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Facilitating Quintuple Helix innovation with Urban Living Labs

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Abstract: This paper discusses the Urban Living Lab approach as a way to put the Quintuple Helix model for innovation into practice. In this analysis we focus on the concepts innovation democracy, 'mode 3' knowledge production, the innovation ecosystem as a system of societal subsystems and socio-ecological transition. The empirical analysis is performed by means of a multidimensional case study design, applied on a project-based ad hoc collaborative innovation development process in an ecological domain. The results of this paper provide theoretical foundations for Living Lab research, but also add to the practical understanding of the Quintuple Helix model for innovation, which often has a rather conceptual nature.

Keywords: Urban Living Labs; Quintuple Helix; Innovation management; Open Innovation; Quadruple Helix; Triple Helix; Innovation Networks; Social ecology; Sustainable Innovation; Urban Innovation

1 Introduction

Modern society faces challenges of a very complex and global nature. This makes it hard for a single entity to come up with the right solutions. Therefore, firms and other organizations are increasingly reaching out to external sources of knowledge to tackle these challenges. Among the most pressing challenges are ecological issues such as global warming, air quality and climate change. It is clear that these need to be dealt with by a diverse ecosystem of private actors, universities, civil society and politics, but that such ecosystems also need to take into account the natural environment itself.

However, in innovation management theory, the question is not why, but rather *how* such challenges can be solved. Complex problems require complex solutions. In collaborative knowledge production and innovation management literature, one of the frameworks that attempt to take the natural environment into account is the *Quintuple Helix model* for innovation (Carayannis & Campbell, 2010). Although this rather recent analytical framework looks very promising, only little empirical evidence exists that explores its possibilities and limitations. Given the growing importance of sustainable and eco-friendly innovations, further research is needed to explore collaborative innovation development within a socio-ecological context. As such, environmental challenges can be perceived as an opportunity to innovate, not only in equilibrium with civil society, but also with the socio-ecological context.

To broaden the general understanding of this concept and to relate it to actual practices, this paper explores the Quintuple Helix model for innovation from a practical point of view in an urban context, following an Urban Living Lab innovation development approach.

2 Literature

The growing complexity and competition on the market challenges the traditionally closed innovation models and has fostered a wave of increased collaboration and knowledge exchanges (Ortt & Duin, 2008). This new innovation paradigm, driven by the idea that a single firm is unable to have all the required knowledge ‘in house’, is referred to as an Open or Distributed Innovation approach (Bogers & West, 2012; Chesbrough, 2003). In this approach, knowledge is exchanged between different actors in order to innovate more efficiently and more successfully. Furthermore, innovation development processes are no longer considered linear, but rather cyclic or even adaptive, which adds to the complexity of innovation management.

Understanding complex collaborative innovation

A useful framework for the analysis of complex collaborative innovation networks that takes into account the evolving states of the different actors is the Triple Helix model for innovation. The original Triple Helix model concept focuses on collaboration and

knowledge production in university-government-industry partnerships (Etzkowitz & Leydesdorff, 2000). It was later expanded with a fourth helix to incorporate civil society (Carayannis & Campbell, 2009) and a fifth one to also take the natural environment into account (Carayannis & Campbell, 2010).

To explain the processes of knowledge exchange, these models work with the concept of *democracy of knowledge* and '*mode 3'* knowledge production and *open innovation diplomacy*. The first concept is used as a metaphor to highlight the contextual environment of collaborative innovation ecosystems, which take place in an advanced knowledge based economy (Carayannis & Campbell, 2011). 'Mode 3' knowledge production, on the other hand, is an extension of 'mode 1' knowledge production (traditional research by universities) (Godin & Gingras, 2000) and 'mode 2' knowledge production (knowledge which is generated when applying and using 'mode 1' knowledge) (Gibbons, Limoges, Nowotny, *et al.*, 1994; Nowotny, Scott & Gibbons, 2003). 'Mode 3' adds a third component by highlighting the overarching system in which this knowledge is produced and exchanged (innovation networks and knowledge clusters). Finally, 'open innovation diplomacy' is used to describe the way in which different organizations and ecosystem are able to collaborate and bridge the divides that exist between them (e.g. social, organizational, cultural, or technological) (Carayannis & Campbell, 2011).

However, both Open Innovation and Quintuple Helix frameworks have a strong theoretical tendency and require active interpretation and translation in order to be adequately managed in practice. One approach that offers such structured facilitation is the *Living Lab* approach, which can be defined as an ecosystem approach in which end-users and other stakeholders are involved in the development of an innovation over a longer period of time, in a real-life environment, following an iterative process (Niitamo & Kulkki, 2006; Schuurman, Lievens, De Marez, *et al.*, 2012). Living Labs originated as a simulated testing environment for user-centric innovation development (e.g. Intille, Larson, Beaudin, *et al.*, 2005) and evolved towards multi-method user-centric innovation research approach with a strong focus on user empowerment and real-world experimentation (Følstad, 2008; Schuurman, Baccarne, Kawsar, *et al.*, 2013; Ståhlbröst, 2008). Furthermore, it offers a structured way to govern input from a wide variety of stakeholders and research methods (Eriksson, Niitamo, Kulkki, *et al.*, 2006; Ståhlbröst & Holst, 2012). However, despite strong European support, this research concept is still struggling for a better and more profound theoretical anchoring and remains too much of a 'practice-based' concept. Quintuple Helix (related) concepts provide valuable concepts and assumptions that are promising for the assessment and theoretical foundation of the more practical oriented Living Lab literature. On the other hand, Living Lab literature might provide a practical framework to put Quintuple helix into practice.

Why Urban? Innovation in an urban environment

More specifically, this paper focusses on innovation in an urban environment. Increasing urbanization, grand societal challenges and rapid technological evolutions force cities to look for new ways to reinvent themselves (Viitanen & Kingston, 2013). Rapid technological, demographical and societal evolutions put pressure on the delicate balance

between societal progress, economic growth and innovation on the one hand, and the natural environment, quality of life and a sustainable future on the other hand. This makes urban innovation an interesting context to assess the Quintuple Helix model. While urban new media are rapidly changing the fabric of everyday life in the city (Atkinson, 1998; Foth, 2009), local governments still lack the capability and resources to react to these changes in a flexible way (O'Flynn, 2007). In the search for new ways to cope with this tension, transparency and close interaction with grassroots initiatives is increasingly put forward as one of the solutions to overcome this gap (ARUP, 2010). This strategy is, to some extent, in line with the Open Innovation approach, causing city governments to question the dominant paradigm of top-down innovation development and implementation, and to experiment with city innovation processes together with, and even by citizens (Paskaleva, 2011). While the first generation of such '*Smart City*' projects has a rather technological-deterministic point of view (Cosgrave & Tryfonas, 2012) the conceptual understanding of the Smart City concept is slowly changing towards a more citizen-centric approach, focusing on smart citizens rather than on the Smart City as a high-tech solution to urban challenges (Dameri, 2013). These initiatives embrace more user-centric points of view, such as an increased attention for user innovation, co-creation and collaboration with a wide variety of city stakeholders (Caragliu, Del Bo & Nijkamp, 2009). Second-generation smart cities thus aim to increase the quality of life in the city, using innovative methods and building on multi-stakeholder participation and engagement, for which innovative technologies serve as an enabler rather than as a driver. Nevertheless, these interactions need to be governed and in some way be able to connect the traditional top-down approach with a grassroots or bottom-up approach.

In this context, the Living Lab approach gains importance as a way to govern such urban innovation collaboration (ARUP, 2010; Paskaleva, 2011). This is also reflected in European policy, such as the JPI Urban Europe, which encourages the use of Living Labs for interdisciplinary, sustainable, collaborative urban innovation[1]. Although the process is similar, *Urban* Living Labs have a distinct nature since the focus is on civic participation and the output is increased quality of life in the city, rather than the development of a commercial product or service (Baccarne, Mechant, Schuurman, *et al.*, 2014). As such, Urban Living Labs are an instrument to include a wide variety of stakeholders (citizens, municipalities, entrepreneurs, etc.) in the search for innovations that meet local socio-ecological challenges (Franz, 2014). Juujärvi & Pesso (2013, p.22) define Urban Living Labs as "a physical region in which different stakeholders form public-private-people partnerships of public agencies, firms, universities, and users collaborate to create, prototype, validate, and test new technologies, services, products, and systems in real-life contexts". A final noteworthy characteristic of Urban Living Labs is the close interaction with the governmental stakeholder, which often has a leading or important role in the innovation ecosystem (Baccarne, Schuurman, Mechant, *et al.*, 2014).

[1] http://jpi-urbaneurope.eu/

Whereas the Quintuple Helix framework is conceptual in nature, only little is known about the practical implications of the propositions associated with this framework in a local innovation ecosystem (more specifically, in an urban context). As mentioned before, increasing urbanization challenges the balance between technology, society and the ecological environment. Cities can be perceived as hubs where, due to the dense populations, problems emerge, but also where the solutions to these problems can be discovered and experimented with. Although ecological and sustainability challenges transcend regions, nations and even continents, cities are often considered as the main driver for change. Moreover, the dense population in cities has a lot of potential when it is approached as a pool of creative minds. Against this backdrop, cities increasingly experiment with technology-driven innovations, in which agile experimentation and collaborative value creation are key to sustainable innovation development. The collaborative nature of Smart Cities is related to both the Urban Living Lab concept and the Quadruple Helix model for innovation. However, cities also exist within a socio-ecological context which is put under pressure by the growing city environment, but also threatens quality of life in the city. Therefore, it makes sense to explore the Quintuple Helix concept against this backdrop.

Since Living Labs focus on innovation development and iterative experimentation within the use context of the innovation, and *in situ* or in a *real-life environment*, this provides another interesting argument to include the fifth helix in the equation. Taking the collaborative nature and the centrality of experimentation in a real-life environment into account, Urban Living Labs might provide a valuable approach to relate this 'practice-driven' approach with the conceptual Quintuple Helix model. Therefore, the goal of this paper is to explore how Urban Living Labs can be a way to put Quintuple Helix innovation into practice. In other words, we investigate the value of the theoretical Quintuple Helix concept by studying a practice-based Urban Living Lab project.

3 Research design and theoretical framework

As discussed in the previous section, current academic work on Quintuple Helix innovation is rather conceptual in nature. Although some analytical simulations have been performed, empirical studies are still lacking. The goal of this paper is twofold. First, we want to explore the conceptual premises with empirical data. Second, we want to look into Urban Living Labs as a possible framework to practice Quintuple Innovation.

The research design of this study is a multidimensional case study design combined with elements of action research. Given the complexity of the subject and the exploratory nature of the research question, an in-depth semi-structured case study is a favourable method (Eisenhardt, 1989; Yin, 1984). This allows us to study the subject in its natural context and to include multiple sources of evidence (Yin, 1984). According to Yin (p.18), "[a] case study is an empirical research enquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". The unit of analysis for this study is a project-centric innovation ecosystem that was set up around the development of

an interactive platform to engage, collaborate and communicate on the topic of air quality in the city of Antwerp, Belgium. Since the author team purposefully designed and participated in the project, this research can also be considered action research. As such, it was possible to go beyond the study of the phenomenon, but also to design and alter it in order to collaboratively look for solutions and sustainable innovation. By interfering in the process, a better understanding of the process can be obtained, both for the researcher and the other involved stakeholders (Reason & Bradbury, 2001).

The sources of evidence include ethnographic field notes, in-depth interviews, e-mail communication, meeting reports of steering committees, initial project proposals, project reports and project deliverables. These documents were collected during the timespan of the project (November 2013 – December 2014). Using triangulation, these were analysed following the theoretical propositions of the Quintuple Helix concept. The theoretical foundations and analytical framework are discussed in the next paragraphs.

Assumptions of the Quintuple Helix framework

Innovation diplomacy. A first dimension of the Quintuple Helix model is innovation diplomacy. This concept focussed on the praxis of bridging barriers between traditionally separated actors and fields (Carayannis & Campbell, 2011). The theory states that properly targeted initiatives are able to connect know-how, tacit knowledge, creativity and formal knowledge between different domains. If successfully targeted, these diplomacy strategies have the potential to incubate collaborative solutions, nurture entrepreneurship and accelerate economic development.

'Mode 3' knowledge production is a knowledge production, distribution and application system, in which it is assumed that new knowledge is generated through the exchange of knowledge between actors in the ecosystem (Carayannis & Campbell, 2012). The ecosystem is described as a nexus where "people, culture and technology meet and interact to catalyse creativity, trigger invention, and accelerate innovation across scientific and technological disciplines, public and private sectors in a top down, policy driven as well as bottom-up entrepreneurship empowered fashion" (Carayannis & Campbell, 2011, p. 330). These assumptions are based on a system-theoretic perspective in which knowledge is moulded, remixed, shared and applied within a knowledge driven society.

A system of subsystems forms the heart of a Quintuple Helix ecosystem. It encompasses the different domains that resonate and collaborate to solve mutual challenges. The Quintuple Helix model describes five societal subsystems (Carayannis, Barth & Campbell, 2012):

1. The educational system – which has the generation and dissemination of new knowledge as a central goal (generated by human capital).
2. The economic system – which has economic capital (financial, material, resources, entrepreneurship, …)
3. The political system – which has political and legal capital (laws, clearances, policy, public goods, …)

4. Civil society – which has social capital and is characterized by traditions, values and behavioural patterns.
5. The natural environment – which has natural capital (natural resources, climate, air quality, geological stability, …)

Each of these systems has capital at its disposal. The Quintuple Helix environment extracts knowledge from the different societal subsystems and provides it as input for the other subsystems in a non-linear way, which generates circulation of knowledge. This can also be conceptualized as chains of affordances (see Baccarne, Mechant & Schuurman, 2014).

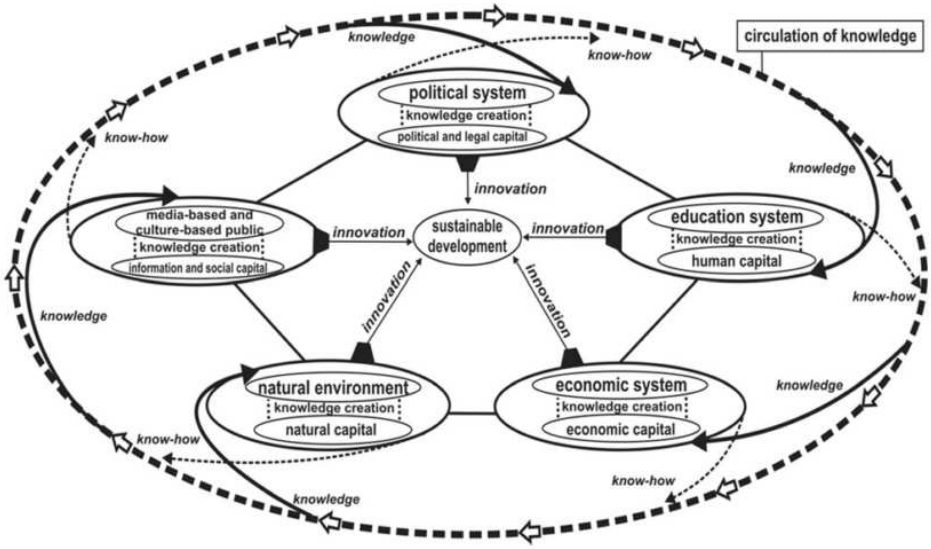

Figure 1 circulation of knowledge in a Quintuple Helix model (Carayannis, Barth & Campbell, 2012)

Socio-ecological transition. The main contribution of the Quintuple Helix model is the integration of the natural environment, which is conceptualised as a contextualisation of the four helices of the Quadruple Helix. The rationale behind this concept is that this dimension should also be considered as a stakeholder in the development of society and as a driver for knowledge production and innovation. If this is taken into account, it is possible to achieve sustainable socio-ecological transition, creating synergies between economy, society and democracy (Carayannis & Campbell, 2011). But including the natural environment can also be an incentive to harness eco-driven opportunities and foster innovation (e.g. ecological entrepreneurship).

4 Results

Providing a process

First of all, an Urban Living Lab follows a structured process in which a central problem, idea, concept or prototype is at the heart of the collaboration. This process implements a combination of different methodologies to involve a wide variety of stakeholders and govern this interaction process. Each of these methodological stages was governed by a social scientist who designed and implemented experiments and interaction formats in order to capture knowledge and stimulate interaction between stakeholders. This project consisted of the following formal stages.

1. Offline opportunity identification, conceptualisation and contextual mapping
   (*stakeholders*: local government, eco-entrepreneurs, academia)
   (*output*: longlist of opportunities, knowledge of the contextual variables and policy goals)
2. Online opportunity identification and project definition
   (*stakeholders*: local government, eco-entrepreneurs, academia)
   (*output*: elaborated longlist of opportunities, priorities and extra details)
3. Quantitative baseline measurement (survey-based)
   (*stakeholders*: citizens, eco-entrepreneurs, academia)
   (*output*: need identification, adoption potential, target groups)
4. Problem definition and co-creation of a solution
   (*stakeholders*: citizens, eco-entrepreneurs, academia)
   (*output*: in-depth knowledge of behavioural patterns and everyday life context, functional design requirements, paper prototypes of the innovation concept)
5. Co-design of the central concept and ecosystem architecture
   (*stakeholders*: local government, eco-entrepreneurs, academia)
   (*output*: redesigned paper prototype, knowledge on complementarity with policy and existing initiatives, governmental design requirements, local value network)
6. Field trial and real-world experimentation
   (*stakeholders*: citizens, eco-entrepreneurs, academia)
   (*output*: feedback on prototype, insights in usage patterns and behavioural change)

   (Extract from the steering committee documents, which were held between each stage and consisted of eco-entrepreneurs, living lab management and researchers)

This formal, but flexible staged process was instigated by the eco-entrepreneurs (covered roughly 17.5% of the research and management costs), was financially supported by the Flemish government (covered the other 82.5% of the costs), and was managed by iMinds Living Labs[1]. The project was also supported by a doctoral student (part of the author team). This process structured the innovation development process and governed the

[1] https://www.iminds.be/en/succeed-with-digital-research/living-lab

interaction between the different stakeholders. Besides this formal and structured process, informal interactions occurred as a result of, and in resonance with the innovation development track.

Innovation diplomacy

Complex multi-stakeholder collaboration is hard to manage in a fix structure. The formal commitments within this project were limited to the eco-entrepreneurs, iMinds Living Labs and the city of Antwerp (local government). This project was not able to convince other key actors in the ecosystem to become a formal part of the Urban Living Lab track because these actors were not willing to commit themselves to an uncertain and open project. However, once the project gained momentum, collaborations were still possible on an ad hoc base. This attracted not only the key stakeholders in the ecosystem, but also several smaller organisations and initiatives who were very willing to contribute and share their knowledge (research institutes, companies and civic initiatives). The agile way of collaborating (including the option to end the collaboration anytime) proved to be a good way to lower the barrier to share knowledge. The fact that every collaborator had its own agenda did not interfere with the goals of the project. Furthermore, the project served as an entry point for future collaborations. While it can be hard to collaborate without pre-existing reciprocal knowledge, a project-centric semi-formal ad hoc innovation ecosystem approach generates fertile ground for future collaborations since organisations are in full control of how, what, why and when they share their knowledge.

'Mode 3' knowledge production

When it comes to air quality, a lot of knowledge is generated in 'mode 1'. Traditionally, research institutes obtain grants to study atmospheric particulate matter (such as $PM_{2.5}$) or ozone concentrations. Most of these data remains hidden to the public. However, there are some initiatives that attempt to communicate these data to the citizens. Most of the time, these initiatives are built upon open data principles and are translated in dashboards that show the values of the air quality. In the city of Antwerp, this has also resulted in public visualisations of the air quality (figure 2).

Figure 2 visualisation of air quality data in the city of Antwerp, Belgium

In theory, these initiatives distribute the knowledge that is being generated in universities and other research institutes. However, this Urban Living Lab project revealed that this information cannot be interpreted by regular citizens. Even if the raw numbers are

translated in visual information, several problems occurred: (1) the academic complexity was not interpretable for citizens (e.g. background noise, conditioning variables or measurement errors) and (2) citizens had no idea what to do with this information (e.g. call politics to action, stay inside or use eco-friendly transportation). This caused a clash between academic complexity and nuance on the one hand and a clear message to citizens on the other hand. Although 63.2% of the citizens in the study were concerned about air quality, only 21.1% knew how to translate this concern into actions.

Through a multi-method approach, needs and knowledge of all stakeholders were captured and combined in a conceptual model for socio-ecological change (figure 3), which served as the basis for design requirements and the development of the prototypes. This model could only be developed by combining knowledge of the different stakeholders in the innovation ecosystem.

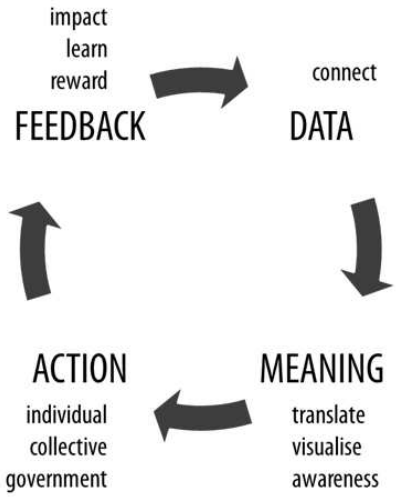

Figure 3 example of 'mode 3' knowledge production.
Conceptual model for socio-ecological change
(*output of fourth phase*)

The ecosystem and circulation of knowledge

The formal ecosystem consisted of (1) an eco-start-up (economic system), (2) the living lab facilitator (educational system) and (3) the city of Antwerp (political system). Other stakeholders were involved in a semi-structured way: (4) the Living Lab panel members (civil society), (5) civic movements (civil society) and (6) environmental research groups (educational system). Given the central goal of the project (to mobilize all stakeholders in the city on the topic of air quality), the natural context (7) was not only taken into account, but also an incentive to innovate. Our case study found evidence for different kinds of knowledge exchange. Some examples include knowledge transfers from the economic system to civil society (understanding the complexity and taking this into account when creating their own solutions), the educational system to the economic

system (Living Lab research methodologies and data related knowledge regarding air quality), the political system to the economic system (regarding policy, internal procedures, the value network and business model opportunities) and from civil society towards both the educational system (regarding the interpretation of complex data by citizens and the relation to their everyday behaviour) and the economic system (regarding needs, target populations and adoption potential).

Furthermore, for the local government, the project also connected different branches *within* the organisation. The initiative served as a vehicle that enabled links between different departments and brought a wide variety of people and projects together around a single concept or theme. As such, the project facilitated horizontal and agile collaboration and knowledge exchange on an ad hoc base, largely bypassing traditional structures and processes.

Socio-ecological transition

As for the natural context, this project aimed to involve this 'stakeholder' by giving it a voice and a language that could be understood and acted upon by all stakeholders in the ecosystem. Not only by visualising the air quality, but also by coupling this to easy understandable information and concrete actions. As mentioned before, ecological concerns were the main starting point for this project, so the Quintuple Helix model for innovation proved to be a valuable approach to study *and* implement this innovation development process.

However, when it comes to the sustainability of the project, which is inseparable from the transition potential, some challenges remain unsolved. A first challenge is the repeated use of the platform. Despite the user centric development, the current concept still struggles with a lack of repeated visits, which reduces it to a 'nice demo'. A second challenge is the difficulty to find viable business models in a domain which is characterized by a strong 'public' nature. Both civil society and the economic system think it is the job of the political system to take responsibility, but the political system is facing budget cuts, which make it hard to develop a sustainable business model. This has caused the eco-entrepreneurs to pivot strongly and focus on related markets and narrower customer segments (such as schools or people with health issues).

Nevertheless, socio-ecological transition must also be considered in a broader sense. Although the innovation itself is possibly hard to maintain in a sustainable way, experiments and collaborative knowledge exchanges also contribute to higher levels of change. Since Urban Living Labs are limited in place, scope and time, they provide an interesting window for experimentation. As such, the involved stakeholders have a temporarily increased flexibility to facilitate the experiment (e.g. the financial system invests in uncertain projects, the educational system is as practical as possible, the political system facilitates with clearances and civil society is tolerant for bugs and operational errors). This is important because when this experimental window closed, all stakeholders have experienced the possibilities of the innovation. In this context, Nevens et al. (2013) put forward the concept of the Urban Transition Lab which is described as "the locus within a city where (global) persistent problems are translated to the specific characteristics of the city […] It is a hybrid, flexible and transdisciplinary platform that

provides space and time for learning, reflection and development of alternative solutions […].”From this point of view, project-based Quintuple Helix innovation can foster change on a more latent level, by inspiring and stimulating debate on contemporary urban challenges and solutions.

The Urban Living Lab concept

Our findings support most of the theoretical assumptions of the Quintuple Helix model and elaborate on the Urban Living Lab approach as a way to put this into practice. Urban Living Labs can be a way to work with ad hoc collectives, which lowers the barriers for collaboration as opposed to formal commitments. On the other hand, the project-centric nature is a catalyst for knowledge exchange, which also has the possibility to nurture future collaborations. In this context, Urban Living Labs can be metaphorically represented as ‘innovation acupuncture’, which temporarily focusses the collaborative energy of the involved stakeholders on a single point in time and space. The evidence supports that a project-driven local innovation ecosystem like this can succeed in creating synergies and collaborative knowledge creation between industry, society, academia, government and the ecological context. These processes are in line with the assumed circulations of knowledge between knowledge clusters in which each cluster has its own affordances, capital and input/output qualities.

Furthermore, the notion of coevolution and co-specialization can be optimally fostered and catalysed within an Urban Living Lab through close interactions and common project goals. This way, democratization of knowledge creation is put into practice. An Urban Living Lab can be considered as a collaborative innovation ecosystem which allows the co-creation of sustainable, future proof innovations that improve life in the city. The Urban Living Lab framework is a useful framework to combine top-down governance with bottom-up initiatives in the city. However, some challenges remain. Whereas experimental activities within an Urban Living Lab activate and reinforce the Quintuple Helix ecosystem, facilitating collaboration and enabling interaction with the city government and environment, it is still hard to harness the creation potential within the city in a sustainable way. Nevertheless, sustainable enabling value is being created at higher levels (e.g. by intermediary infrastructures, increased transparency, favourable policy, a lowered barrier for knowledge exchange and collaboration). Urban Living Labs facilitate urban transitions through an accumulation of experiments, which allow city inhabitants and policy makers to experience change, causing transitions on the meso level (i.e. facilitating infrastructures) and the macro level (i.e. policy and society) in the long run.

Furthermore, Urban Living Labs could act as ‘reuse enablers’ through central governance of ‘fertilizing’ resources. In the evolution towards an Open Government, the Urban Living Lab should also govern and disclose networks (interpersonal and inter-organizational), infrastructure (e.g. sensor networks), artefacts (e.g. code and algorithms) and knowledge (e.g. research data) to increase connective capacity (Lichtenthaler & Lichtenthaler, 2009) in the city, thus enhancing the sustainability of the generated value and knowledge.

5 Conclusion and discussion

This paper provides empirical evidence for the theoretical propositions of the Quintuple Helix model for innovation, which was previously lacking. Although this analysis has an exploratory nature, it elaborates in more detail on the interactions between knowledge clusters, the way in which knowledge is created and translated, and the relation with socio-ecological transition. This paper contributes to academic insights on collaborative knowledge creation and its relation with innovation development. On top if that, it provides an actionable approach to practice Quintuple Helix innovation. Related to this observation, the Urban Living Lab approach also contributes to sustainable socio-ecological transition. This is mainly facilitated by an interdisciplinary (and transdisciplinary) temporal experimental window which promotes collaborative learning and stakeholder engagement.

For Living Lab academics, this paper contributes to the quest for more solid theoretical foundations. The Quintuple Helix concept is a useful concept to understand and analyse how knowledge is created and exchanged in a collaborative innovation development ecosystem. It also supports the need to involve a broad range of stakeholders; including the notion of the ecological environment as a distinct 'stakeholder'. When innovations are being developed collaboratively in an innovation ecosystem, innovation practitioners and academics should also take into account the ecological environment. While such awareness is growing in most organizations, this dimension is not present in most Distributed Innovation theories and processes. An Urban Living Lab, which can be considered a local innovation ecosystem, can generate and evolve tacit and codified knowledge while focusing on the exchange of knowledge within a natural environment system. This way, both the innovation outcomes and the urban socio-ecological transition can become more sustainable and recover ecological balance, thus ensuring the quality of life for future generations.

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