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Innovation Spaces as Drivers of Eco-innovations Supporting the Circular Economy: A Systematic Literature Review[1]

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ABSTRACT

This paper explores the way in which academics address the role of innovation spaces in the development of the circular economy. Considering their characteristics, objectives, and functioning, we assume that innovation

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spaces can be favorable environments for eco-innovations facilitating the implementation of circular economy strategies. To examine this hypothesis, this paper mobilizes a mixed research method based on bibliometric analysis of keywords and content analysis. The results show that these collaborative environments can: foster sustainable experimental learning, provide methodologies and tools for the co-creation of circular solutions, drive the transition toward sustainable smart cities, foster the creation of new sustainable business models, promote sustainable urban entrepreneurship, and facilitate knowledge exchange on circular solutions. However, most of the reviewed literature focuses mainly on their impacts on sustainability and less on the concept of the circular economy per se. Consequently, this work provides insights on the potential of these spaces in the circular strategies' implementation.

KEYWORDS: Circular Economy, Eco-Innovation, Innovation Spaces, Sustainability, Systematic Literature Review

JEL CODES: Q01, O30, Q56, B40

Circular economy (CE) principles contrast with the linear model of current industrial systems based on the "take-make-use-dispose" logic. It represents a new economic model capable of achieving a sustainable development that is inspired by natural ecosystem functioning (EMF, 2012). Indeed, the CE has been recognized by the scientific community as a transformation process of production and consumption modes requiring a series of changes and reconfiguration of the techno-economic systems (Ghisellini *et al.*, 2016; Kirchherr *et al.*, 2017). Eco-innovation as a means to operationalize these changes can play a central role. It proves to be one of the relevant factors of resource productivity and efficiency intervening at the micro (product, company), meso (networks and cooperation), and macro (territories and policies) scales, thus responding to environmental and societal issues (De Jesus *et al.*, 2019; De Jesus, Mendonça, 2018; Vence, Pereira, 2019). Despite the growing scientific dynamic dealing with the importance of eco-innovation in the transition to a CE, understanding of the mechanisms and conditions favoring their emergence remains limited. In fact, the systemic nature of the CE approaches requires a set of interacting actors exchanging material and/or informational flows that require collaborative physical environments with access to technology, knowledge, and experimentation. This leads us to question the processes and environments conducive to the creation of these conditions.

Moreover, in the field of innovation, a new phenomenon has attracted the attention of researchers and practitioners in recent years, that of innovation spaces (IS) like fab labs, makerspaces, hackerspace, living labs coworking spaces…. These spaces play the role of innovation intermediaries, provided with devices, tools, and new methodologies designed to strengthen innovation capacities (Hossain *et al.*, 2019; Morel *et al.*, 2018; Osorio *et al.*, 2019). They have been designed to address societal and environmental issues and phenomena by making innovative tools and methods available to a wide public and by enabling different stakeholders (*e.g.* companies, research centers, public actors, universities, and users) to form inter-organizational networks engaging processes of creating, prototyping, validating and testing new technologies, services, products and systems in real-life contexts (Leminen *et al.*, 2012). The interest in these IS as new innovation enablers has been growing among academics. Several studies have focused on the emergence, design, and management of these spaces (Boutillier *et al.*, 2020; Kristensen, 2004; Lewis, Moultrie, 2005). These research efforts seek to understand the nature of these spaces, how they are composed, who benefits from them, and how they perform. Thus, the impact on their environment has been less explored. Today, even though this is a research strand that is still in development, the knowledge and popularity of IS continues to spread. In this paper, our aim is to understand the real potential that these innovation enablers can have on societal issues. Indeed, because of their specificities and innovative collaborative approaches, we assume that IS can potentially facilitate the emergence of eco-innovations and creative solutions that allow both technological and non-technological changes supporting CE projects.

Through a systematic literature review, we aim to investigate this hypothesis. For this, a mixed research methodology is used based both on bibliometric analysis of scientific publications keywords and their qualitative content analysis. Based on the Scopus and Web of Science databases we selected 80 significant publications that have been qualitatively analyzed following a coding process. This provides a general overview of the literature dealing with the relation between these two themes and showing how IS encompass the main characteristics of spaces conducive to eco-innovation and circular solutions.

This paper is divided into four main parts: the first provides a state of the art on the circular economy and shows how eco-innovation processes can lead to transformative solutions and circular transitions. It also presents an overview on the main IS concepts. The second part describes the method used for performing this review. Finally, the third and fourth parts present a summary and discussion of the main findings of the review before concluding with final remarks and perspectives.

State of the Art

The Circular Economy, an Umbrella Concept: Background

The concept of CE has been gaining momentum since the 2000s, but its conceptual foundations date back to pioneering works highlighting the necessary transition to new production and consumption modes that consider the scarcity of the planet's resources (Boulding, 1966; Stahel, Reday-Mulvey, 1981). It also developed from other concepts such as cradle to cradle (McDonough, Braungart, 2002), industrial ecology, and industrial metabolism (Frosch, Gallopoulos, 1989), thus becoming an umbrella concept with fuzzy boundaries (Kirchherr *et al.*, 2017). In the recent scientific literature, CE is represented as a synthetic concept bringing together different approaches, which mainly include: activities that extend the product's life span, waste and resource management (Bakker *et al.*, 2021; King *et al.*, 2006), reverse logistics, and the integration of the CE in production planning (Suzanne *et al.*, 2020), with a growing interest in sustainable supply chain management (Angelis *et al.*, 2018; Safiullin *et al.*, 2020).

The institutional literature has also significantly contributed to the definition of the CE and the dissemination of its principles by providing an operational framework allowing its deployment at different organizational scales. For example, the international Ellen MacArthur Foundation (EMF) defines the CE as "*a new economic model that aims to decouple global economic development from the consumption of limited resources. The circular economy responds to the pressing resource-related challenges facing companies and countries, and has the potential to generate growth, create jobs, and reduce environmental impacts, including carbon emissions*" (EMF, 2012, p. 2). The studies of the EMF underline the diversity of CE practices including use of renewable energies, renewable flow management, eco-design, economy of functionality, etc.

Globally, when defining the CE, the focus is on product and material flows and their management as well as the management of their supply chains, *i.e.* a technico-scientific approach. However, the implementation of the CE requires a systemic change (Ghisellini *et al.*, 2016; Kirchherr *et al.*, 2017) and thus the inclusion of socio-economic dimensions. Indeed, according to De Jesus and Mendonça (2018), the CE is "*a multidimensional, dynamic, integrative approach, promoting a reformed socio-technical template for carrying out economic development, in an environmentally sustainable way*" (De Jesus, Mendonça, 2018, p. 76). Kirchherr *et al.* (2017) put forward the idea that "*It operates at the micro level (products, companies, consumers), meso level* *(eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers*" (p. 229).

Based on these scientific and institutional backgrounds, it is possible to identify four main CE strategies: (i) waste management and flow recovery strategies (including recycling and recovery practices); (ii) sustainable use and manufacturing strategies (focusing on sustainable supply and eco-design processes); (iii) sustainable use and consumption strategies (integrating responsible consumption and extending product lifespan practices); and (iv) sustainable organizational and territorial strategies (including economy of functionality and industrial ecology approaches). The transition toward a systemic circular functioning is based on the implementation of all these strategies at the micro, meso, and macro scales.

Circular Economy and Eco-Innovation: Toward Technological and Non-Technological Change

The potential benefits of implementing the CE are numerous on the environmental, social, and economic levels. Its application within modern economic systems and industrial processes leads to multiple benefits resulting from reduced costs of resource-related inputs, supply chain optimization, reduced waste management costs, and the generation of additional revenues (EMF, 2012). On a broader scale (business zone, agglomeration, city, territory, country, etc.), the CE can be a source of development and dynamism for the economy. The implementation of sustainable organizational and territorial strategies such as the economy of functionality and industrial ecology can lead to new forms of organization and management of industrial and urban activities and to the emergence of new innovation dynamics (Deutz, Gibbs 2008; Gallaud, Laperche, 2016; Kasmi, 2020). Despite these advantages, the implementation of CE strategies comes up against several obstacles, like technical and economic difficulties, that hinder the optimization of resources or organizational difficulties, relating to the regulatory/institutional context, and to coordination and governance issues, or also social difficulties notably related to human behaviors (De Jesus, Mendonça, 2018; Kasmi *et al.*, 2017).

Transition is an innovation-intensive process of reconfiguration and adaptation. It requires profound changes anchored in a specific context over a long period of time. In this sense, recent literature emphasizes that the transition to a CE requires new forms of innovation to overcome the obstacles.

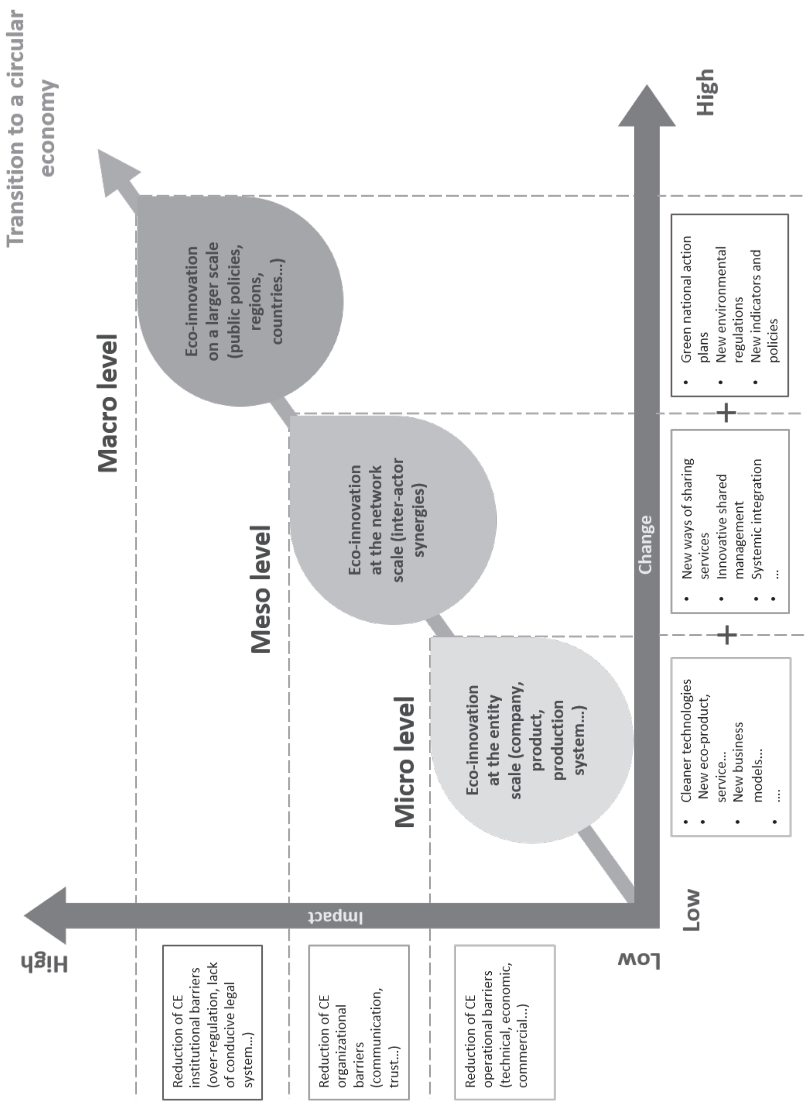
The focus here is mainly on eco-innovation (De Jesus, Mendonça, 2018). Eco-innovations are generally defined as "*the assimilation or exploitation of a product, production process, service, management or business method that is new to the firm or user and that results, throughout its life cycle, in the reduction of environmental risks, pollution and other negative effects of resource (including energy) use*" (Kemp, Pearson, 2008, p. 3). They can be of different types: incremental, which consists of improving existing technology without changing uses and practices; radical, which then allows for radical technical changes while preserving existing practices; or transformative, corresponding to the implementation of new technological systems. The latter requires a complete reconfiguration of production processes and lifestyles (Galiègue, 2012).

According to Cainelli *et al.* (2020), "*the dynamics of circular economy-related innovation imply a slow techno-economic transformative process. It is possibly more a 'reform' than a 'revolution', passing through the adoption of both incremental and radical innovations*" (p. 10). Moreover, since the CE is a process based on multi-actor cooperation and systemic integration (De Jesus *et al.*, 2018), transformative eco-innovations need to be technological to address technical issues (related to the product, process, or production systems), but also non-technological issues (organizational, institutional, commercial, financial changes, etc.) to facilitate and promote cooperation among stakeholders (De Jesus, Mendonça, 2018; OECD, 2009; Vence, Pereira, 2019).

Some studies show that eco-innovation can be a lever for this systemic transition (De Jesus *et al.*, 2018, 2019). Indeed, at the macro level, eco-innovation accompanies global transition dynamics by strengthening cooperation between the public and private sectors and new public policies, thus contributing to the reduction of regulatory/institutional and governance limits; at the meso level, eco-innovation allows new ways of sharing services, public services and by-products, thus promoting collaborations around sustainable products/services and reducing coordination limits; at the micro level, eco-innovation can improve the eco-design processes of products, services, and sustainable consumption, thus enabling technical, economic and social limitations (Figure 1).

In sum, a growing number of research studies presents eco-innovation as a major asset facilitating the development of the CE. Despite this, the understanding of the links between these two concepts needs to be deepened, in particular to better understand the conditions and types of environments that support eco-innovation, which comes with more radical circular changes. For this purpose, this paper explores a new field of analysis studying the role of IS in the transition from a traditional approach of eco-innovation focused on technology at a micro scale (closed laboratory-based R&D and

Figure 1 - Eco-innovation as a lever of systemic transition toward a CE



Source: Authors based on OECD (2009) and De Jesus *et al.* (2018, 2019) then industrialization) to a more collaborative approach combining both technological and non-technological solutions.

Overview on the Concept of Innovation Spaces

Over the last few years, new structural and organizational entities facilitating the emergence of innovation have emerged. These are physical and/or virtual environments, playing the role of innovation intermediaries, provided with devices, tools, and new methodologies designed to strengthen innovation capacities in a context of exchange, sharing and collaboration in order to achieve a goal of common interest (Dupont *et al.*, 2015; Morel *et al.*, 2018; Osorio *et al.*, 2019) in a climate of trust (Dupont *et al.*, 2019). These new forms of work organization address the need for organizations to open their boundaries to their external environment in order to capture new knowledge in a collaborative and open innovation process (Boutillier *et al.*, 2020; Capdevila, 2019).

The concept of IS refers to different types of co-creation environments such as fab labs, makerspaces, hackerspaces, tech shops, living labs, and coworking places (see their definitions in appendix A). Other terms like "third place" (Oldenburg, 2001) or "open labs" (Merindol *et al.*, 2016) are used as more generic terms.

A growing number of academics have been interested in these collaborative spaces. Kristensen (2004) has explored the importance of the space in enhancing creativity: "*creativity takes place in a physical context, i.e. in a confined space*" (p. 89). He explains that such environments allow the creation of cognitive processes and facilitate information exchange and the availability of knowledge tools. But this result depends on designing and mobilizing spaces according to the nature of the stages of the creative processes. Capdevila (2015) also shows that IS are environments conducive to collective creativity by studying creative practices and approaches, the type of governance and modalities of collaboration between the members of these spaces, as well as their motivations. Lewis and Moultrie (2005) focused their analysis on understanding the design, role, and objectives of IS, which they call "innovation laboratories". They demonstrate their benefits in strengthening organizations' commitment to innovation and creativity by enhancing their learning capacity to improve their organizational routines.

Recently, within a special issue of the *Journal of Innovation Economics & Management* on this theme (Boutillier *et al.*, 2020), the articles contributed to understanding of the functioning and mechanisms of the IS in particular through: analysis of the role of the resources provided by these spaces (physical infrastructure, human and financial resources) in the strengthening of collaboration between companies and the actors of their ecosystem (Tremblay, Scaillerez, 2020) and the analysis of the evolution of the spaces, their design, and the factors allowing their durability (Osorio *et al.*, 2020).

Thus, the study of the design and management of innovation spaces, the analysis of their functioning, their evolution and the conditions favoring their sustainability, are at the core of academic research interests. However, these studies focus on a micro scale (the study of the space itself or the direct impact on the organization to which it is attached). Because of their specificities (innovative technologies, innovative collaborative methodologies, knowledge sharing, adaptable infrastructure, diversified skills, network creation…), these spaces can play a more systemic role by providing creative solutions that can respond to global challenges (economic, social, and environmental) facing their local ecosystems. Their potential therefore seems to be an asset in supporting the transition to new development models such as the CE. Our questioning here aims to understand how and what kind of impact these spaces can bring to facilitate the implementation of the CE? Do they represent favorable environments for the emergence of different forms of eco-innovation? Based on a systematic literature review, we aim to explore this reasoning.

Methods and Data

When guided by a specific research question, the systematic literature review allows us to analyze the evolution of knowledge on a given topic and to identify its related trends and changes (Denyer, Tranfield, 2009). This study draws on previous research that has focused on the constellation of innovation laboratories (Osorio *et al.*, 2019). Based on a bibliometric analysis of 1,307 scientific publications (published between 2000 and 2018), this study highlights the links between the most common concepts referring to IS (innovation labs, living labs, fab labs, makerspaces, third places, etc.). Furthermore, through content analysis it provides insights on the different impacts that these spaces can have on their community, environment, and partners. To reach this goal, we will build from the path established in this previous work by updating and expanding its bibliographic database on IS while looking for intersections with the existent literature on CE.

This review of the literature employs a mixed research methodology based on both a bibliometric and systematic review (Osorio *et al.*, 2019) (Figure 2). The first consists in providing quantitative analyses based on the identification of the corpus of the literature through a set of statistical tools providing a bibliographic overview of scientific productions (Ellegaard, Wallin, 2015). This will allow us to have a global vision on the trends of publications related to our two research equations (the first one focused on CE, and the second one on IS), in particular through the co-occurrence of keywords. The second allows for a qualitative study associated with a meta-analysis of a series of publications made in a more precise manner, facilitating the establishment of syntheses and overall conclusions (Tranfield *et al.*, 2003).

To carry out this bibliographical analysis, several steps were followed:

1. *Identification of the keywords that make up our two search equations:* they are made up of all the keywords used in this search. These were defined according to the objective and scope of our study, as well as the relevant definitions on the CE and IS (Figure 2).

2. *Identification of research conditions:* in order to have a large sample of publications related to our research question, we used the scientific databases Scopus and Web of Science. The search of keywords targeted titles, keywords, and abstracts of publications without defining a time limit nor a research discipline. To have a general vision of the publications, we chose to analyze journal articles, books, and book chapters (Figure 2). By pooling Scopus and Web of Science publications and removing duplicates, 863 publications were retained.

3. *Bibliometric analysis of publications:* At this step, the data extracted from Scopus and Web of Science were organized in a CSV file containing the title, abstract, keywords, name of the journal or publisher, DOI, and document type. These data were then explored in the VOSviewer software, which mapped all the keywords of the 863 publications and provided an overview of their degree of relatedness in the form of a network. This first step allowed the formulation of five main categories representing the major trends in the literature that were subsequently used in the next qualitative analysis to code the final selected articles. In parallel, a scan of the titles and keywords (and sometimes abstracts) of the 863 showed that not all the publications directly addressed the role of IS in the development of the CE or more generally in sustainable development. Thus, a preliminary filter to the qualitative analysis was applied. This filter made it possible to select articles in which the keywords from our two search equations were found simultaneously in the title, the abstract, and the keywords. A total of 107 publications were obtained.

4. *Qualitative analysis of publications:* 80 publications were retained for the qualitative analysis after a manual inspection of the titles of the 107 publications. A first step of scanning these articles was carried out by following a coding protocol using the Nvivo tool. The abstracts of each

publication were first coded/screened according to five key dimensions: "context", "literature gap", "research questions and objectives", "methodology", "results"/"contributions" classified as "nodes" in Nvivo. This step allowed a closer understanding of the topics of the articles. Subsequently, particular emphasis was placed on the content of the "nodes": "research questions and objectives" as well as the "results and contributions" of each article. The reading and analysis of these dimensions made it possible to classify each of the 80 articles into one of the categories identified through the bibliometric analysis (Appendix B), to be used afterwards in feeding the results.

Findings

Evolution over Time of the Studied Publications

The 863 publications identified in the first step were transferred as bibliographic data to the VOSviewer software. This made it possible to build a network of keywords linked by co-occurrences (Figure 3). The distance between the different keywords represents the degree of closeness or distance between the selected publications. The color of each node in the network refers to its evolution over time. Between 2015 and the end of 2016, we observe a growing interest of researchers in the concept of the living lab and its link with the notion of sustainability. An interesting trend linking living lab, sustainability, and work on smart cities, innovation and co-creation can be noticed during this same period. More recently, researchers have increasingly been focusing on the notions of makerspaces, circular economy, and urban living labs. The main purpose of these observations is to describe the evolution of the interest in the different notions that make up our network of co-occurrences. In the next steps of our analysis, we take a closer look at their articulations.

Analysis of the Keywords Co-occurrences Network

From the analysis of the 863 publications, 15 clusters were identified (Table 1: 1st and 2nd columns). Each cluster is composed of several keywords linked to each other but also to other clusters. This bibliometric analysis represented by the clusters provides a global view of the links between the different themes of the publications. At this stage, in the majority of clusters, keywords referring to sustainability and/or comprising the search equation "circular economy" appear (see these keywords in bold in Table 1, Column 2).

The qualitative scan of this table allowed us to make a comparison between clusters that have similarities in terms of relationships in the network but also in terms of their common themes and scientific domains, in the form of categories or major themes (for example city and smart city or education, open education, action research...). To support this keyword analysis, a few examples of publications have been consulted in order to understand the themes they address. The objective of this step was not to analyze the 863 documents qualitatively, but to support the construction of categories and their descriptions according to publication trends.

A first proposal of five main categories has been established, which we have at this stage reformulated as follows: Urban Living Labs & Development of Sustainable Smart Cities, Co-creation, Participatory Design & Real-life Experimentations for Circular Solutions, Sustainable Business Models within Innovation Spaces, Innovation Spaces as Accelerators of Innovation, and Sustainable Transition, Research & Education for Sustainable Transitions (see Table 1, 3rd column). These categories have been considered at this point as hypotheses on how the literature brings our two concepts (IS and CE) closer together, which needs to be confirmed by qualitative analysis.

In parallel, the qualitative scanning of the titles and abstracts (consulted when the title did not clearly identify the research issue of the article) of the 863 showed that all the publications that helped build the network did not directly address the link between the two research equations. This reading has also helped to reinforce the five categories identified from the cluster table.

Figure 2 -Adopted methodology

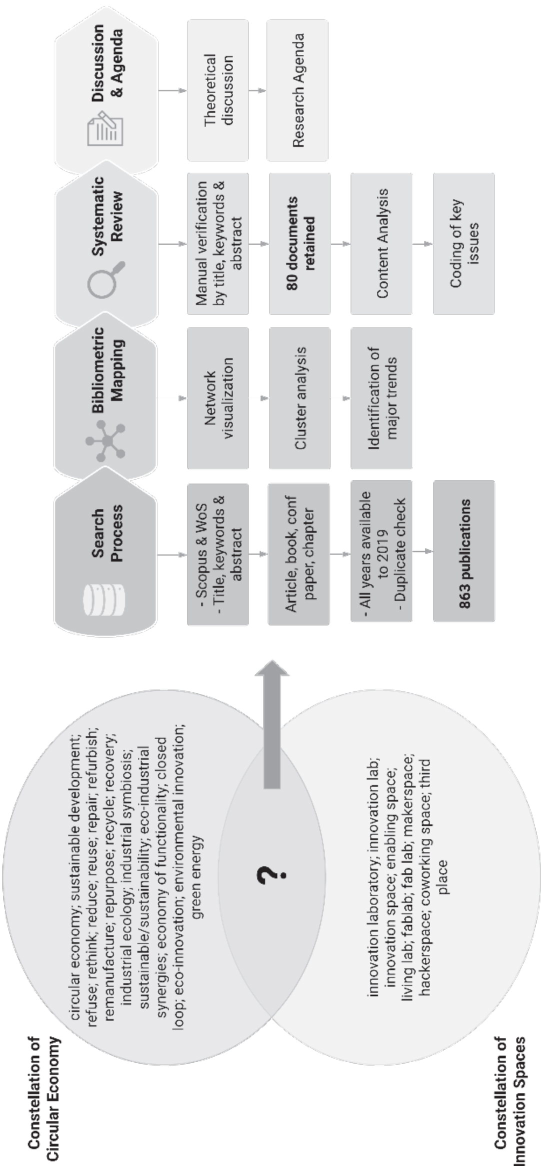


Figure 3 - Evolution over time of the scientific publications on the studied keywords

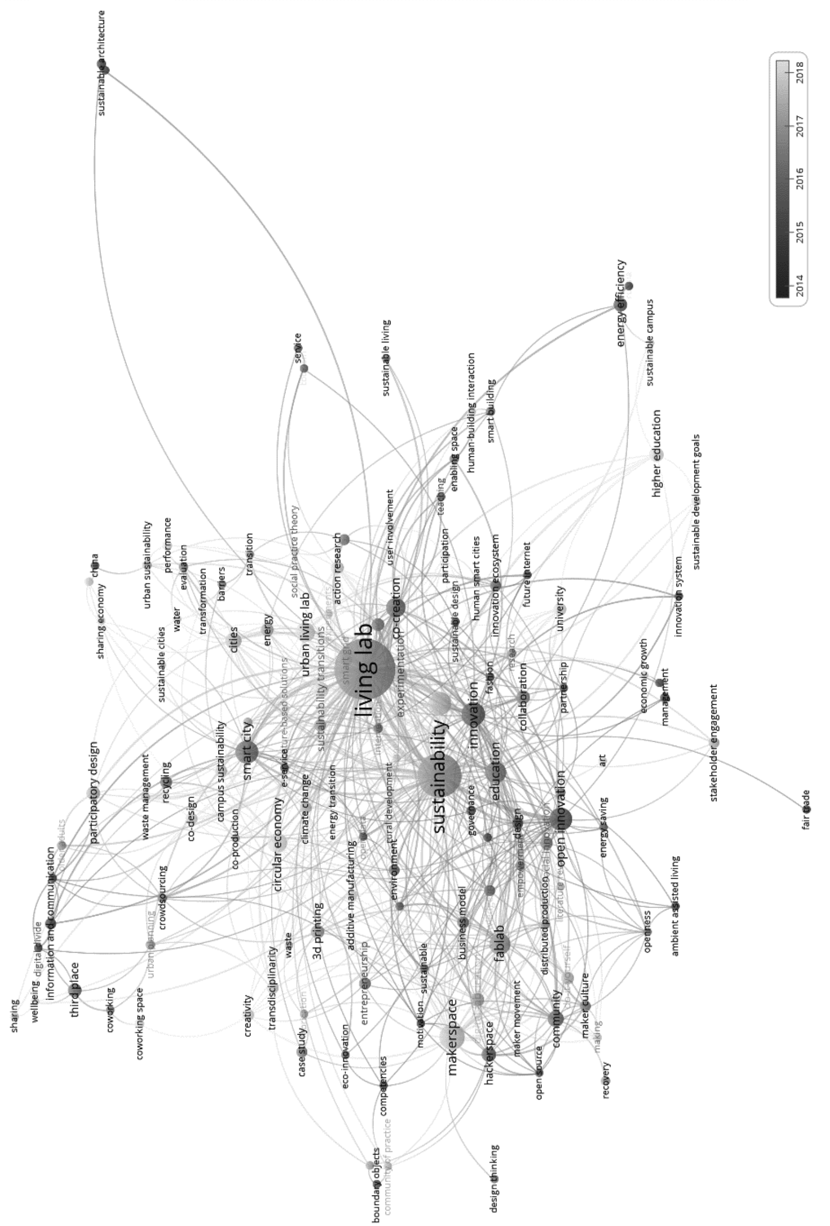


Table 1 **- Categories of publication trends**

Clusters	**Keywords**	**Categories of the publications trend**
Cities	barriers; China; energy; evaluation; experiments; nature-based solutions; performance; prosumers; resilience; sharing economy; smart grid; social practice theory; **sustainable innovation**; transformation; transition; urban governance; **urban sustainability**; water	Urban Living Labs & Development of Sustainable Smart Cities
Smart city	collaboration; design; experimentation; fashion; future internet; human smart cities; innovation ecosystem; participation; **sustainable cities**; **sustainable design**; urban living lab; user involvement	
Makerspace	community; design thinking; digital fabrication; do-it-yourself; fablab; hackerspace; maker culture; maker movement; making; motivation; open source; **recovery**	Co-creation, Participatory Design & Real-life Experimentations for Circular Solutions
Third place	coworking; coworking space; creativity; digital divide; entrepreneurship; information and communication technology; sharing; urban planning; wellbeing	
Living lab	behavior change; empowerment; governance; intervention; knowledge management; leadership; partnership; project management; research; university	
Participatory Design	co-design; crowdsourcing; energy transition; older adults; rural development; social inclusion	
Business Model	boundary objects; co-production; collaborative innovation; community of practice; competencies; **eco-innovation**; social learning; **sustainable**; transdisciplinary	Sustainable business models within innovation spaces

Clusters	Keywords	Categories of the publications trend
Innovation	co-creation; enabling space; human-building interaction; innovation system; learning; smart building; **sustainable living**; teaching	Innovation spaces as accelerators of innovation and Sustainable Transition
Circular economy	**campus sustainability**; distributed production; literature review; **recycling**; **sustainability transitions**; **waste management**	
Sustainability	**energy efficiency**; fair trade; higher education; Russia; **sustainable campus**; **sustainable development goals**	
Sustainable development	agriculture; economic growth; management; stakeholder engagement	
Education	3d printing; additive manufacturing; art; case study**; climate change**; e-service; education; **environment**; fabrication; open data; **waste**	Research & Education for Sustainable Transitions
Open education	ambient assisted living; energy saving; internet of things; openness; social innovation	
Action research	service; tourism	
Sustainable Architecture	Solar Architecture	

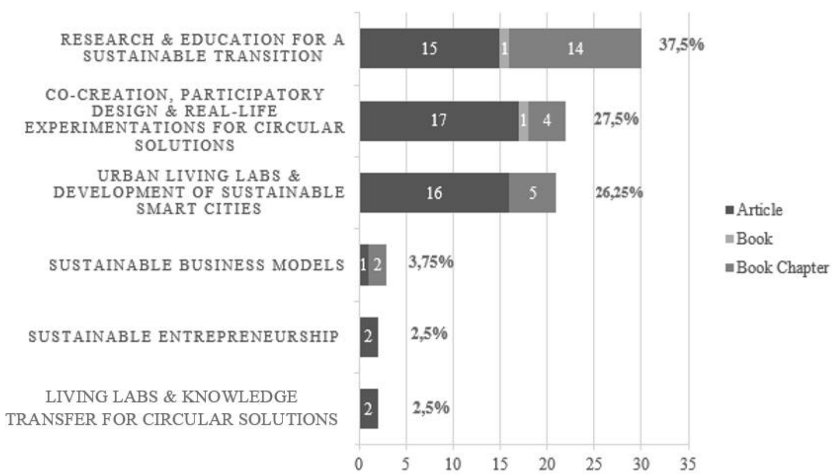
The process of bibliometric analysis revealed in particular the limitation of the bibliometric tool/analysis to provide an in-depth answer to our research question. This analysis, based solely on co-occurrence, provides automated results that are insufficient to draw lessons concerning specifically the objective of this research; a qualitative analysis then seems necessary. However, this step was important to understand the major themes addressed in the literature and identify categories that allowed for easy coding and qualitative analysis of the selected articles.

The qualitative content analysis was important to confirm the adequacy of the categories identified based on the bibliometric study with the content of the analyzed publications. But it also made it possible to: 1) change one of the five categories "Innovation Spaces as Accelerators of Innovation and Sustainable Transition" to "Living Labs & Knowledge Transfer for Circular Solutions" which proved to be more adapted to certain publications; 2) highlight a new category that was not identified, which we formulated as follows: IS for sustainable entrepreneurship development.

Qualitative Analysis of the Publication Trends: Toward an Understanding of the Impact of Innovation Spaces in the Development of the Circular Economy

The results obtained show that most of the reviewed literature integrates into the following categories: Research & Education for Sustainable Transitions, Co-creation, Participatory Design & Real-life Experimentations for Circular Solutions and the Urban Living Labs & Development of Sustainable Smart Cities. These publications represent respectively 37.5%, 27.5%, and 26.25% of the total of 80 publications. The remaining publications are included in the Sustainable Business Models (3.75%), Sustainable Entrepreneurship (2.5%), and Living Labs & Knowledge Transfer for Circular Solutions (2.5%) categories (see Figure 5 and appendix C). A growing interest from scientific journals in these themes can be observed; 53 publications are articles against 25 book chapters and two books.

Figure 4 - **Trends of the scientific publications**



Category 1: Research & Education for Sustainable Transitions: University Campuses as Living Labs for Sustainability

A large part of the literature considers that the living lab approach, when developed at the university level, can play an important role in the transition toward more sustainable development. IS (in particular living labs) are defined here as university campuses adopting this approach (Cianfrani *et al.*, 2018; Favaloro *et al.*, 2019; Hansen, 2017; Hua, 2013; Hugo *et al.*, 2018; Jernsand, 2019; Kilkiş 2017; Lindstrom, Middlecamp, 2017; Pantaleão, Cortese, 2018). When university campuses are transformed into living labs (which some authors call "student living labs") (Cooper, Gorman, 2018; Jernsand, 2019), they become supportive environments for experimental learning in real-life situations. Experimentation would allow students to become experts in the technical and cognitive processes that are required in sustainability projects. These academic living labs allow students to exchange and reflect on complex and sensitive issues, but also to identify opportunities for action and solve real problems through collaborative projects that materially contribute to sustainability.

Students engage with experienced partners (faculty, staff, former students...) on sustainability issues in a transdisciplinary way. This facilitates the collaboration between different stakeholders within the university (academics, practitioners and students), and strengthens the sense of commitment to sustainability goals within a learning community (Buralli *et al.*, 2018; Cooper, Gorman, 2018; Sulkowski, 2017). Through the living labs, the university also opens up to the general public by integrating citizens into educational projects. This is also the case with other territorial actors such as local authorities, business communities and companies involved in urban projects focused on sustainability actions. This allows a wide dissemination of knowledge and innovation in the context of education for sustainable development (Zen *et al.*, 2017). Some authors emphasize the importance of pedagogy in supporting this type of experiential learning. This plays a key role in teaching sustainability concepts, practices and policies (Lusk *et al.*, 2017). Bürgener and Barth (2018) underline that this depends on the teachers' commitment and competencies.

Category 2: Co-creation, Participatory Design & Real-life Experimentations for Circular Solutions

The publication trends in this category focus on the approaches and practices developed in IS by involving the users. The potential for transformation of living labs in terms of sustainability is often linked to user participation and their role in changing behavior toward environmental issues (Liedtke *et al.*, 2012; Menny *et al.*, 2018). Some authors focus on sustainable domestic technologies and the adoption and appropriation of these solutions by users in their daily lives (Keyson *et al.*, 2017; Romero, 2017). The authors approach co-creation spaces as a socio-technical infrastructure to support user-centered innovation processes by fostering collaboration and exchange with professionals. The authors also consider that users play an active role in the generation and application of contextualized practice-based knowledge in the innovation process. In this sense, the research and experimentations carried out in these co-creation environments can be conducive to: market innovations by producing breakthroughs in sustainable household technologies that will be easy to install, user-friendly, and meet real-life environmental performance standards, and to the practice of innovation by paving the way for new forms of contextual and user-centered research.

In this category the publications not only deal with living lab approaches but also physical co-creation spaces, including Fab Labs and makerspaces (Fleischmann *et al.*, 2016; Jurietti *et al.*, 2017; Kohtala, 2017; Prendeville *et al.*, 2017; Sugiyama *et al.*, 2015; Thompson, 2018; Von Geibler *et al.*, 2019). They study their impact on changing user behavior and especially the opportunities offered by this type of space and the means they offer in the development of circular solutions, practices, and technologies. These manufacturing spaces (open-access design and manufacturing workshops) provide new contexts, notably for sustainable co-design.

Digital Manufacturing Labs (such as fab labs) provide open access to technologies for producing objects, from the initial idea to final production, and encourage the open and free sharing of knowledge between "experts" and the general public. Their functioning is based on community-based digital fabrication workshops that transform design, innovation, production and consumption practices, while describing positive environmental impacts and social goals (Crumpton, 2015; Kallio-Tavin, 2018). They are also spaces that provide practical guidance for interweaving circular practices by fostering a supportive culture, creating local links, nurturing individuals/community capacity and stimulating practical know-how. In this framework, the role of the facilitators of these spaces is also explored. Facilitators have the knowledge and skills that contribute to the development of circular economy practices. They are recognized as initiators of circular practices.

Category 3: Urban Living Labs & Development of Sustainable Smart Cities

For some authors, Urban Living Labs (ULL) are physical and virtual spaces aimed at the co-creation of eco-innovative solutions and strategies for urban areas. It is a new approach to open innovation linking technologies to people, urban territory, and cities (Bulkeley *et al.*, 2016, 2019; Evans *et al.*, 2018; Mai, 2018; Paskaleva, 2011; Sharp, Salter, 2017; Tremblay, Scaillerez, 2020; Van Geenhuizen, 2019). It is about using open innovation to share visions, knowledge, skills, experiences, and strategies to design the delivery of sustainable services, goods, and policies in cities.

ULL can thus be considered both as a physical space (geographically or institutionally delimited spaces) and as an approach for intentional collaborative experimentation between researchers, citizens, businesses, and local governments. This leads to questions of governance. A significant part of the literature addresses the issue of experimental governance that is facilitated and reinforced in ULLs. It promotes collaboration and innovative Public-Private Partnerships (PPPs) for more sustainable urban transformation (Bulkeley *et al.*, 2016; Dupont *et al.*, 2015; Evans, Karvonen, 2011; Sharp, Salter, 2017; Voytenko *et al.*, 2016; Amenta *et al.*, 2019) through a user-centered design, collaborative processes, citizen workshops, and new financial and organizational responses, enabling collaboration between private companies and public institutions. In parallel, some authors highlight the role of public/institutional actors in this experimental governance process as facilitators through a set of enabling policies and policy instruments aimed at overcoming the challenges of sustainability (Buhr *et al.*, 2016; Mukhtar-Landgren *et al.*, 2019).

The living lab tools and methodologies promote urban experimentation, a practice that is becoming increasingly important in cities and territories. Experimentation allows us to find new and more sustainable ways of planning and developing cities by integrating environmental concerns into development plans. It is a process by which city-based innovations are launched to test solutions that, if found to be effective, are intended to be scaled up with the ambition of leveraging a broader transition to urban sustainability (Bulkeley *et al.*, 2019; Mukhtar-Landgren *et al.*, 2019; Von Wirth *et al.*, 2019).

Cities become smart and sustainable when they provide intelligent services to citizens using information and communication technologies while considering environmental, economic and societal challenges (Alam, Porras, 2018; Palgan *et al.*, 2018). ULLs enable the demonstration of these smart technologies that allow a real application of the smart city concept to the population and external actors (Alam, Porras, 2018; Bracco *et al.*, 2018).

Category 4: Innovation Spaces for Sustainable Business Model Development

On the one hand, publications in this category study the impact of coworking practices on the development of innovation, in particular business model innovation for sustainable performance. Empirical analyses carried out on companies working within coworking spaces show a positive impact on their business model innovation due to the creativity capacities that they can strengthen (Cheah, Ho, 2019).

On the other hand, some authors address the issue of sustainable product and service systems (SPSS), the latter being an innovative form of business model. They highlight the importance of sustainable living labs for the implementation and dissemination of sustainable resource-efficient product and service systems in the context of a green economy (Baedeker *et al.*, 2017). Indeed, these living labs contribute to the evolution of production-consumption systems toward sustainability by modifying processes and SPSS on a microeconomic scale. In the same vein, the Sustainable Living Lab (SLL) focuses on sustainability innovations and offers a number of new features reflecting areas of intervention (Burbridge *et al.*, 2017). For the authors, the SLL approach offers a basic research infrastructure for sustainability, in which the relevant actors are actively involved in the development, design and testing of new SPSS aimed at the transition to circular and sustainable development.

Category 5: Innovation Spaces for Sustainable Entrepreneurship Development

In this category, the authors study the contribution of living labs and coworking spaces to the promotion of urban entrepreneurship in cities and their sustainability (Rodrigues, Franco, 2018; Seo *et al.*, 2017). Through qualitative analyses, they show that living labs are the "cradle" of this type of entrepreneurship allowing economic, social, and environmental development. Three characteristics of these spaces have been detected as enabling the dynamism of sustainable urban entrepreneurship: the open network, the entrepreneurial spirit, and the benefits/results of the living labs (creation of activities/jobs and generation of new local economic dynamics) (Rodrigues, Franco, 2018). These findings are supported by the results of another publication showing that community and communication are the most important factors within coworking spaces, followed by space and interior (infrastructure, technical and technological means), diversity of services, and the facilitation of relationships and networking for the users (Seo *et al.*, 2017).

Category 6: Living Labs & Knowledge Transfer for Circular Solutions

Living labs are represented in the publications identified in this category as open innovation systems that promote different knowledge transfers between the involved local actors, thus providing solutions for the development of innovation. However, beyond the knowledge created and disseminated by living labs at the local level, some authors focus on the transfer of knowledge at the regional level (between regions) via living labs (strengthening extraterritorial networks). Extraterritorial learning can be an asset for the development of knowledge, the emergence of innovation, and diversification at the local level. It can strengthen and improve the sustainability strategies and policies implemented by regions and cities. Such a transfer can lead to sub-optimal solutions, especially when the imported practices concern complex phenomena, involving networks of multiple actors and relying on place-specific dynamics (Schuurman *et al.*, 2016). This is illustrated by (Amenta *et al.*, 2019) based on the study of the role of networks of peri-urban living labs in the emergence of eco-innovative solutions supporting the valorization of wastes.

Discussion: How Do Innovation Spaces Enable the Transition Toward A Circular Economy?

The Potential of IS for Eco-Innovation, Sustainability, And CE

Based on our literature review we were able to identify links between IS, eco-innovation, sustainability, and CE. From each category of publication trends, we have identified a categorization of these spaces and the features that allow them to generate certain types of eco-innovation, even though generally the term eco-innovation is replaced by "innovation", "environmental innovation", or "sustainable technology", etc. (see Table 2). We were also able to point out that IS can have an impact in: fostering the development of new forms of sustainable experiential learning (category 1); providing methodologies and tools for the co-creation of circular solutions while favoring users' behavior change (category 2), driving the transition toward sustainable smart cities (category 3), fostering the creation of new sustainable business models (category 4), promoting sustainable entrepreneurship (category 5), and facilitating knowledge exchange on circular solutions (category 6).

IS for the CE Strategies Implementation

Despite the growing interest in the relationship between IS and CE, it has been observed that the majority of such literature has focused specifically on sustainability and circular solutions, rather than the concept of CE per se. Moreover, no publication provides a general view on the involvement of these different environments in the CE, but they are studied separately.

Nevertheless, the mobilization of the results of this literature review provides several insights. Thus we will draw, on the one hand, on the characteristics and impacts of IS highlighted in the results of this research (Table 2), and, on the other hand, on the CE strategies identified in Section 1, as well as the lessons drawn from the literature on the technological and non-technological changes and eco-innovations necessary for the implementation of these strategies (Figure 1). The objective is to discuss and propose a link between each type of IS and its potential impact on the development of new solutions or eco-innovations that can intervene in the implementation of the CE, enabling it to overcome its limitations. Based on this discussion, we will propose a categorization of IS according to the needs and characteristics of each CE strategy, which we will summarize at the end in the Table 3.

Strategies of Waste Management and Flow Recovery

Some types of IS can facilitate the implementation of recovery and recycling strategies. Indeed, the reintegration of material and energy flows into production processes is not always simple, and obstacles, particularly technical ones, such as the complexity of the flows and their technical characteristics, can hinder this. These are university campus living labs and fab labs. University campus living labs can offer technical learning and training in the field of waste management to train experts in technical processes (technicians, engineers, etc.) and specific skills relating to processes, residual materials, and the different ways of recovering flows (Laperche, Merlin-Brogniart, 2016). These environments can thus be conducive to the development of innovative learning methodologies and know-how to reduce the problems related to the valorization of material flows.

The fab labs offer freely accessible means, machines, and manufacturing technologies. They can foster the creation of new technologies, test new processes, and manufacture new eco-innovative products from waste streams. We can mention the example of the additive manufacturing of recycled plastics (3D plastic printers) (Santander *et al.*, 2020). Fab labs can thus be enabling environments for technological eco-innovations that provide solutions to recycling problems.

Sustainable Use and Manufacturing Strategies

These strategies aim to increase the efficiency of manufacturing or product use by using fewer natural resources and materials. The sustainable purchasing practices and eco-design that are part of this strategy concern the product and its supply chain as well as the stakeholders involved in all stages of production from manufacturing, to transport, consumption, and end of life

Table 2 - **The IS features in favor of sustainability, eco-innovation, and CE**

Publication trends categories	IS types	IS role from the literature review	Types of eco-innovation	Examples of references	Synthesis of IS contributions
Category 1	University campus living labs	• Experimental learning in real life situations • Exchange and reflection on complex environmental issues • Identification of opportunities for action to solve real problems	Innovative learning methods for sustainability issues	Hansen (2017), Hugo *et al.* (2018), Horan *et al.* (2019)	Fostering the development of new forms of sustainable experimental learning
Category 2	Living labs	• Users' involvement in testing and demonstration of environmental innovations (*e.g.* sustainable household technologies) • Users' adoption and appropriation of these technologies	Technological and social user-centered eco-innovations	Liedtke *et al.* (2012), Keyson *et al.* (2017)	Providing methodologies and tools for the co-creation of circular solutions while favoring users' behavior change
	Fab labs and makerspaces	• Open access to technologies for co-creating sustainable objects • Free sharing of knowledge (experts and the general public) • Communities creation	Process, product, and social eco-innovations	Crumpton (2015), Fleischmann *et al.* (2016)	

Publication trends categories	IS types	IS role from the literature review	Types of eco-innovation	Examples of references	Synthesis of IS contributions
Category 3	Urban living labs	• Facilitating urban experimentation and demonstration of smart technologies • Multi-actors' collaborative experimentations • Experimental governance	City-based eco-innovations (smart sustainable services, goods and policies) User-centered eco-innovations (adapted smart services)	Dupont *et al.* (2015), Paskaleva (2011)	Driving the transition toward sustainable smart cities
Category 4	Coworking spaces	• Increase creativity capacities in favor of sustainable performances	Sustainable business model innovation	Cheah and Ho (2019)	Fostering the creation of new sustainable business models
	Sustainable living labs	• Implementation and dissemination of sustainable resource efficient • Design and testing of new SPSSs		Baedeker *et al.* (2017), Burbridge *et al.* (2017)	
Category 5	Coworking spaces	• Facilitate communication, information, and networking • Provide diversity of services and infrastructure	Organizational and social eco-innovations	Seo *et al.* (2017)	Promoting sustainable urban entrepreneurship
	Living labs	• Creation of open network • Entrepreneurial spirit		Rodrigues and Franco (2018)	

Publication trends categories	IS types	IS role from the literature review	Types of eco-innovation	Examples of references	Synthesis of IS contributions
Category 6	Extraterritorial living labs	• Knowledge co-creation and transfer between territories • Creation of extraterritorial networks • Improvement of sustainability strategies and policies	Social and institutional eco-innovations	Schuurman *et al.* (2016), Amenta *et al.* (2019)	Facilitating knowledge exchange on circular solutions

of the products (ADEME, 2013). Based on the results of our literature review, it is possible to see that living labs and fab labs are environments that can be involved in these strategies. Indeed, living labs bring together different stakeholders in collaborative experimentation approaches. These stakeholders can be members of a supply chain. These innovative methodologies can reduce the organizational and coordination problems linked to the production of an eco-product. But they can also encourage the development of sustainable purchasing practices, in particular by strengthening short supply chains at the local level (Gallaud, Laperche, 2016; Torre, Dermine-Brullot, 2019).

For their part, the fab labs can serve as a space for demonstrating and testing new eco-design technological solutions. They act as facilitators in the exchange of knowledge and skills related to circular technologies. These technological innovations can thus respond to the technical problems of eco-design, but also by offering alternative solutions to reduce the economic costs faced by companies, and in particular smaller companies (Gallaud, Laperche, 2016).

Sustainable Use and Consumption Strategy

Citizens and users are at the center of the functioning of ULL. This involvement of citizens allows, on the one hand, to raise their awareness and bring about changes in their behavior with regard to environmental issues by encouraging them to adopt circular practices such as sorting, recycling and responsible consumption. On the other hand, their integration in the transition processes toward the intelligent sustainable city makes it possible to successfully develop sustainable intelligent services, to disseminate them, and to facilitate their use by citizens.

The integration of citizens in university campus living labs in educational projects around sustainability issues, such as responsible consumption and reuse practices, can also influence their behavior through experimental learning and knowledge acquisition.

Fab labs and makerspaces can also have positive impacts on consumer/user behavior by encouraging them to promote practices that repair and extend the life of products. They give them access to workshops with open manufacturing tools and allow them to participate in the creation of new objects from recycled products or to repair their objects/products. This is the case, for example, with shared wood manufacturing workshops that encourage users to make or repair products such as recovered wooden furniture. These spaces are not only limited to users and citizens but also to social and solidarity economy actors (Torre, Dermine-Brullot, 2019). These spaces are therefore sociotechnical infrastructure to support user-centered technological and social innovation processes by promoting collaboration and exchange with professionals. Such innovations help to reduce the environmental impact and social barriers associated with the implementation of the CE.

Sustainable Organizational and Territorial Strategies

These strategies are based on the economy of functionality and industrial ecology approaches that operate on a larger organizational scale (Maillefert, Robert, 2014; Merlin-Brogniart, 2017), even integrating other CE approaches or strategies such as waste recovery, recycling, and eco-design.

- *Economy of functionality* focuses on use rather than possession and tends to sell services related to products rather than the products themselves. The sale of a service replaces the sale of a good and where product-service systems are becoming more widespread. Its implementation requires major organizational transformations. Firms that choose to adopt the economy of functionality face the challenge of identifying the changes induced in their business model (Meier, Massberg, 2004). They must thus overcome organizational (capacity constraints, inadequacy of available technologies) and economic (costs) limits. To face these limits, two types of IS can potentially intervene: coworking spaces and living labs. Indeed, the creative practices developed in the IS by companies contribute to the development of innovative business models. The same goes for living labs, which promote the implementation and dissemination of sustainable and resource-efficient product and service systems (SPS).
- *Industrial ecology* strategy can be defined both by an operational dimension that focuses on the practices of the material and energy flow valorization, but also by the managerial, organizational, and territorial dimensions linked to the exchanges of these flows (networks of actors forming industrial symbiosis) (Kasmi et al., 2017). Accordingly, its implementation involves not only technical issues but also those related to the coordination of the actors involved and the governance of the related territorial projects. There are several obstacles to its implementation: technical, economic, organizational, regulatory, and relational (coordination and governance). Several types of IS can facilitate the implementation of industrial ecology approaches.

University campus living labs can offer experimental learning for students or even experimental training for employees (integration of the concept of industrial ecology in training programs). This can reduce the technical problems linked to the company's lack of expertise in the field of valorization. The same applies to the eco-technologies developed in the fab labs and makerspaces.

The principle of urban living labs is based on the integration of a heterogeneous set of actors in local projects. This type of environment can be an important asset for the success of industrial ecology projects and the sustainability of industrial symbiosis. Their characteristics and the innovative methodologies they offer can facilitate exchanges and strengthen relations between the actors involved. Experimental governance actions can provide new organizational, financial, and regulatory responses/eco-innovations, allowing collaboration between private companies and public institutions. These eco-innovations can reduce communication and trust problems that hinder cooperation.

Extraterritorial living labs promote different knowledge transfers at regional level (between regions or territories). The exchange of good practices on territorial industrial ecology projects between different territories and extraterritorial actors through living labs can be an asset for its development. Organizational eco-innovations can emerge, which can favor the creation of industrial networks and symbiosis, but also institutional ones that favor the adoption of new environmental policies that are favorable to the implementation of industrial ecology.

***Table 3*- The role of IS in the implementation of CE strategies**

CE strategies	**CE practices**	**Type of IS**	**Type of role and potential eco-innovation**	**CE Limitations**
Strategies of waste management and flow recovery	Recycle and recovery	University campus living labs	Experimental learning and knowledge creation	Technical limitations
		Fab labs Makerspaces	Product and process innovations (*e.g.* 3D printing of recycled plastic)	Technical limitations
Sustainable use and manufacturing strategies	Sustainable supply and Eco-design	Living labs	Organizational innovations favoring collaborative experimentation	Organizational limitations
		Fab labs Makerspaces	Co-creation, demonstration, and test of technological eco-design innovations	Technical and economic limitations

CE strategies	CE practices	Type of IS	Type of role and potential eco-innovation	CE Limitations
Sustainable use and consumption strategy	Sustainable/ responsible consumption and Extend lifespan of products	Urban living labs	Collaborative experiments and sustainable intelligent services inducing social innovations	Social limitations (behavior change)
		Campus living labs	Experiential learning and knowledge acquisition	Social limitations
		Fab labs Makerspaces	Technological tools for creation and reparation of products	Technical and economic limitations
Sustainable organizational and territorial strategies	Economy of functionality	Living lab and coworking spaces	Business model innovation (sustainable product-service systems)	Organizational and economic limitations
	Industrial ecology	Campus living labs	Experimental learning and knowledge creation	Technical and economic
		Fab labs and makerspaces	Product and process innovations (*e.g.* 3D printing of recycled plastic)	Technical and economic
		Urban living labs	Organizational eco-innovations (experimental governance actions)	Organizational/ institutional limitations
		Extraterritorial living labs	Knowledge transfers at regional level	Organizational/ institutional limitations

Conclusion

The objective of this research was to understand how the literature studies the contribution of IS in the CE with a particular focus on the eco-innovations that these spaces can generate. The literature review showed that the interest of scholars in this issue is growing continuously. However, compared to the existing number of publications in these two fields, this research dynamic remains insufficient. In addition, these studies specifically focus on sustainability rather than the concept of CE and address the impact of each space separately. As a consequence, this study introduces a categorization of IS conducive to the CE and identifies the eco-innovations they may induce.

From a theoretical point of view other insights have been identified in this research that can be considered as a research agenda proposition to deepen the analysis of this topic:

- Great importance is given to the concept of the living lab in relation to sustainability and CE. However, its definition remains complex (a physical space, a virtual space, a methodology?) which can create confusion in the understanding of its contribution to the CE strategies. Consequently, the other types of IS and their impacts are studied less compared to the living labs.
- The contribution of IS in supporting territories' and regions' transition toward a systemic development of new sustainable models such as the CE is not directly and sufficiently developed in the publications. Especially the industrial territories that are strongly concerned by sustainability issues and circular strategies.
- There is a need for further empirical studies to assess the real impacts of IS on CE strategies.

From the managerial perspective, the identified roles and impacts could nourish IS strategies, leading to the exploration and further implementation of clearer strategies for those intending to insert their own lab in the CE dynamics. These potential roles could also help by shedding light on the possible interconnections and collaborations among IS, eventually leading and facilitating the establishing of shorter, more effective local circular cycles.

From the policy-making perspective, the IS phenomenon continues to be spread all over the world, and more and more policy and decision-makers are favoring the implementation of these physical innovation environments. Therefore, the results from this work can represent a valuable input for guiding new policies, investments, but also clarifying expectations toward the real impact these kinds of initiatives may or may not have in overcoming CE barriers.

However promising IS are, it is important to stay aware of their limitations. The capacity of IS to deal with more systemic challenges is yet to be understood. Nevertheless, the answer to this may rely on the ability of IS to be not only the experimentation and learning arena for a local group of actors, but rather to serve as the interconnectors that enable favorable conditions for territories to work together and exploit complementarities toward more sustainable practices. To understand these limitations more closely and learn from them, this theoretical research will be the object of an empirical investigation. Thus, the next step will consist in analyzing a set of concrete IS cases. A particular interest will be focused on IS linked to universities and their contribution to fostering CE in the territories while relying on sustainable development models such as the quintuple helix (Provenzano *et al.*, 2018).

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Appendix

Appendix A
Innovations spaces related concepts

Concepts	Short definitions	Source
Fab Labs	"Spaces favoring the sharing knowledge, experimenting with new technologies and exploring interdisciplinary projects while at the same time achieving personal achievement and enjoyment"	(Mortara & Parisot, 2018)
Makerspaces	"Makerspaces, which are defined as community workshops where members (known as makers) share access to tools for professional benefit and hobbyist pursuits"	(Van Holm, 2015)
Hackerspaces	"Hackerspaces, which are defined as place with a spirit of equality, non-profit and open, where people share tools and ideas with a strong emphasis on digital technologies"	(Moilanen, 2012)
Tech shop	"Tech Shop is a private entity provided with digital equipment and spaces that are made available to customers against payment to carry out their projects"	(Morel et al., 2018)
Living Labs	"Defined as the place in which all stakeholders from public-private-people partnerships collaborate to create, prototype, validate and test new technologies, products, services or systems in real-life contexts"	(Hossain et al., 2019)
Coworking spaces	"The places for the "third way" of working, halfway between the well-delimited traditional workplace and independent working life as a freelancer, where the worker stays at home in an isolated way"	(Gandini, 2015)
Third places	"Third places are usually described as social settings separated from the first place (home) and second place (workplace). In addition, they are given some characteristics as anchors of community life and promoters of creative interactions"	(Oldenburg, 2001)
Open labs	"A place and an approach driven by diverse actors, with a view to renewing the methods of innovation and creation through the implementation of collaborative and iterative processes, open and giving rise to physical or virtual materialization"	(Merindol et al., 2016)

Source: adapted from (Osorio et al, 2019)

Appendix B
The reviewed publications

Publication trends	Themes	Authors
Research & Education for sustainable transitions (29)	Living Lab in Ageing and Long-Term Care A Sustainable Model for Translational Research	(Verbeek et al., 2020)
	Living lab campus connecting sustainability and educational mission	(Cianfrani et al., 2018)
	Regenerative sustainable development of universities and cities	(Koenig, 2013)
	Sustainable campus as a living laboratory for climate change	(Hua, 2013)
	Living lab & co-production of knowledge	(Evans et al., 2015)
	Living lab research infrastructure & opportunities for sustainable products and services	(von Geibler et al., 2017)
	Social lab classroom in higher education	(Lake et al., 2016)
	Sustainable university campuses as living labs for managing environmental quality	(Kılkış, 2017)
	University experiential learning partnerships as living laboratories for sustainability	(Sulkowski, 2017)
	Education for sustainability a campus-based learning as living lab	(Hansen, 2017)
	University Campus as living lab of healthy and ecological materials	(Webster-Mannison, 2017)
	Integrating living lab approach & Politics of Sustainability course	(Lusk et al., 2017)
	Chemistry science and connections to sustainability in campus living lab	(Lindstrom & Middlecamp, 2017)
	Living labs for education for SD in higher education	(Filho et al., 2020)
	Biorefinery education as a tool for teaching sustainable development	(Jääskeläinen & Hakalehto, 2018)
	Sustainable Development Goal (SDG) university Innovation Lab experience	(Buralli et al., 2018)
	Insertion of sustainability in the university campus based onliving lab approach	(Pantaleão & Cortese, 2018)
	University as a Living Lab to facilitate collaboration and learining communities for sustainability	(Cooper & Gorman, 2018)
	Sustainable University Campus Model an Integrated Living Lab for sustainale energy	(Da Silva et al., 2018)
	Sustainability competencies in teacher education	(Bürgener & Barth, 2018)
	Physics science & campus as living lab for sustainability	(Lindstrom & Middlecamp, 2018)
	University campus living lab for sustainability and innovation	(Hugo et al., 2018)
	Education and research for zero waste cities	(Hannon et al., 2019)
	University Campuses (UC) for experimentation demonstration of innovative sustainability solutions in a ‘real-world’ context	(Horan et al., 2019)
	College campuses as living lab for sustainable experiential learning	(Favaloro et al., 2019)
	University and regional circular economies by sustainability innovation labs	(Weber & Heidelmann, 2019)
	University living learning labs as a transformative approach	(Zen et al., 2017)
	Student living labs for sustainable tourism	(Jernsand, 2019)
	Universities & Sustainable transition	(Purcell et al., 2019)
Co-creation, participatory design & real-life experimentations for circular solutions (23)	Accelerate innovation towards sustainable living in building sector	(Andersson & Rahe, 2017)
	Circular Makerspaces	(Prendeville et al., 2017)
	Daily life practicies & Sustainability living lab	(Romero Herrera, 2017)
	Digital earth living lab	(Schade & Granell, 2014)

	Digital fabrication technologies in Fab Labs for sustainable design and co-creation	(Fleischmann et al., 2016)
	Fuzzy front end of innovation for SDG	(von Geibler et al., 2019)
	How Sustainability is Constituted in Fab Lab Ideology	(Kohtala, 2017)
	LCA tool within a design platform for a sustainable-aware PSS design	(Fontana et al., 2018)
	Living lab & sustainable living	(van Timmeren & Keyson, 2017)
	Living Lab facilities for sustainable innovation at home	(Keyson et al., 2017)
	Living Lab for developing testing and demonstrating innovations in sustainable transport	(Haider et al., 2016)
	Living lab stakeholder's co-development of innovations in real-world contexts	(Ståhlbröst, 2012)
	Living labs & user-driven innovation for sustainability	(Liedtke et al., 2012)
	Living labs method in the context of sustainable and responsible tourism and hospitality business	
	Maker culture as a method for a sustainable future	(Kallio-Tavin, 2018)
	Makerspace and Sustainable Transformation	(Crumpton, 2015)
	Management challenges in FabLabs for sustainable actions	(Galuppo et al., 2019)
	Rebound effects in innovation design within Living Labs	(Buhl et al., 2017)
	Role of users in co-creation within urban living labs to foster sustainability in cities	(Menny et al., 2018)
	Third place & sustainable relationships in service businesses	(Sugiyama et al., 2015)
	Third Places and Local Social Ties for sustainability at high density aeras	(Thompson, 2018)
	User-centered design for the sustainable tourism services	(Pucihar et al., 2014)
	Virtual CSR for co-creation among users & companies the case of a Sustainable Living Lab	(Jurietti et al., 2017)
Urban living labs & development of sustainble smart cities (21)	Architecting and Designing Sustainable Smart City Services in a Living Lab	(Alam & Porras, 2018)
	Circulating experiments Urban living labs and the politics of sustainability	(James Evans et al., 2018)
	Innovative public-private partnership to support Smart City	(Dupont et al., 2015)
	Living lab & open innovation towards Sustainable smart cities	(Paskaleva, 2011)
	Living Labs and societal urban challenges	(Hossain et al., 2019)
	Living labs politics and epistemology of urban transition	(J. Evans & Karvonen, 2011)
	Peri-urban living labs as co-creation approach for circular metabolism	(Amenta et al., 2019)
	Planning & demonstrating smart city sustainable districts, living lab smart cities	(Bracco et al., 2018)
	Public actors & Urban experimentation	(Mukhtar-Landgren et al., 2019)
	Smart Sustainable Districts (SSD) & co-creation environment	(Rosado et al., 2015)
	Sustainable energy planning using living lab methodological approach	(Giannouli et al., 2018)
	Urban linvig labs & experiments in the multi-stakeholder governance of sustainability	(Darren Sharp & Robert Salter, 2017)
	Urban Living Lab & Experimental city	(Bulkeley et al., 2019)
	urban Living lab & urban governance for sustainable cities	(Voytenko et al., 2016)
	Urban living labs & Responsible Research and Innovation	(Van Geenhuizen, 2019)
	Urban living labs & sustainability in communities in China	(Mai, 2018)
	Urban living labs & sustainability transitions	(von Wirth et al., 2019)
	Urban living labs Catalysing low carbon and sustainable cities in Europe	(Palgan et al., 2018)

	Urban living labs for governing urban sustainability transitions	(Bulkeley et al., 2016)
	Urban Living Labs for Sustainability in Suburbs	(Buhr et al., 2016)
	Use of living labs to drive innovation in sustainable urban development	(Tremblay, 2017)
Living lab & Knowledge transfer for circular solutions (2)	Living labs & Circular economy knowledge transfer	(Dąbrowski et al., 2019)
	Living Labs as open innovation systems for knowledge exchange	(Schuurman et al., 2016)
Sustainable business models (2)	Coworking spaces & sustainable Business Model Innovation (BMI)	(Cheah & Ho, 2019)
	Business models for sustainability in living labs	(Burbridge et al., 2017)
	Sustainable living lab for Sustainable Product-Service Systems in (SPSS) in green economy	(Baedeker et al., 2017)
Sustainable Entrepreneurship (2)	Sustainable living lab for PSS in green economy	(Rodrigues & Franco, 2018)
	Coworking spaces and sustainable entrepreneurship	(Seo et al., 2017)