tourists. The value added by these applications is estimated to be around 1 million euros. [85]

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The Austrian capital not only evaluates individual projects, but also measures progress towards its long-term goals. A total of 120 experts from around 50 municipal departments, funds, enterprises and companies of the City of Vienna, as well as all its administrative groups, participated in the first monitoring cycle. Some achievements presented in the Monitoring Report 2017 (from the Smart City Wien Framework Strategy) are presented below [86] :

- ‘Smart environment’: Vienna’s CO2 reduction target for 2030 (35% reduction in per capita emissions compared to 1990 levels) was almost fully achieved just one year after the SCWFS was adopted. Compared to the baseline year of 1990, per capita emissions declined from 3.8 tons to 2.6 tons in 2014, which is equivalent to a reduction of some 33%. In absolute figures, greenhouse gas emissions diminished by 19% for the city of Vienna as a whole.
- ‘Smart mobility’: a strong decline in car traffic from 31% to 27% from 2010 to 2013. The share of passenger cars with alternative propulsion technologies in 2016 amounted to as little as 0.9%
- ‘Smart governance and IoT’: 210 open government data applications based on open govern-ment data from the City of Vienna (as per end of 2016). Th website of the Smart City Wien Initiative recorded around 50,000 visitors in 2016. As per end of 2016, 425 public WiFi hotspots were working in Vienna.

5. Conclusions

Despite the impressive growth of smart city initiatives worldwide, an organizational theory of smart city has yet to be developed, and we lack models addressing the unprecedented organizational and management challenges that emerge the ‘smartness’ in cities and boost the sustainability in their projects. It is increasingly clear that the adoption of configurational approaches that enable the ‘governance’ models is needed to better understand and apply the organizational dynamics as key factors towards ‘smart models’ in modern cities.

In this paper, we overview the dimension of the ‘smart city’ ecosystems as a mechanism to promote the expected outcomes of their sustainable development and to highlight the importance of conceptualizing cities at their organizational and managerial perspectives. By ‘sustainable transformations’, the literature usually indicates all those multi-level change processes (in production processes, laws, business models, people’s behaviour, etc.) that target an improved balance of the three pillars of economy, society and environment. At the same time, we explored typical models of ‘collaboration’ of key pillars to enable simultaneously the ideas of ‘smart’ and ‘sustainable’ and we studied interesting applications of them, such as the case of Amsterdam and Vienna; particular importance at our study had the paradigm of the city of Barcelona and its initiatives as a ‘good practice’ of how the collaboration among the different actors and citizens boost and promote the smartness towards a better QoL of its users.

A first key issue of the study has been the understanding of the ‘smart’ context in cities and the study of previous works. Particular importance is provided for the concept of the ‘governance’ and its role as a driving force to engage the relevant stakeholders and empower citizens to respond to their concerns. The third section, which is the main core of the current study, presents the role of the ‘ecosystems’ and the term of ‘collaborative ecosystems’ as well as their contextual influences to enable more innovative dynamics and understand the complexity of the ‘city systems’ and its ‘sub-systems’; this is a main challenge to the smart city processes and its importance evident for the achievement of its ambitions and strategies.

A second important issue that emerges from this study and the related literature is the presentation of the main elements of the ‘collaborative eco-systems’ and its applications ‘on-site’; the City Protocol, the Triple, the Quadruple and the Quintuple models are only some of them. All these studies converge in suggesting that smart city initiatives’ success depend on the collaboration and intertwined dynamics of a wide range of different actors, far beyond traditional organizational boundaries and strategic planning approaches.

The smart city field may be studied at the global, national or urban/regional level emerging the demand for organizational sectors and synergies at the urban but also its regional level. Boosting the

smart city movement in sustainable context is promising, but usually the only path to face the rapid urban metabolism and the consequences of the continuous transformations in modern cities due to the climate change, etc. but also to understand the complex and unique dynamics, mechanisms and particularities of each of them.

This study, of course, has constraints, which correspond to opportunities for further and more analytical research. Given its reviewing nature, this article provides a general framework of the importance of the terms of 'collaboration', 'governance', 'management', 'ecosystem' but the challenges of 'planning smartly' are ongoing and the 'sustainability' at the level of its 'organization' remains a critical step in this pioneering phase of smart city study.

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Nomenclature

Acronym	Definition
IoT	Internet of Things
ICT	Information and Communication Technology(ies)
ITU	International Telecommunication Union
IT	Information and Technology
QoL	Quality of Life
SSC	Sustainable Smart City(ies)
EU	Europe/European

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