

Review

Unveiling the Evolution of Innovation Ecosystems: An Analysis of Triple, Quadruple and Quintuple Helix Model Innovation Systems in European Case-studies

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Abstract: Despite the rising interest in smart city initiatives worldwide, governmental theories along with the managerial perspectives of city planning are a great lack in the literature. It is definitely understandable that the adoption of configurational pathways towards the 'smart' 'governance' models is required as key factor and smartness' facilitator in modern cities. In this manuscript, we display an exhaustive analysis on the importance of the n-Helix models along with a benchmarking critical approach through selected European case-studies. The study, through the literature review, revealed the lack of exhaustive analyses for the methodological investigation, identification and adoption of the most appropriate governance model and collaborative approaches per project and collaborative approaches and create modular frameworks to address efficiently the continuous urban challenges, such as the rapid urbanization or the climate change.

Keywords: Case-study analysis; Citizen engagement; Collaborative ecosystem; Governance; Innovation systems; n-Helix model; Smart city

1. Introduction

'Smartness' has increasing trends in the literature as a promising solution for modern cities to face complex phenomena. The innovative ecosystems facilitate the 'smartness' and promote the citizens' engagement towards its achievement through the extensive use of information and communication technologies ([1]-[2]).

Through a global angle, Lee *et al.* [1] developed an analytical scheme of the 'smartness' along with six pillars: 1) urban openness, 2) innovation, 3) partnership, 4) proactiveness, 5) integration and 6) **governance**, as a lever to enable growth and city development [3], nonetheless, this line is still under investigation [4].

Particular importance of this work is the analysis of 'n-helix' models built on 'innovative' initiatives aiming to the acceleration of the so-called 'emerging knowledge'. As an analytical approach, each Helix displays a distinct aspect of how societies produce, disperse, and promote 'knowledge'. As standardizing tools, they are used to instruct policy and decision-makers in a transdisciplinary method including all the possible synergies from academia, government, and society (citizens), while both cases lead the applications along with adjoining disciplines [5]. From a more 'technical approach', the city represents a unique *ecosystem* for the accommodation of innovative and 'smart' systems and perceived as 'Intelligent Communities', in which the synergies and the collaboration promote

the social and technological originality by establishing solid engagements among the involved parties [6]. Pierce *et al.* [7] emphasize on the importance of collaboration in smart cities' functions and the actors' synergies beyond traditional processes.

Literally, the term 'ecosystem' is usually associated to the 'smartness' [8] as the concept, which reflects the 'information', 'communication', 'collaboration' and 'technology', but it resembles varied kinds of other components, as proposed by Benson [9] (Figure 1), which require more universal approaches on how ecosystems bring together technology, government and society to achieve 'smart' objectives of the city planning [10].



Figure 1. Smart City 'Ecosystems'

From the other side, Ooms *et al.* [3] highlight the importance of 'governance' to stimulate 'smartness', thus a city is viewed as an ecosystem composed of physical boundaries (location, geography and topography), its population and the interactive flows (i.e. functions, society, growth, etc.) [11].

To the roadmap of 'smartness', cities seek for more innovative standards of production along with technological achievements in their organizational dynamics [12]. **It appears, that 'actors' collaboration and synergies' remain the primordial challenges** for the 'smart' success, whereas the degree of accomplishment is a factor of technological, governmental, institutional and beyond integration, [13], without neglecting the importance of participatory processes and the citizen engagement to the 'smart action plan' [14].

Nonetheless, the 'ecosystem' has a wide spectrum of interpretations varying from its technical to the more human-oriented and social approaches towards a 'smart' urban transformation [15] aiming at the benefits of the QoL and the long-term and 'intelligent' city development [16]. To visualize better the design and implementation of 'smartness' through more tangible results, Appio *et al.* [6] organized Giffinger's typical 'smart' model of the six pillars following the model of Hutchinson's pyramid (Figure 2):

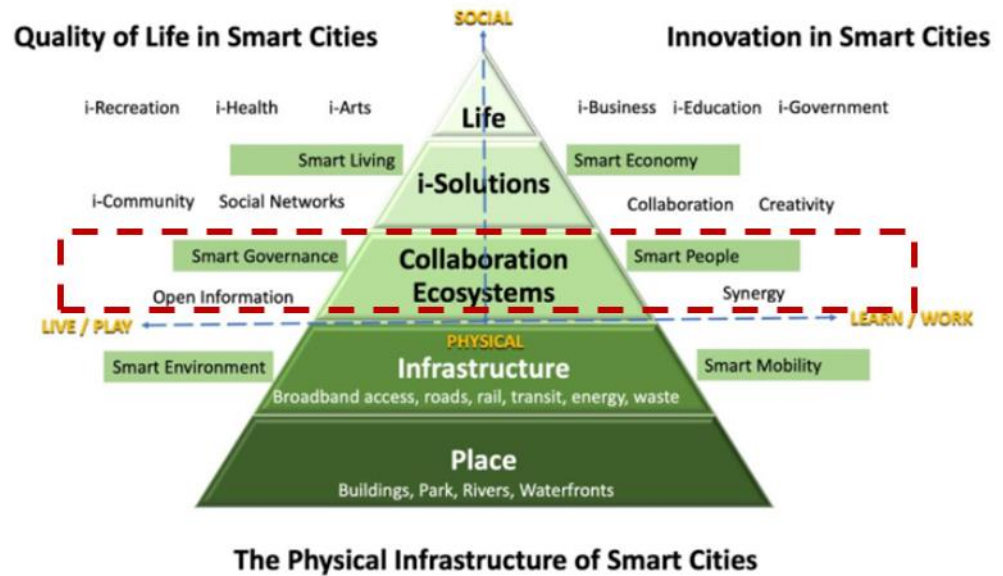


Figure 2. An adaptation of Hutchison's pyramid proposed by Giffinger for the understanding of the 'collaboration city ecosystems'

Nam and Pardo [17] relate the 'smartness' in cities to human-oriented and technological aspects and consider it as a lever for innovation and knowledge. At the same time, Dameri [16] enforce the 'smart' idea to accelerate the economic growth on cities but also to reply to the citizens' needs. Complementary to these arguments, Van den Bergh *et al.* [18] urge the concept of 'ecosystem' to deal with the urban modern challenges, which involve numerous and conflicting actors. Abella *et al.* [19] consider the concept as an added value to promote the 'digital' integration and the information processes.

From the other side, Ooms *et al.* [3] conceptualize the term 'ecosystem' along with: (1) the 'smart attributes, including the different stakeholders, (2) the governance and (3) the necessity of being 'sustainable' in long-term horizons. Chan [20] describes the SSC as 'an ecosystem comprised of people, organizations, policies and processes towards desired outcomes—a city adaptive to its environment and responsive to technological evolution to accelerate and to facilitate its actions', in which sustainability is prioritized. Figure 3 represents the 'smart city' model in 'layers' organization, in which each has a particular role for the accelerating integration of the technology to mutate the ecosystem. This process is usually supported by the synergies between stakeholders, while a key factor for its success is undoubtedly the 'governance'.

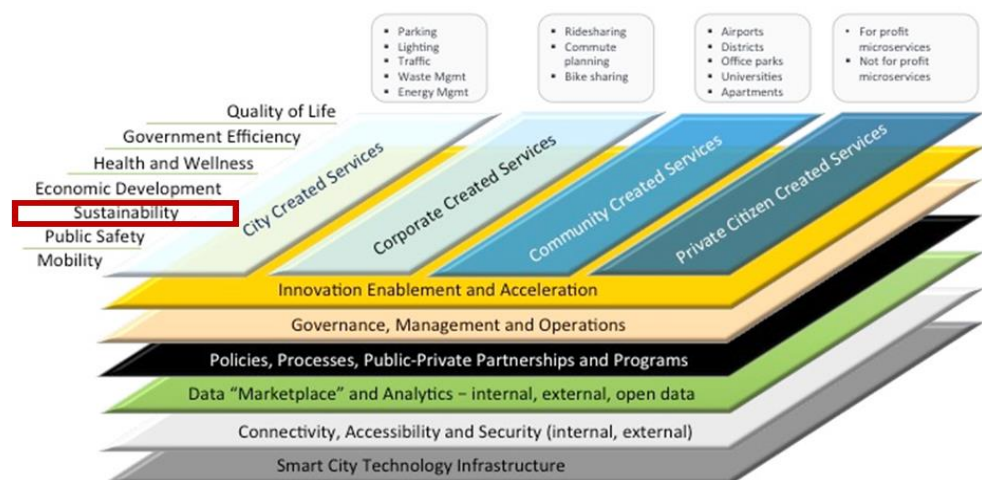


Figure 3. The 'smart city' model in layers

Schaffers *et al.* [10] highlight the significance of collaborations and synergies in ecosystems for the ‘smart’ sharing of resources, the experimentation of technologies and applications to explore the city challenge. Three pioneering perspectives are argued for the smart city ecosystem (Table 1), which are summarized on:

- The Internet and Research, focusing on a technological-oriented contribution to the smart city ecosystem;
- The policies around the city planning and development;
- The exploration of innovative solutions stimulating the participatory processes towards ‘smart’ solutions.

Table 1. Perspectives of synergies developed in smart city ecosystems

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

1.1 Scope of the Work and Research Questions

The purpose of this work is to review the (n)-helix models’ configurations to their processual nature, how they emerge and evolve, while complementary present selected case-studies and applications to provide insight (or add value) from an empirical perspective and delivered at very close timeframes (i.e., from 2014 to 2016), a fact that will allow for their comparative analysis to prove the empirical benefits of the evolution of the helix models under the same time-window investigated. The cases studies analyzed in this work comprise urban projects realized in European cities. Finally, we aim to reveal the potential relationships between the key barriers and drivers of the n-helix case-studies, in general, and propose alternative strategic options that could ameliorate the organizational mechanisms of the innovation ecosystems’ approaches.

1.2 Structure of the Paper

The study begins with the contextualization of the research topic and the identification of its key factors (section 1): an emphasis is given to the ‘governance’ as a driving force to enable motivations and action plans to the city planning and the notion of ‘ecosystem’ (section 2). Section 3 analyzes the theoretical approaches of the selected n-Helix models highlighting the benefits through practical applications on European case-studies. Section 4 emphasizes on the benchmarking results, while to this end, Section 5 discusses the main findings of this study and the perspectives for future work.

2. Collaborative and Smart Ecosystems. The Role of ‘Governance’

The stepping stone for the emergence of the ‘smart city’ movement was another concept that made its appearance at the last decade of the 20th century, the so-called ‘smart growth’ [21]. It supports innovation in policies for urban planning, while it has been widely adopted at the industry level after 2005, as it supports the deployment of complex information systems towards the inclusion of services and infrastructure. Hitherto, the concept has been gradually extending and updating to its current conceptualization state

which practically encompasses any form of technologically-led innovation exploited for the planning and development of cities. Pierce et al. [7] make a distinction between the terms ‘sustainable city movement’ and ‘smart idea’, even when they admit the existence of a connection between the two. Specifically, they discuss that the main principle of the later is the exploitation of technological-driven innovation for sustainable transitions, which is relatable with a framework that advocates strong interlinks among stakeholders and ecosystems. The existent literature body revealed three main categories of ideal/typical definitions of smart cities: as cities exploiting smart technologies for their smart transitions, as cities that focus on human-oriented innovations for their smart transitions, and lastly as cities that perpetually strive to update their *governance* in a more eco-systemic approach [22]. Some elements that have assisted in the wider recognition of the smart city concept’s value are the potential: amelioration of citizens’ QoL, capabilities it creates for achieving sustainability (i.e., environment, economy, society), increase of cities’ attractiveness [23].

Toppeta [24] in his definition of the ‘smart city’ focuses on the combination of technological and ICT capabilities with designing, planning and organizational approaches that aim to accelerate the administrative and bureaucratic processes in order to formulate innovative solutions that will facilitate the management of complex city mechanisms. Caragliu *et al.* [25] expanded the aforementioned orientation by complementary integrating the concept of ‘participatory governance’; particularly they defined ‘*we believe a city to be smart when investments in human and social capital and traditional and modern communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance.*’

To visualize the discussed definition, a schematic that connects the smart cities’ envisaged smart visions with the exploitation of technology and ICT through integration, the human factors to be taken into consideration via learning, and the institutional factors that could be reinforced via *participatory governance*, is given at Figure 4 [26]:

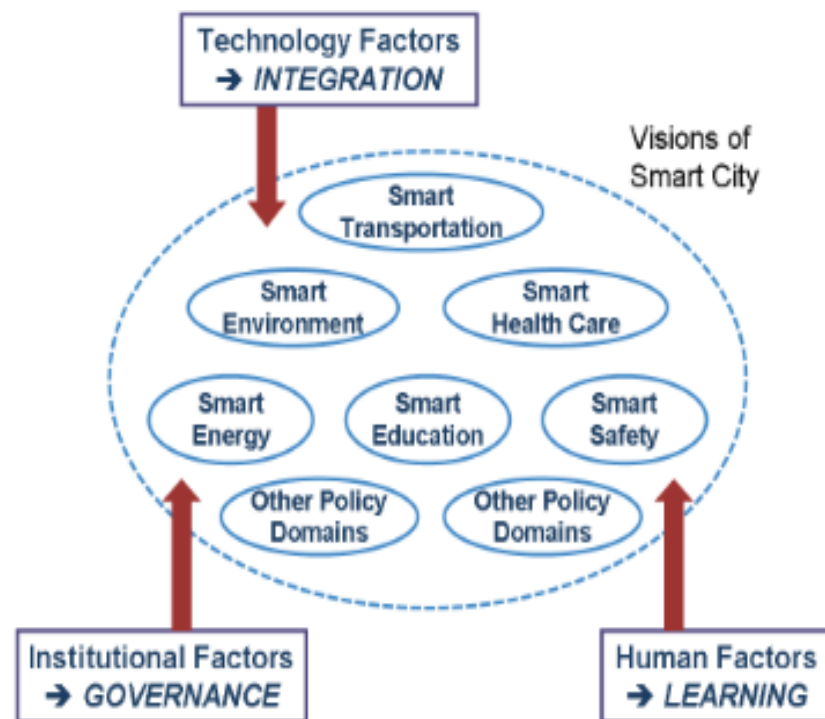


Figure 4. Visions of ‘Smart City’

Governance encloses all governing processes, while the governing authorities could be a government, market or network, formal or informal organization or territory, and the landing could be delivered via laws, norms, power or even language [27].

Tomor et al. [28] propose three governance components that entail the concept of 'smartness' cities:

- Governmental organization: It yields for the local stakeholders' commitment towards the development and deployment of 'smart' initiatives with the use of ICT and their appropriately designed operational management;
- Citizen participation: It ensures the citizens' engagement and empowerment in policy decision-making processes and through different stages of the realization of the project [29];
- Use of technology: Various digital technologies could be exploited to maximize the impact of participatory processes (e.g., communication and management platforms, project dissemination websites, discussion forums and meetings)

Complementary, Ooms *et al.* [3] display the need for the emergence of governance models with more complex structures and processes, whilst in the pursuit of 'smartness' in cities through the active inclusion of multiple actors. The literature review revealed two different focus orientations while exploring the significance of 'governance' in smart cities: the roles of specific urban actors and stakeholders [30], or the role of human capital. Nonetheless, the exact causal relationship(s) between 'smartness' and the role of 'governance' are yet to be fully understood and defined.

Deakin [31] mentions that, under the policy lens, the 'governance' is linked with participatory processes via academic leadership and corporate strategies. More specifically: '*the capacity to process the transition reflexively from creative to intelligent and as part of the cities' "smartness".*' This notion strengthens the collaboration between all involved stakeholders within 'smart city ecosystems', which subsequently leads to successfully reaching the envisaged objectives and city 'innovation'. Schaffers *et al.* [32] highlight the significance of synergies and partnership in sharing research and resources to create co-operation models. Participatory governance and citizen involvement are, in any case, key components in the 'smart city' framework and are at the core of 'smart' initiatives. These two keep decision-making active and ensure the cooperation of multi-stakeholders throughout a project [33].

Complementary, during SINFONIA EU project, researchers [34] conducted a feasibility study and analyzed the experiences of over a hundred completed and ongoing Smart City projects. They identified public participation, cooperation between different stakeholders and the long-term political commitment to be the most powerful drivers. Additionally, they revealed that public participation is furthermore the most utilized factor to overcome the key recognized barriers. Thus, special attention will be given in the citizen participation parameter in the selection of the case studies and their respective conclusions.

3. Analytical Framework of Helix Models and Case-study Applications

From a structural view, the creation of 'collaboration' in cities promotes the innovative synergies and the citizen awareness and engagement of public and private involved institutions. Thus, the 'smart ecosystem' involves a wide spectrum of stakeholders engaged in a continuous collaboration on a human-oriented knowledge and learning process towards 'intelligent' solutions to urban challenges.

Appio *et al.* [6] emphasize the benefits of the n-Helix models (and more precisely of the 'triple') for the economic growth and attractiveness and the environmental challenges, while the importance of the evolved models of 'quadruple' or 'quintuple' approaches accentuate the significance of a continuous and interactive process involving diverse stakeholders, investors, without neglecting citizens. Figure 5 [6] illustrates the evolution of the n-Helix models in regards to the knowledge production and innovation.

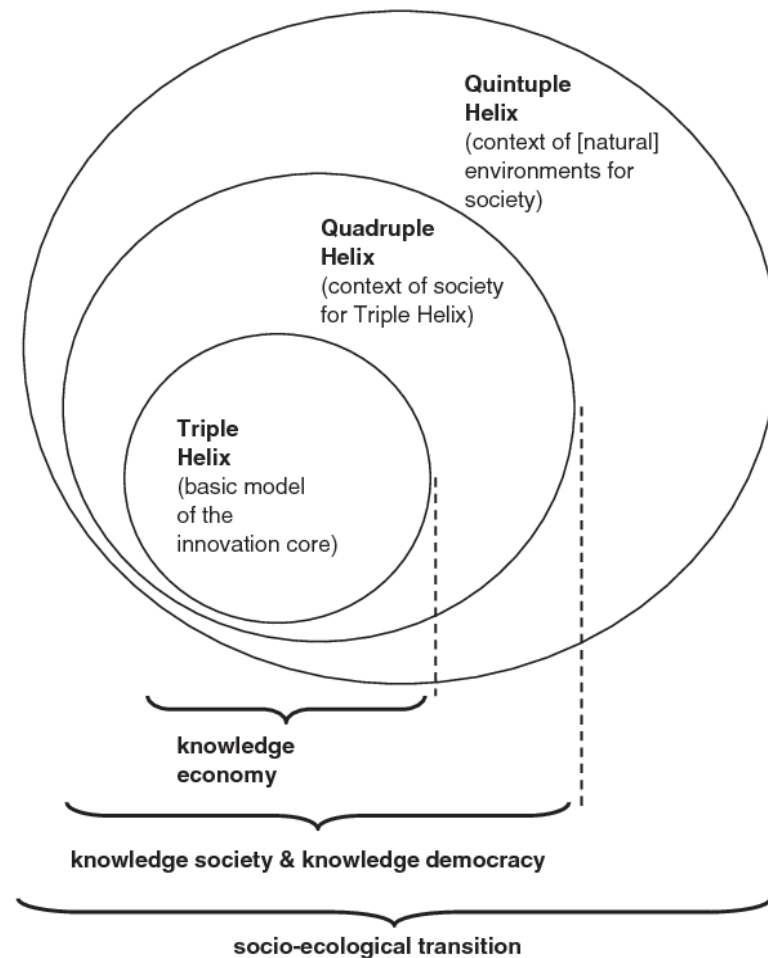


Figure 5. Knowledge Production and Innovation Models

The Triple Helix model was firstly proposed by two scholars: Etzkowitz and Leydesdorff [35] and became the pioneer of ‘smart’ collaborative ecosystems. The traditional stakeholders in charge of developing and sharing innovation in the industrial sector sphere, and creating knowledge in the academia interact with the political dimension of transferring the knowledge to promote the economic growth in cities through top-down approaches. This model stresses the importance of different pillars, the well-known as ‘helices’, to generate ‘innovation’ in the precedent sectors: academia/industry/government placing an emphasis on the ‘tri-lateral’ interconnections contextualized by the broader dimensions developed on forthcoming evolved forms, such as the Quadruple or the Quintuple Helices.

In fact, all the (n)-helix models share attributes of complexity in their functions [36]. Firstly, the models are inter and trans-disciplinary, meaning that coming both from natural and social sciences highlighting what is ‘innovative’ as well as the importance of multiple sub-systems (of actors). At the same time, their dynamic changes forge societal, institutional and organizational contexts, which enable (or hinder) the innovation processes by expanding it beyond the pure technological aspects [37].

McAdam and Debackere [38] claim that the helix models have the ability to understand the rising interactions between the developed subsystems as a primordial attribute of the innovation processes and beyond this to assess the interactions between the components of their spectrum. In this context, the Triple Helix Model has been particularly influential in the literature, while as a continuity the Quadruple and Quintuple not only promoted the policy making but also encouraged the transdisciplinary analysis of the Sustainable Development. This link is thoroughly explained by Etzkowitz and Zhou [39] who

stress the connection in particular with the SDG9 regarding the infrastructure, the industrialization and the innovation. A more detailed presentation of the three representative helix models is followed along with selected case-studies in Europe.

3.1. Triple Helix Model

The central idea of this model is that the 'ecosystems of innovation' in cities are developed along with three types of agents [40]:

- Universities: which have the main behavior as a 'magnet' to stimulate the scientific and technological knowledge;
- Industrial sector: which is the key to boost the creation of economic growth;
- Government (local, regional, national, international): which has an active role of actions, management, and land use policies.

The Triple Helix model is one of the most referenced in the literature used to define an innovation ecosystem and postulates that the interaction of the three elements, as mentioned above, to improve the requirements for 'being innovative' in a knowledge-based society unveiling the need of interactions among its elements, as illustrated in Figure 6 [40]:

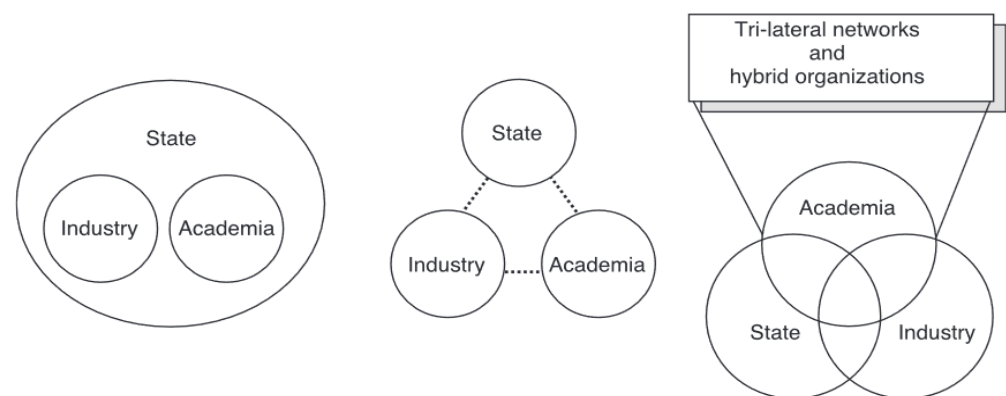


Figure 6. From 'etatistic' and 'laissez-faire' to the model of 'Triple Helix'

Appio *et al.* [6] argue that in reality in cases, in which the model was developed, the environment has been more competitive and 'economically attractive' enabling the pillar of 'smart economy'. Nonetheless, the model does not work satisfactory in all its applications due to the influence of barriers between the different parties involved and the lack of using interfaces creating limitations on its use ([35]-[36]).

3.1.1 Case-study Analysis

An example of the Triple Helix application is studied in the project of Berlin-Adlershof Science city as an idea of integrating three complementary elements: university research, institute research and private businesses, to serve as keystones of a dynamic cluster with a focus in technology development, with an initial support from the government side towards the settlement of research institutions reinforced by new companies [43]. The particular case is selected in order to show the weaknesses and threats that a successful Triple Helix implementation may hinder and contemplate on the final importance of them and the absence of public participation to the quality assurance of the project. Berlin-Adlershof is the largest cluster dedicated to high-technology in Germany, integrating industrial, media and scientific on a site [44], while by 2016, the park hosted more than 1,000 companies and scientific institutions that attracted 15,996 people for work and 6,524 for study [45]. Science and Technology Park Berlin Adlershof is one of the most successful high-technology places in Germany and among the 15 largest industrial parks in the world (Figure 7) [46].



Figure 7. Illustration of the Project of Berlin-Adlershof Science City

In this case study, following the triple helix model, the stakeholders are represented by all commercial enterprises (industry), University and research institutes (academia) and the Senate Department for Urban Development and the Environment (SenStadtUm) and the administrative district (Bezirk) of Berlin Treptow-Köpenick (government). The government of Berlin defined an entity, called WISTA, as a public and private partnership company, which is responsible of operating the park, the construction, lease and operation of the incubator and technology centers [47].

The triple helix model was considered for analyzing whether the housing planning for the innovation hub can be integrated and envisioned as a pioneering product in terms of the collaboration model. The triple helix approach is exploited to enable the organization and project management as well as the synergies among its involved parties (stakeholders), which are related to different processes of innovation. Bellgardt *et. al.* [44] focused a study on the socio-cultural aspect in the urban development context, regarding science cities, since this socio-cultural approach was discarded in previous research on the triple helix model (Figure 8) [44]:

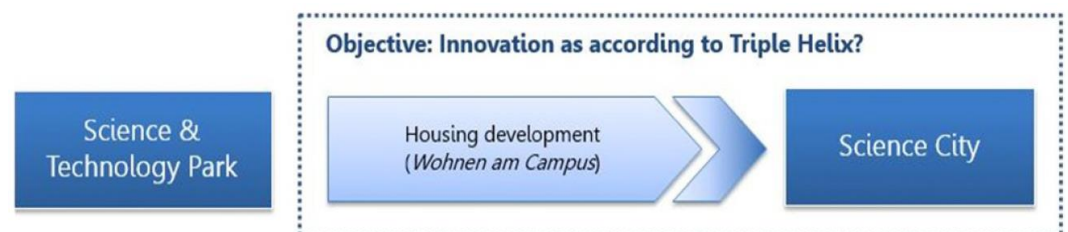


Figure 8. From an Innovation Park to a Science City (project of Berlin-Adlershof)

There are several success factors in Berlin Adlershof case. Among them, the governmental provided support since the beginning, in terms of financial approach, which gave an encouraging ambience for innovation and creativity [6]. Also, this governmental actor supported effective park management and development through the public private partnership and the political planned determination [47]. Additionally, an important factor of success is the existence of a long-term plan to promote and expand the site and create links and working relations between the three helices.

According to Bellgardt *et al.* [44] the triple helix approach cannot be usefully applied to the actors' interactions in residential development in science cities, since is not suitable to mediate the process of planning for this urban approach. Firstly, in terms for urban planning development, demand for housing is not distributed across the three helices in an even way. The triple helix model undertakes that the helices interact at the same time under the fact that this interaction will create added value; although industrial stakeholders choose not engage in the planning process because they predict no immediate economic benefit [48].

Another negative factor for this model is that the stakeholders' interactions are reliant on their resources. The capability for the academia (Humboldt-University) to participate was limited by its financial and recruitment resources, in comparison with the industrial actors. Lastly, there is no existence of an external organization, a fusion organization from the three helices intersect was not functioning independently.

3.2. Quadruple Helix Model

As explained previously, the Triple Helix model is a scheme for action of knowledge-based economy [49]. In this evolution, the Helix encounters the 'citizens' in a helix, recognizing their increasing role of the society [50] and as a further helix the economy associated by the 'media-based and culture-based public' [51]. Inspired by Carayannis *et al.*, the fourth helix reflects on phenomena such as the 'media-based democracy' by being at the same time human-centered and in favor of knowledge. The main objectives of the Quadruple Helix model are summarized on:

The lack of cohesion and presence of a limited intellectual exchange in the shaping of the smart city modelling (Figure 9) [51]:

- The need to offer a 'technological determinism', in which utopia is imposed within the need for innovation to reply to the requirements of urban sustainability;
- The legitimization of research trajectories among the relevant publics aiming at having public impacts to more sustainable solutions [52].

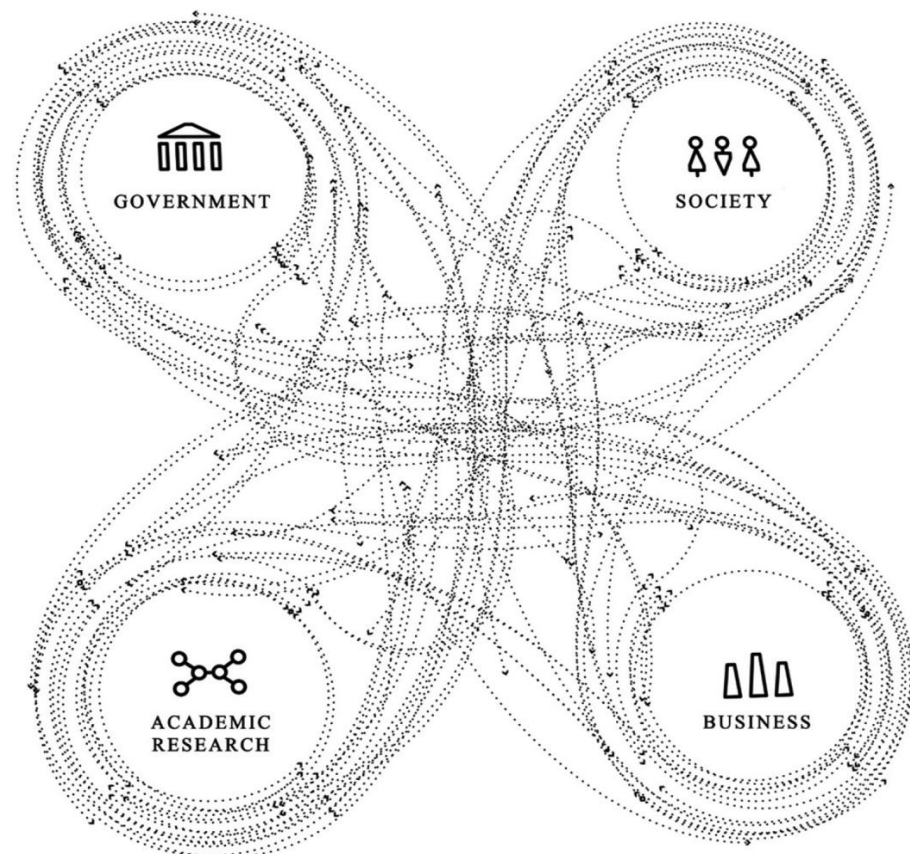


Figure 9. Representation of the Quadruple Helix Model

The Quadruple Helix model, from the explanatory potential of this helix, focuses one hand the culture and values and the way of how this 'public awareness' is constructed and then communicated, while at the same time this relation influences every system of the model [53]. Nordberg [54] defines the fourth helix as the more 'cultural' dimension and the backdrop towards the roadmap to innovation, while Ivanova [55] discusses about this topic but from a more systemic view focusing on services, arguing that the quadruple helix model not only addresses the consumer but also the communication and the media.

From the other side, Höglund and Linton [56] argue that the fourth helix is not a separated additional helix but an integrated part of the society and its significance is to reply to the citizens' requirements. Nonetheless, and despite the undeniable contribution of the quadruple helix model, there is a methodological challenge on the way of the citizens will introduce their public perspective but also how the different actors will define their functional role of the society as a fourth pillar and in collaboration with the innovative processes.

3.2.1 Case-study Analysis

An empirical basis that explores how the Quadruple Helix model unfolds and functions is the renovation of a bridge located in Uppsala, whose local authorities initially considered integrating a renewable energy technology by collaborating with researchers involved in academic entrepreneurship [57]. This project was originally designed to follow the Triple Helix Model, but the necessity to include the citizens later on in the project makes it a good case to stress the significance of thorough planning that engages the public at the early stages of decision-making. Failure to do so may lead to catastrophic outcomes and may, therefore, undermine the whole scope of a project.

This project was initiated in 2014 by the Regional Development Office of Uppsala (hereinafter referred to as the "regional office"), whose original leader had a personal interest in environmental issues. Situated in Sunnersta (Southern Uppsala), the Flottsund bridge is a key connection for the city and the county, and is a vital route for vehicular, bicycle, and pedestrian traffic (Figure 10) [58].



Figure 10. The Flottsund Bridge

The late engagement and inclusion of the citizens in the Flottsund bridge renovation project, however, proved ineffective as citizens already felt left out of the decision-making process; open meetings meant to create a dialog with citizens ended up as one-way, and local authorities from the regional office only engaged with the residents to seek approval for a project that had been already decided upon without the latter's prior involvement. Since the concern of the citizens primarily lay on the disruption that would be caused by the renovation, the regional office marketed the project as one whose social value was an upgraded recreational area for the community. In the end, the renovation project proceeded without the integration of the marine power current turbine, thus failing to achieve the original objective of commercializing the said technology.

3.3. Quintuple Helix Model

Carayiannis et al. [53] explain the *Quintuple Helix model* as an interdisciplinary and transdisciplinary at the same time in the sense that the fifth helix structures a more analytical aspect for a dynamic involvement of all the involved parties. The most important ingredient of this evolved model, apart from the active and more 'human-oriented' approach, is the resource of 'producing' knowledge through a circular process between the sub-systems (society, economy, etc.). Thereby, the Quintuple Helix model visualizes the importance of collectivity and the exchange along with the education, the economy, the environment, the society and the political systems as represented in Figure 11 below [53]:

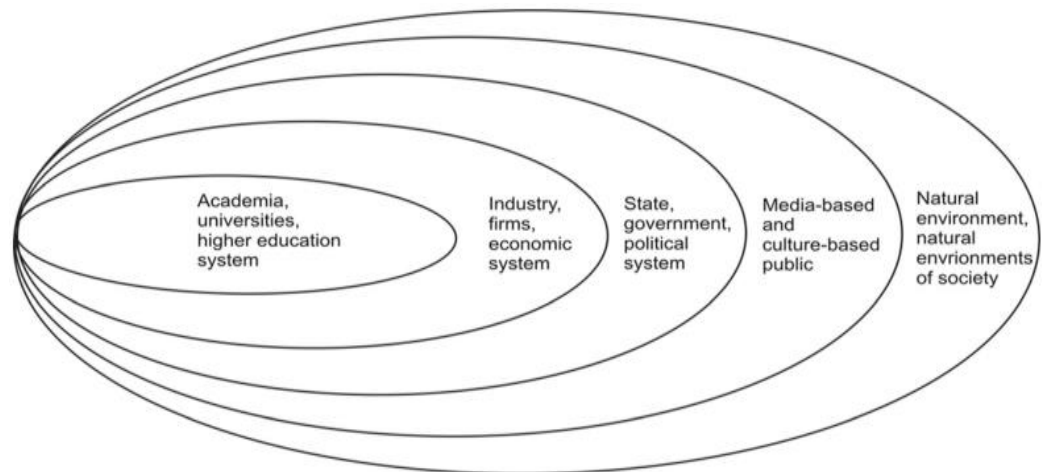


Figure 11. The Sub-systems of the Quintuple Helix Model

The Quintuple Helix model of innovation adds a fifth dimension to the innovation processes, with the emphasis of the *nature* and *social ecology* [59]. Nonetheless, a question, which usually remains unsolved within the Quintuple Helix model, is the way to connect the five helices in an innovation process. To this topic, Markard *et al.* [60] argue that a response is around the 'ecology', which is the interdisciplinary either of relations between living organisms (social) or either between them and their environments (natural), which is subsumed as 'ecosystem'. All these concepts around the Quintuple Helix Model converge the society-nature transition. Thus, in the Quintuple Helix the focus is around the translation of the environmental and ecological issues by identifying them as 'drivers' for future knowledge and innovation.

3.3.1 Case-study Analysis

The examined case study under title "Remote Control of Ventspils Water Supplying System and Smart Metering Services", completed in 2016, while the main leader of the project was the Municipality of Ventspils. The project's main objective was the creation of a remote control and smart metering system for a water supplying system in Ventspils city and the social sensibilization, education and awareness of the services' use, but also the improvement of the synergies among the users and the involved investors or other stakeholders. The literature review, while trying to select a Quintuple Helix case study, revealed that the maturity of this concept yields for the realization of highly sustainable and resilient projects that share multiple common characterizes in the governance orchestration mechanisms; this is a typical early application example of the examined model found in the literature. The project has a variety of tasks, which were attributed to the different involved stakeholders as briefly presented below [61].

Ventspils University College and Kaunas Technological University were responsible for the creation of a novel electronic equipment for reading and transmitting data from water network nodes, appropriate software to respectively store and process all the retrieved data and finally e-services that exploit the gathered data and software. Entrepreneurs such as the small enterprise, Smart Meter Ltd and Ventspils UDEKA (municipal

enterprise of water supply) were responsible for equipment testing, services implementation, and general systems' maintenance after the project's end.

The non-governmental professional institution, Latvian Internet Association's (LIA's) primary goal is to educate society in internet technologies' usage and to ameliorate SMEs' business environment in the country, acting as the moderator between government and entrepreneurs. Therefore, they were eager to participate at such a project, due to its significant potential for positive influence on the development of e-services within Latvia, and contributions towards society's education and entrepreneurs' engagement. Their role was to create education materials for the public and relevant to the upcoming e-services, while additionally assisting the municipality in the organization of seminars to introduce citizens in the new e-services possibilities. Finally, they acted as one of the dissemination stakeholders, along with the media.

Taking into consideration that proper dissemination plays a vital role in the success of Quintuple Helix innovation models, as well as that the local media can contribute towards this objective by providing proper communication with the local community, the participation of the local newspaper named "VentasBalss" was secured. Moreover, other typical social media channels were exploited for the cause of the project by all its partners.

The project belongs to the Quintuple Helix model innovation ecosystem category, as it successfully achieved the cooperation of various stakeholders from the government, academia, industry (with SMEs and mass media engagement) and with an environmental-oriented goal (e-service for a remote control and smart metering system for a water supplying system) and socio-ecological outcomes. Moreover, special attention was given to the education of society in ways to exploit the new electronic services, and to improve the levels of cooperation between the residents and the municipal utility companies, accumulating thus greater experience and knowledge in cooperation within complex innovation ecosystems. The base of cooperation amongst the different involved stakeholders was established with the development and usage of a communication and management platform for the project.

One of the key factors that secured the success of the project was the careful selection of the stakeholders to be engaged and the roles that they were assigned, something that accelerated the progress of the project, ensured top quality and success.

Specifically [61]:

- For projects that target local goals, it is most wise to involve the respective local government. In this case, the water control and smart metering system, was targeting the sustainable transition of the whole Municipality of Ventspils city, and thus the respective municipality was the main contractor of the project. Via the quintuple helix cooperation relationships established between this and the rest stakeholders, the outcomes achieved were mainly twofold: on the one hand the municipality updated and modernized their structures and services, with the realization of the novel remote-control water supply system for end users and utilities, while on the other hand the communication with society was greatly facilitated and strengthened, as the municipality ensured transparency throughout the project's processes for the society and additionally offered organized educational approaches, via both the existing municipal portal and the local mass media, for the introduction of the new e-services to the local community;
- Involving universities in social-ecology projects, increases the potential to achieve high quality technological achievements. But most importantly, it allows for scientists, scholars, young researchers and students to engage in the philosophy of technological progress aligned with social benefits for the society;
- NGOs play also a key role, as they have the potential to facilitate the communication amongst industry and the society, contribute towards the expansion of e-services domain and accumulate new knowledge regarding the communication and cooperation with new partners, for example academia;

- Entrepreneurs (in this case, SMEs), are benefited and contribute both towards the exploitation of novel equipment and services, and from the knowledge they can gather on the information and development workflow management and the communication practices with society and potential audiences;
- The inclusion of the (local) media is also important for the success of the project, as it has the potential to internally monitor development processes. The simplest way to practically introduce a local public audience to new e-services is via points of easy access for them, such as the local media, municipal portals, and newspapers.

Another identified vital point for the success of the examined project was the proper and thorough information of the local community and the increase of their self-awareness, as mentioned in the initial goals of the project [*...and to educate society in how to use the new electronic services, and to improve levels of cooperation between the residents and the municipal utility companies*]. This was achieved with the cooperation of all stakeholders, while the Latvian Internet Association prepared the content, and the dissemination was done via the mass media and municipal portals. Efficiently including and educating society in quintuple helix model projects is pivotal, as via their increased self-confidence on social ecology, social and smart economy (i.e., reduction of bills for water and a fairer price for consumption with simultaneous understanding of the importance of achieving overall sustainable development) they facilitate a holistic sustainable development. With the services of this project, citizens were able to follow water usage and to engage in the nature recourse saving program. Moreover, in projects like the one under investigation, where e-services are created for the environmental monitor and management from end users, the success of the results might be measured in statistical savings, yet they are explained via the citizens participation, something not quantitatively discussed or measured in the case-study literature. However, because of the proper planning from the involved project partners for making the information easily available and providing efficient training on the ways of the new e-services usage, the citizens started to exploit the e-services, and this is what contributed towards the successful water management quantified results.

Finally, another recognized strength of this project was the establishment of an effective information exchange, cooperation, and communication channel among stakeholders, via the development of a management and communication platform. This allowed for the emergence of a cooperation model between project partners from various groups (i.e., municipality, academia, non-government, SMEs, mass media), and to the adequate management of resources (e.g., technical, human, economic, time, etc.) for the final completion of a successful project with the new products and services and within the originally set time horizon.

4. Results and Discussion

A benchmarking (SWOT) analysis of the main findings of the case-study analysis is explained analytically in Table 2.

Table 2. Benchmarking (SWOT) Case Analysis of Selected Applications

	Strengths	Weaknesses
Innovation Park to a Science City	Interactions of actors Regular evaluations and auditing processes	Limited cooperation and interaction between the three helices in planning steps Uneven distribution of demand limits the interactions
	Existence of public-private engagement model Existence of expertise, awareness, and methods for designing implementation of new technologies and solutions	Model basically assumes the entrepreneurial model Lack of adequate communication and transparency between project participants and the public to raise awareness Inadequate/General definition or documentation of processes
Flottsund Bridge	Efficient and constraint-driven project management Public participation	Short-sighted planning Lack of adequate communication and transparency between project participants and the public to increase awareness
	Existence of expertise, awareness, and methods for designing and implementation of new technologies and solutions Interoperability between systems	Exclusion of citizens from the earlier stages of planning and decision-making processes Lack of cooperation and distrust between different stakeholders Inertia Lack of binding agreement among involved parties Lack of integrity from the regional institutions Failure to integrate varying stakeholder interests into a shared vision Absence of well-defined or documented in detail processes
Cooperation for E-Services Development and Education of Society. A Case Study in Latvia	Careful selection of stakeholders and assignment of their roles and responsibilities Proper and thorough communication between project participants and the public to increase awareness and involvement Efficient communication and management platform with sharing of valuable data between different departments and partners Cooperation and trust between different stakeholders Interoperability between systems Monitoring Public participation	Technologically non-literate majority of (elderly) citizens Inertia

	Strengths	Weaknesses
	<p>Existence of expertise, awareness, and methods for designing and implementation of new technologies and solutions</p> <p>Existence of financial schemes</p> <p>Existence of training material</p> <p>Credibility and trust</p> <p>Well-defined or documented in detail processes</p>	
	Opportunities	Threats
Innovation Park to a Science City	<p>Long-term strategies</p> <p>Strong political commitment over the long term</p> <p>Foster of innovation processes</p>	<p>Insufficient financial support</p> <p>Absence of financial models suitable for the innovation to address stakeholders</p> <p>No attention to values of citizen engagement and management</p> <p>Merged organization from the three helices intersect was not functioning independently</p> <p>Potential conflict of stakeholders' interests in collaboration ecosystems</p>
Flottsund Bridge	<p>Enabling political framework for renewable innovation & entrepreneurship</p> <p>Potential testing & upscaling of the project</p> <p>Additional income generation from green tourism and commercialization</p> <p>National roadmaps, strategies, and policies for energy goals</p> <p>Existence of affordable and mature technologies suitable for local conditions</p>	<p>Public acceptance of technologies</p> <p>Insufficient financial support</p> <p>Changes in the administration and political agenda and lack of leadership</p> <p>Potential conflict of stakeholders' interests in collaboration ecosystems</p>
Cooperation for E-Services Development and Education of Society. A Case Study in Latvia via	<p>Facilitation of urban long-term sustainable socio-ecological transitions</p> <p>Trend for future knowledge production and innovation based on eco-innovation and eco-entrepreneurship (eco-evolution of knowledge</p> <p>Concept of knowledge by incorporating innovation</p> <p>Aligning technological progress with social benefits for the society via academia</p> <p>Facilitation of the communication amongst industry and the society via industry</p>	<p>Empirical evidence within quintuple helix ecosystems</p> <p>Potential conflict of stakeholders' interests in collaboration ecosystems</p> <p>Procedures for authorization of technologies</p> <p>Public acceptance of technologies</p> <p>Existence of data security and privacy</p>

Opportunities	Threats
Reinforcement of entrepreneurs' information and development workflow management Existence of affordable and mature technologies suitable for local conditions Political commitment over the long term National roadmaps, strategies, and policies for energy goals Effectiveness of regulations for implementation of technologies and solutions Obligations given to project participants	

Based on the aforementioned key positive and negative factors identified, the four resulting areas of the SWOT analysis are set against each other to understand and reply to the queries of:

- Which opportunities can enforce specific strengths, or which strengths can be used to exploit specific opportunities?
- Which opportunities can contribute towards the minimization of the weaknesses?
- How can strengths be exploited for the minimization of threats?
- How can weaknesses be minimized to eliminate threats?

The most appeared, and for the authors, significant findings of all the case-studies, in relation to the most powerful drivers as mentioned in a previous section (i.e., **public participation**, cooperation between different stakeholders and long-term political commitment) are summarized below, in an attempt to unveil the causal relationships between the examined drivers and barriers and propose robust organizational mechanisms and strategies for achieving efficient innovation 'ecosystems' [62]:

a) Connection between strengths and weaknesses

Strengths: Public participation & Proper and thorough communication between project participants and the public to increase awareness and involvement

Weakness: Inertia

Typically, it is expected that a behavioral change will not happen easily, something that applies on matters of implementation of new technologies and services. Yet, this weakness could be eliminated by the realization of relevant advice campaigns for the public. It is highly recommended that the dissemination of knowledge and information must be 'translated' and handed over in a simplistic way for everyone to understand. These advice campaigns have the potential to lead to easier end-users' behavior changes, as they will have advice for their smooth transition into the new services or technologies. Moreover, by actively involving the educated citizens into the decision making, they will more likely regain their trust in the proposed project and make conscious choices and not intuitive.

b) Connections between strengths and threats

Strength: Public participation & Proper and thorough communication between project participants and the public to increase awareness and involvement

Threat: Public acceptance of technologies

The lack of public acceptance for new technologies might be traced back to the lack of appropriate information on costs and benefits of the technologies, which subsequently leads to the lack of trust that the upcoming decisions will be beneficiary for all involved stakeholders [34]. By actively engaging the public into discussions with the rest stakeholders, the knowledge of the former on costs and benefits will increase and thus misconceptions are expected to diminish. Complementary, by comprehensively educating (i.e., advice or educational campaigns) the public on the new technologies and transparently involving them into the decision making on technological activities, the feeling of suspiciousness is expected to decrease significantly.

Strength: Existence of expertise, awareness, and methods for designing and implementation of new technologies and solutions

Threat: Potential conflict of stakeholders' interests in collaboration ecosystems

Even though different projects may apply similar smart governance solutions during the realization of smart city projects, it is reminded that each project is referring to a different city with different contexts and different ecosystem balances. This means that the smart governance mechanisms cannot be generalized for other cities or even projects within the same city, as the balances among the involved stakeholders are liquid and subject to change per case. However, this issue could be addressed by the integration of expertise, awareness, and methods for designing and implementing projects. Multidisciplinary teams of experts could analyze the social, economic, political, environmental, and legal conditions of the project and design and orchestrate localized governance mechanisms, that will respond to the specific needs of the project.

c) Connections between opportunities and weaknesses

Opportunities: Political commitment over the long term & National roadmaps, strategies, and policies for energy goals

Weakness: Lack of adequate communication and transparency between project participants and the public to increase awareness

There are cases that the communication and trust between project partners and the public are insufficient. Nonetheless, it is expected that the interest of the public and their efforts for communication with the other partners will increase, if they are ensured that there will stability and responsible actions towards the implementation of a project, independently on the political party in charge. This feeling of collectively striving for a common sustainable goal, could be magnified by the existence of national roadmaps, strategies, and energy for energy goals on the long run.

d) Connections between opportunities and threats

Opportunity: General environmental issues and (socio)-ecological transitions

Threat: Public acceptance of technologies

A potential absence of acceptance for new technologies and services may lead to delays regarding the progress of the project. However, the treatment of environment and the adoption of a 'social-ecology' mentality could alleviate this threat. Empirically it is known that the treatment of environmental issues draws investors' interest and leads to both increased public participation and acceptance of smart city projects [34].

These are the key identified ways that innovation ecosystems can orchestrate robust collaborative governance mechanisms to design long term smart and sustainable transitions, by reinforcing both the exploitation of the drivers and the minimization of the barriers. The focus was on the three key drivers, as identified above, nonetheless it is reminded that multiple more combinations exist.

5. Conclusions

The evolution of innovation ecosystems models (i.e., from Triple to Quintuple Helix) yields for the parallel evolution of smart urban governance approaches. The state-of-the-art review reveals that research is already being done towards this direction, yet the complexity imposed by the emerging innovation ecosystems demands the perpetual reinforcement of governance mechanisms and definition/conceptualization of most appropriate, modular/dynamic and customized frameworks to the smart city transitions or even to the specific smart project to be envisaged

The selected case-studies revealed various findings. To begin with, the Triple Helix case revealed that depending on the nature and the scope of the project, public participation might not be necessary for securing the success of the project. Nevertheless, we highlight that public participation is recommended both for its dynamic for innovation and value creation (e.g., via open participation, open innovation schemes), as well as for the general elevation to a knowledge society (and knowledge economy, knowledge democracy) with 'smart' citizens. In doing so, however, it is crucial to engage the public as early as the planning stage of the project to raise their awareness and to ensure their continued involvement. This must be done through consistent and transparent communication between citizens and all stakeholders involved to build trust and credibility. Failure to do so may negatively impact the realization of the project, as demonstrated in the Flottsund bridge renovation project. Finally, the Quintuple Helix case study confirmed the maturity of the whole framework and suggested that perhaps of the time and the holistic approach it offers to sustainable development, smart city governances are learning from past literature and empirical mistakes and adapting to new global conditions and addressing urban challenges efficiently and effectively. Nonetheless, and as a future work, it is highly recommended to undergo a more extensive and exhausting literature review on stories of success and failure per Helix and create a roadmap of the empirical evolution of the Helix concept. We furthermore suggest that the smart city governance 'ecosystems' should not be examined only internally, but also externally with their interoperability with other urban cases as the knowledge, innovation and creativity are only accelerated by sharing and interacting within complex networks that strive for the same long-term goals (e.g., open innovation 2.0).

The power of innovation ecosystems was complementary elaborated from the perspective that they allow the emergence of multiple potential solutions where strengths, weaknesses, opportunities, and threats of smart governance mechanisms can be orchestrated for ameliorating the design and implementation of smart city projects towards sustainable development. Even though the authors chose to focus on the so-called key drivers for smart city development for the purposes of this review, it is suggested that the multiple relationships between the different areas of the SWOT analysis should be furthermore explored and the case studies analysis will become exhaustively investigated.

The smart city field may be studied at each level and scale from the regional to the more global emerging the rising demands of the cities' populations. In this manuscript, we emphasized on the role of the organization, while given its reviewing character, an analytical process of the n-Helix models with a critical angle is identified as a powerful lever for innovation. Keywords, such as 'governance', 'ecosystem', or 'collaboration', enabled to display the role of 'smart ecosystems' for solutions against challenging phenomena, such as the rapid urbanization or the climate change. The study, through the literature review and the benchmarking process of selected and successful European projects of the models' applied, revealed the lack of exhaustive analyses for the methodological investigation, identification and adoption of the most appropriate governance model and collaborative approaches per project and collaborative approaches and create modular frameworks; nonetheless, more evolutionary frames based on the development of synergies of stakeholders are required to prioritize their importance in the smart city planning.

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Nomenclature

Acronym	Definition
ICT	Information and Communication Technologies
QoL	Quality of Life
SSC	Sustainable Smart City
IT	Information Technology
SDG	Sustainable Development Goal
NGO	Non-Governmental Organization
SME	Small and Medium Enterprises
SWOT	Strengths, Weaknesses, Opportunities and Threats

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