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## **Territorial dynamics supported by a collaborative network of innovation labs: toward an approach to establish a portfolio of indicators to monitor and assess their territorial impact.**

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### **Abstract**

The multiplication of apparently similar Innovation Labs throughout the local territories raises questions about their role and their positioning. Innovation Labs are generally supplied by local resources. This substantial growth could facilitate the connection of various regions within a territory, thereby creating new areas for experimentation. The public authorities need these labs to bring added value to their territory. This study shows that a network of Innovation Labs could be a strategic means to support territorial dynamics at a local scale.

The literature does not provide concrete tools, resources, and methods to evaluate the territorial impacts of Innovation Labs. Furthermore, no literature review regarding the networking of Innovation Labs in a territory has yet been conducted. This paper begins to fill this gap and shows that the linking of innovation labs can support territorial dynamics. Through a review of the literature, research trends pertaining to territorial dynamics and innovation laboratories were identified. The contribution of this article is the proposal of an approach to design a system of indicators to analyze a network of ILs adapted to a local territory as well as a portfolio of indicators. These results will allow us to follow the evolution of these labs, to follow their interactions and their impacts on a local territory.

*Keywords:* Territorial impact, Collaborative network, Literature review, Innovation labs, Indicators selection

### **1. Introduction**

In recent years, more and more local dynamics are trying to reduce our environmental impact by supporting recycling, a short supply chain, a circular economy, zero waste, sustainable development, etc. These local dynamics are supported by states, regions, and local territories because they meet major environmental and societal challenges<sup>1</sup> (Bleischwitz et al., 2022). Thus public actors try to monitor these dynamics through impact assessments. However, to have a homogeneous and coherent impact on a local territory, the public authorities need to link all territorial actions and to be sure of their relevance. To meet this ambition, innovation labs seem to be a relevant intermediary because of their huge development in the territories. Indeed, since 2006, the number of innovation labs (ILs) has been growing exponentially worldwide (Janin et al., 2013). For example, the Fab Foundation announces an increase from 10 to over 2,000 fablabs in 2022<sup>2</sup> and, in parallel, ENoLL<sup>3</sup> (European Network of Living Labs) has certified an increase from 19 Living Labs in 2006 to over 424 in 2022. This phenomenon leads to both redundancies and complementarities in terms of competencies or equipment (Pruvot et al., 2022). These ILs are generally supplied by local resources and are supported by a diversity of local actors. They welcome citizens but are also a real and concrete Public-Private-Population Partnership in contact with companies, public decision-makers, and academics (researchers, students, etc.) . They are seen as an important meeting point for the territory's actors (Hossain et al., 2019; Leminen et al., 2012). However, even if more and more authors are showing that these places support territorial development, circular dynamics or local distribution channels in a territory (Engez et al., 2021; Kasmi et al., 2021; Klein & Pecqueur, 2021), due to the novelty of these

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<sup>1</sup> <https://www.epa.gov/innovation> (accessed: 2023/06/20)

<sup>2</sup> <https://fabfoundation.org/#page-top> (accessed: 2023/06/20)

<sup>3</sup> <https://enoll.org/network/living-labs/> (accessed: 2023/06/20)

places, studies have not yet been sufficiently developed, especially on the assessment of their territorial impacts (Beaudoin et al., 2022; Kasmi et al., 2021) and their modes of collaboration (Pruvot et al., 2022, 2023). A collaborative network between ILs could allow them to improve their innovation process and to reduce costs and risks of innovation projects (Maurer & Valkenburg, 2014; Memon et al., 2018). Moreover, some innovation centers have already demonstrated their ability to influence regional or territorial development (Chowdhury et al., 2022). IL Network could have the same ability. However, the subject of territorial impacts of IL networks have still not been adequately addressed, certainly because of their complexity.

This article addresses the issue of how to build a tool to monitor the added value of an IL network for a local territory by considering the quality of the network and its impacts on the territory. For this purpose, an assumption has been put in place: ILs can support sustainable dynamics in a territory and a network of innovation labs can contribute even more to sustainable development on a territorial scale. To verify this assumption, an overview shows the research trends concerning territorial dynamics linked to IL. Moreover, the identification of concepts to characterize a sustainable local territory made it possible to verify this assumption and thus to be inspired by the impact assessment of territorial dynamics.

This article is structured as follows. Section 2 provides the theoretical background necessary to understand this study. Then, Section 3 presents the research design that was followed. Afterwards, Section 4 presents the findings from the literature review and Section 5 the results, composed of two contributions: the process of creation of the indicator system and a portfolio of indicators. Finally, the paper concludes with a discussion and a conclusion of the key findings, limitations, and future research.

## **2. State of the art and definition of terms**

### **2.1. Innovation labs (ILs)**

Innovation labs are networks of actors brought together to develop innovation through processes of creation, prototyping, validation, and testing in a real context (Del Vecchio et al., 2017). Users of these ILs are varied and are put together to cross points of view to develop innovations in terms of technology, services, products, or systems (Leminen et al., 2012). An IL is organized around a well-defined strategic intent with established innovation processes (Osorio et al., 2019). When the subject is a physical place where innovation activities take place, the term “innovation space” is used. When the subject corresponds to the innovation activities present in these spaces (their management, strategy, skills, values, etc.), the term “innovation lab” is preferred. Each IL has its own competences and aim. There are different types of innovation labs: Service/Process Laboratory, Product/Production Laboratory, Consulting Laboratory, Business Incubator, Network Coordinator, R&D Laboratory, Innovation Labs at University, Learning Lab, Agroecological Experimentation Field, Urban Living Lab, Territorial Living Lab, Innovation Laboratory, Co-Working Space, Makerspaces, Fablab, Techshop, Living Lab, Eco-Village, Hackerspace, Civic Lab, Infolab, Medialab, Museum Lab/Museomix, Social Lab, Co-Design Platform, Open Lab, Creative Space. This list is not exhaustive but shows the diversity of the concept and thus the difficulty of defining them. One place can be oriented toward several forms. Thanks to the variety of actors that cross these places, they can play an important role in the territories to develop innovation. ILs were oriented to develop innovation based on the triple helix concept (university, industry, government)(Carayannis & Campbell, 2010) but today the innovations are based on the quadruple helix concept because they very strongly take citizens into account in their process. To go further we can also talk about quintuple helix concepts because they have the desire to make real changes to reduce economic and territorial disparities between territories (Merino-Barbancho et al., 2023; Provenzano et al., 2018). They have to consider their interactions or impacts on the environment. Moreover, more and more authors are showing the capacity of ILs to initiate change and thus favor sustainable transformations in the territory (Kok et al., 2023; Scholl et al., 2022). To follow this potential for transformation of the territories, research about the impact assessment of these places is needed, and also emerging (Beaudoin et al., 2022; Coffay et al., 2022). Currently, in the literature, there are few publications that have analyzed the territorial impact of ILs (Bronson et al., 2021) and the interactions between them (Memon et al., 2022; Pruvot et al., 2022). Some authors have studied their inclusion in circular dynamics (Kasmi et al., 2021) or the possible complementarities of each of their innovation processes (Memon et al., 2022). Our participation in an international

focus group confirmed the lack of means to monitor and assess the territorial impact of ILs (Beaudoin et al., 2022; Bronson et al., 2021; Nguyen, 2021). The focus group had the objective of developing a research agenda focused on the impact assessment of Living Labs, but it can be generalized to all types of ILs. It was organized in May 2021 by a community of Canadian researchers (Nguyen, 2021). There was a total of 27 participants, including the Canadian Department of Agriculture, researchers, practitioners, sociologists, and economists specialized in agri-environmental Living Lab issues or Living Lab evaluation practitioners. They confirm that there are important questions, in the field of sustainable development, that need to be answered: who should manage the indicators? Who should assess the impact of ILs? (Lowery et al., 2020).

## 2.2. From network to collaborative network

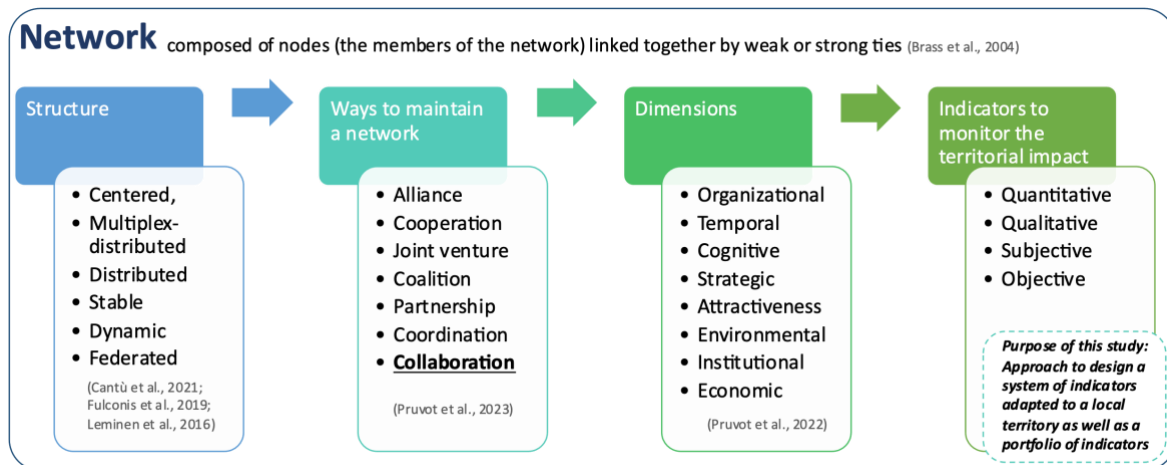


Fig. 1. Findings on network (authors' illustration).

A network is the structure that governs interactions between actors or organizations. A network is composed of nodes (which are the members of the network) linked together by weak or strong ties (Brass et al., 2004). A network is seen as the organization of a long-term relationship between organizations (Tcheubeu et al., 2015); it can be supported by financial exchanges (financial networks), information exchanges (communication networks), or collaborations (collaborative projects, or a combination of multiple types of interactions). This article is inspired by inter-organizational networks. These nodes and relationships can take several forms and thus be structured as centered, multiplex-distributed, distributed, stable, dynamic, federated (Cantù et al., 2021; Fulconis et al., 2019; Leminen et al., 2016). There are several ways to maintain networks: networking, alliance, cooperation, consortium, coalition, partnership, coordination, and collaboration (Pruvot et al., 2023). Collaboration is the most sustainable and complex means to set up because all resources, such as information, expertise, and physical tools are shared. Moreover, collaboration is composed of formal and informal interactions (Graça & Camarinha-Matos, 2017); it makes it possible to develop trust between actors (Lowery et al., 2020). The organizations involved in collaboration frequently carry out projects together (Memon et al., 2018). The network composed of this type of interactions is called a collaborative network. In this study, the term network can be regarded as short for collaborative network. In the literature, the author used interrelation, orchestration, ecosystem, archipelago, constellation, interconnection, combination, association, grouping, gathering, inter-organizational, cooperation, and partnering as synonyms for network.

A network in a territory can permit us to link different competencies, knowledge, and regions. This type of approach can promote dynamics such as circular economy, short supply chain, inter-disciplinary projects, etc. Moreover, linking varied actors present in diverse territories could allow us to homogenize and generalize dynamics, with a positive impact on both the territory and the environment.

To monitor the territorial impact of a network, all the key elements for the proper functioning and structure of the network must be identified by the assessment team. The key dimensions of a network in a territory are organizational, temporal, cognitive, strategic, attraction-oriented, environmental, institutional, and economic

(Pruvot et al., 2022). Moreover, the temporal dimension is an important criterion to determine the success of a collaboration (Ramli & Senin, 2021). This aspect is also to be considered in territorial dynamics. Permanence is an essential element of sustainability (Turku et al., 2022). Thus, collaborations can support sustainable territorial dynamics.

Monitoring a collaborative network is a very complex task because different types of indicators are needed: quantitative, qualitative, subjective, and objective. For example, Tcheubeu et al. suggested the volume of exchanges between partners; the type of exchanges, the satisfaction of both partners; the level of trust between network members, and the degree of innovation (Tcheubeu et al., 2015).

### **2.3. Territorial impact, local territory**

In this study, a network is applied to a local territory. A local territory is a geographical area that easily allows the exchange of information, knowledge, and tangible products. It's also a territorial scale where actors can create relationships. Indeed, according to (Klein & Pecqueur, 2021), "The term 'territorial' refers not to the pre-established political-administrative type of territory, or 'given' territory, but to a local territory established thanks to social construction by the actors where new relationships between socio-economic actors, citizens and institutions and the environment are imposed."<sup>4</sup> These new relationships can take the form of circular economy, sustainable development, innovation network, ecology, industrial ecology, industrial symbiosis, closed loop, eco-innovation, environmental innovation, or short supply chain. The term territorial dynamics is used to cover all these relationships. Territorial dynamics are composed of projects or interactions which are active in developing a territory or following a territorial strategy as previously defined.

Territorial impacts correspond to all effects that have a long-term impact on economic, social, and environmental development (Klein & Pecqueur, 2021).

### **2.4. Impact assessment methods**

There are different methods for assessing impacts (Bach & Wolff, 2017; Bachelet, 2016; Smit & Hessels, 2021). However, several invariants have been identified: the first steps are always composed of the description of the project and its environment (Means, Objective, Goal, Purpose), the definition of the objectives and the success criteria. The boundaries of the subject matter of the impact assessment must also be defined. The objective is to assess the results, effects and impacts of the study object. The results are the changes produced directly by the project (to be compared with the objectives formalized before the launch). The outcomes are the direct and indirect results of the action (direct results of the project but also of external factors). Impacts are the sustainable changes following the action, which remain when the project is completed (Bachelet, 2016).

All the stakeholders (in our case, public authorities, facilitators, leaders, etc.) must provide their opinions to define the objectives and ambition of the impact assessment (Halla & Merino-Saum, 2021). To assess if they achieve this goal, they need indicators. Five categories of indicators exist (Huovila et al., 2019):

- Input indicators are the resources needed to implement the analyzed action.
- Process indicators measure the approach implemented to create the action and allow it to be sustainable over time.
- Output indicators present details on the production of the analyzed action (waste, deliverables...).
- Outcome indicators measure intermediate results generated by outputs. Changes produced directly by the outputs of the action compared with action objectives.
- Impact indicators measure the effects of these exchanges on the territory, and the sustainability of the solutions provided.

The outcome and impact indicators are more often grouped together in the impact indicators category (Seres et al., 2019) because of the difficulty of identifying them separately. An indicator is a variable that is the representation of an attribute (quality, characteristic, property) of a system (Gallopín, 1997; Veleva & Ellenbecker, 2001). Defining clear objectives for each of the indicators is very important (Veleva & Ellenbecker, 2001).

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<sup>4</sup> Translation in English from the authors

Indicators are used to characterize the progress of an ongoing or past activity, its outcome, or its impact (Gendron et al., 2012). The objectives of the indicator, in the case of collaboration, are to facilitate collaboration between members and to increase the performance of collaborative activities (Gendron et al., 2012). It allows us to (Gendron et al., 2012; Singh et al., 2009):

- Anticipate and assess conditions and trends
- Provide early warning information to prevent damage
- Formulate strategies and communicate ideas
- Support decision-making

In addition, indicators can be sorted according to dimensions and are composed of (Veleva & Ellenbecker, 2001):

- Unit of measurement
- Type of measurement (numerical, textual, graphical, structured, a threshold, a discrete interval, or whether it's composed of other indicators ...)(Gendron et al., 2012)
- Periodicity of measurement
- Limits

The assessment must be carried out by the stakeholders of the object studied (local authorities, the project manager, and every actor related to the object studied)(Bachelet, 2016). Once the assessment team is formed, they must identify the different means of collecting data (among other things, the skills required, duration, resource budget, stages of the process, selection process of the actors carrying out the analysis) as well as the form in which the results will be processed and presented.

There are three types of assessment (Gertler et al., 2010):

- “Monitoring is a continuous process that tracks what is happening within a program and uses the data collected to inform program implementation and day-to-day management and decisions.”
- “Evaluations are used to answer specific questions related to design, implementation, and results. In contrast to continuous monitoring, they are carried out at discrete points in time and often seek an outside perspective from technical experts.”
- “Impact evaluations are a particular type of evaluation that seeks to answer cause-and-effect questions. Unlike general evaluations, which can answer many types of questions, impact evaluations are structured around one question: What is the impact (or causal effect) of a program on an outcome of interest?”

In this paper, the objective is to combine a monitoring process to assess the quality of the collaboration and also an impact evaluation to understand the effect of the collaborative network.

### 3. Research Design

Exploratory research was used to identify keywords for the Research Equations (RE). This allowed us to identify works using keywords related to this publication's theme, such as IL, network, territorial dynamics (Kasmi et al., 2021; Osorio et al., 2019; Pruvot et al., 2022). The exploratory research presented in the state of the art has led to the following research question: How do we ensure that networked innovation labs support territorial dynamics responding to current issues: sustainable development, circular economy, industrial symbiosis, etc.? To choose the keywords related to Innovation Labs and networks, a literature review that used a robust approach to select the IL and networking keywords was used (Pruvot et al., 2022).

The three literature reviews are based on one of the most frequently used databases, the Web of Science.

The first literature review was realized with the RE 1 (Table 1), about the link between innovation lab networks and territorial dynamics.

Table 1. Research Equation 1 (keywords abc) for the selection of publications.

Field	Option introduced
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<b>a - Innovation labs</b>	"inno* space" or "inno* lab*" or "living lab" or "fab lab" or "fablab" or "fablabs" or "makerspace" or "hackerspace" or "coworking space" or "third place" or "social lab" or "creative space" or "open lab" or "co-design platform"
<b>b - Networking Keywords</b> (Pruvot et al., 2022)	"inter-*" or "orchestrat*" or "organization" or "ecosystem" or "constellation" or "network*" or "interconnection" or "interrelation" or "combination" or "association" or "collaboration" or "grouping" or "gathering" or "inter-organizational" or "cooperation" or "partnering"
<b>c – Territorial dynamics</b>	"circular economy" or "social" or "terror*" or "sustainable development" or "ecology" or "industrial ecology" or "industrial symbiosis" or "closed loop" or "eco-innovation" or "environmental innovation"
<b>Keywords</b> (adapted from (Kasmi et al., 2021))	
<b>Search in</b>	title, abstract, author keywords, and Keywords Plus.
<b>Period explored</b>	2005 to 2023 August 31
<b>Document type</b>	Article, proceedings paper, book, book chapter, book review, review or early access
<b>Database</b>	Web of Science
<b>Number of publications</b>	436→39 selected

The evolution of IL network publications in a territory (equation 1) (curve 2) was compared with the trend in global publications<sup>5</sup> (line 1) (Figure 2). The number of international articles on IL has grown significantly since 2012. This phenomenon is correlated with the success of IL and reinforced by national policies (Pruvot et al., 2022). The analysis started in 2005 because this date corresponds to the launch of many international dynamics around IL (e.g., the EnoLL network in 2006). From this date many other dynamics started to emerge, for example the Fab Foundation in 2009. Moreover, this representation makes it possible to show that the subject is undergoing exponential growth. This first method identified certain gaps in impact assessment and in methods of IS

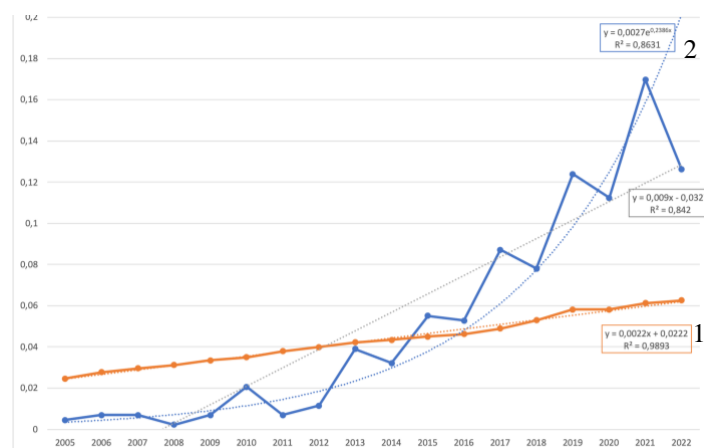


Fig. 2. Evolution of the number of publications of IL networks in a territory (1) compared to global production of articles (2).

networking. The results for the year 2022 are probably partial because some 2022 papers were added late to the Web of Science database.

Moreover, bibliometric analysis has shown that our subject is part of international trends. Table 2 shows the quantitative evolution by country between 2005 and 2023. Only countries with more than seven articles were included (98,86% of the total).

Table 2. Geographical trends.

Countries/Regions	Record Count	% of 436
Italy	52	11.927
USA	48	11.009
France	37	8.486
Germany	35	8.028

<sup>5</sup> <https://dblp.uni-trier.de/statistics/publicationsperyear.html>

Spain	34	7.798
England	30	6.881
Australia	25	5.734
Canada	22	5.046
Brazil	21	4.817
Finland	21	4.817
People's Republic of China (PRC)	19	4.358
Russia	16	3.670
Netherlands	15	3.440
Mexico	10	2.294
Portugal	10	2.294
Belgium	8	1.835
Austria	7	1.606
Denmark	7	1.606
Poland	7	1.606

The second step of the bibliometric analysis was keyword mapping, done with VOSViewer.

Keyword co-occurrence analysis begins to validate the assumption. The map of co-occurrence keywords is represented in Figure 3. There are four clusters which address territorial notions such as the social component (in red) (with keywords community, third place, living lab, social networks...), the economic component (in yellow) (with keywords coworking, organization, economy...), spatial planning (in blue) (with keywords proximity, digital fabrication, social capital, network, smart city, education, science, urban planning...), governance component (in purple) (with keywords management, sustainability, cities, resilience, transition...). The cluster with keywords network, model, and social network analysis can also be seen as an independent cluster like the cluster with innovation, social innovation, etc. because these two topics are transversal and very strongly linked to the four other clusters.

The first four clusters (social, economic, spatial planning, and governance) represent the dimensions of a territory (Medeiros, 2020). The environmental dimensions, including keywords such as transitions, sustainability, circular economy, are mixed in the governance clusters because these are still emerging topics (Figure 4). Thanks to this research equation, keywords show that international authors studied IL with the territories. This fourth component is relatively new in the literature (Figure 4); our subject of study is therefore emergent as a scientific topic. Clusters related to innovation and networks are at the intersection of these first four clusters. The keyword network is very strongly linked to the sustainability aspect and to social innovation. Moreover, the sustainability aspect is related to a territorial dynamic, circular economy. Thanks to the co-occurrence analysis of the keywords,

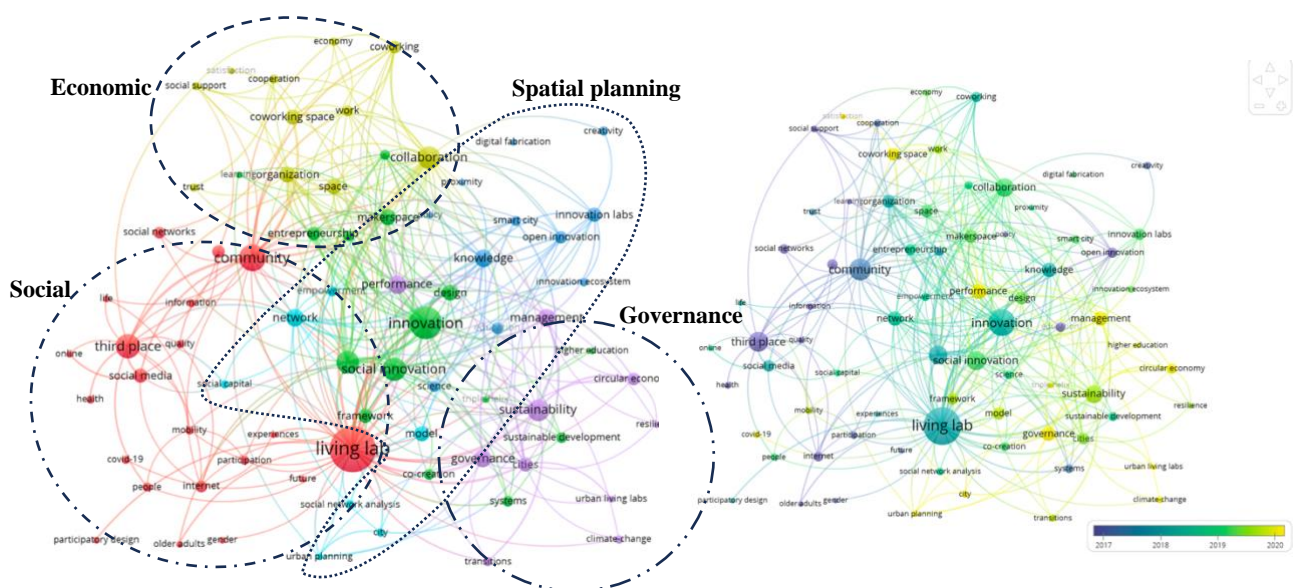


Fig. 3. Co-occurrence map with the four clusters made with VosViewer

Fig. 4. Temporal analysis of the co-occurrence keywords map made with VosViewer



the use of the hypothesis is potentially confirmed. The keywords environment and impact assessment are missing in the keyword map so the research with the second equation is justified to confirm this gap.

Thanks to the bibliometric analysis, the lack of keywords related to impact assessments motivated the second research equation (RE 2 in Table 3) to identify means to assess the territorial impact of a network of ILs. Only twenty-two publications were found. To fill this lack of publication, the third literature review was conducted to find publications on the territorial impact assessment of territorial dynamics because this thematic has already been thoroughly studied (Table 4). Hence, the keywords were searched only in “author keywords.”

Table 3. Research Equation 2 (keywords a, b, d) for the selection of publications.

Field	Option introduced
<b>a - Innovation labs</b>	
<b>Keywords</b> (Adapted from (Kasmi et al., 2021; Osorio et al., 2019))	"inno* space" or "inno* lab*" or "living lab" or "fab lab" or "fablab" or "fablabs" or "makerspace" or "hackerspace" or "coworking space" or "third place" or "social lab" or "creative space" or "open lab" or "co-design platform"
<b>b - Networking Keywords</b> (Pruvot et al., 2022)	"inter-*" or "orchestrat*" or "organization" or "ecosystem" or "archipelago" or "constellation" or "network*" or "interconnection" or "interrelation" or "combination" or "association" or "collaboration" or "grouping" or "gathering" or "inter-organizational" or "cooperation" or "partnering"
<b>d - Impact assessment</b>	
<b>Keywords</b>	"territor* impact" or "local impact" or "regional impact" or "territor* assessment" or "territor* evaluation" or "territor* valuation" or "territor* appraisal" or "territor* effect" or "local assessment" or "local evaluation" or "local valuation" or "local appraisal" or "local effect" or "regional assessment" or "regional evaluation" or "regional valuation" or "regional appraisal" or "regional effect" or "territor* development" or "local development" or "regional development" or "indicator"
<b>Search in</b>	title, abstract, author keywords, and Keywords Plus.
<b>Period explored</b>	2005 to 2023 August 31
<b>Document type</b>	Article, proceedings paper, book, book chapter, book review, review or early access
<b>Database</b>	Web of Science
<b>Number of publications</b>	22 →9 selected: 7 in common with RE 1

Table 4. Research Equations 3 (keywords c, d).

Field	Option introduced
<b>c – Territorial dynamics</b>	
<b>Keywords</b> (adapted from (Kasmi et al., 2021))	"circular economy" or "sustainable development" or "ecology" or "industrial ecology" or "industrial symbiosis" or "closed loop" or "eco-innovation" or "environmental innovation"
<b>d - Impact assessment</b>	
<b>Keywords</b>	"territor* impact" or "local impact" or "regional impact" or "territor* assessment" or "territor* evaluation" or "territor* valuation" or "territor* appraisal" or "territor* effect" or "local assessment" or "local evaluation" or "local valuation" or "local appraisal" or "local effect" or "regional assessment" or "regional evaluation" or "regional appraisal" or "regional effect" or "territor* development" or "local development" or "regional development" or "indicator"
<b>Search in</b>	Author keywords
<b>Period explored</b>	1950 to 2023 August 31
<b>Document type</b>	Article, proceedings paper, book, book chapter, book review, review or early access
<b>Database</b>	Web of Science
<b>Number of publications</b>	935 → 45 selected

To select the articles, a strict process was followed: reading of the title to select only papers that deal with the topic of collaborative networks comprising an IL and a territory, then the abstract and finally the full papers to select only interesting ones. Indeed, articles dealing with technical or overly specific subjects were not selected. For RE1 and RE2, thirty-three selected documents were analyzed and, for the third literature review, thirty-five articles were selected. All the articles dealing with overly specific themes (such as water, habitat, tourism, diseases, wealth, agriculture, etc.) have not been retained. The selected papers deal with generic indicators and/or with an approach to select and evaluate them.

The assumption was validated with key findings and a proposal for an approach to design a system of indicators was developed, as well as a portfolio of indicators related to the territorial impacts of an IL network. This portfolio could serve as a basis to build the system of indicators thanks to our approach. Figure 5 presents the whole approach.

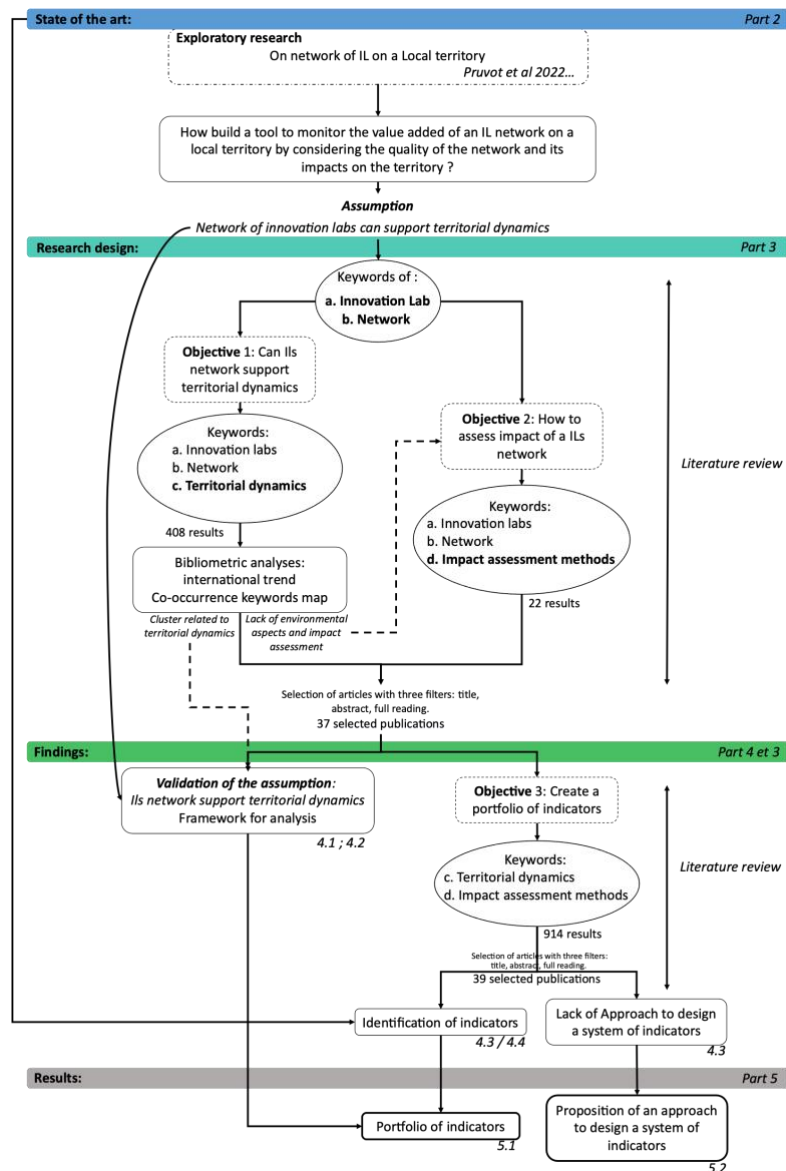


Fig. 5. Research approach designed for this study.

## 4. Findings

### 4.1. Innovation lab: a mean to support territorial development.

The literature review from RE 1 and RE 2 shows that to develop the territory in all fields of activity (health, industry, etc.), innovation labs are a powerful lever thanks to their varied actors (Del Vecchio et al., 2017). They are a way to break territorial development resulting from a top-down approach (Bonis, 2012) and to develop territorial innovation or transversal innovation.

As presented by (Engez et al., 2021; Kasmi et al., 2021; Klein & Pecqueur, 2021; Pawlicka-deger, 2020; Tyl & Allais, 2021), ILS could become important tools in a local territory, for innovation, ecology, economics, and urban and social development.

To develop a territory in a uniform and sustainable way, an initial analysis of (Medeiros, 2020) presents the definition of five concepts for a sustainable territorial development policy. The analysis of the literature identified that many ILS were already individually supporting some of these concepts (cf. Appendix 1). Furthermore, some

key points have been identified in the IL literature to confirm the added value of IL for territorial development (cf. Table 5). The names of examples of ILs dealing with these five concepts are presented in Appendix 1.

Table 5. Innovation labs support sustainable territorial development.

Sustainable territorial development concepts (Five concepts)	Sources	Conclusion from the literature on the links between ILs and the concepts
Circular Economy (CE)	(Kasmi et al., 2021)	ILs can <b>support four CE strategies</b> : Strategy of waste management and flow recovery, Sustainable use and manufacturing strategy, Sustainable use and consumption strategy, Sustainable organizational and territorial strategy
	(Prendeville et al., 2017)	“‘makerspaces are not seen to be geared toward manufacturing’ at present. In contrast, makerspaces are described as ‘knowledge centers’ well suited to ‘experimentation with different approaches to see what works’ <b>for developing circular ideas</b> ”
	(Tyl & Allais, 2021)	IL can support the development of reuse and repair activities in territories thanks to their local stakeholders. Solutions created respond to specific local issues and support sustainable and/or urban transition.
	(Weber & Heidelmann, 2019)	IL could <b>support a territorialized network of reuse and repair</b> . IL makes it possible to engage a <b>sustainability approach</b> supported by an institution such as a university. When using <b>Sustainability Innovation Labs</b> in a sequence of events, the <b>potential of a Regional Innovation System (RIS) rises</b> .
	(Engez et al., 2021)(Turku et al., 2022)	An IL contains several ecosystems in which multiple projects take place to serve the goal of that particular ecosystem. This empirical case study depicted and validated how the <b>three major ecosystem types (ecosystems for economic value, knowledge, and material flow) may occur in IL</b> (Engez et al., 2021).
	(Cantù et al., 2021)	IL “has hosted about 40 R & D projects and experiments that promote <b>smart technology, sustainability and CE solutions</b> .” IL “seems to be a promising type to advance various sorts of sustainability” (Turku et al., 2022) “a crucial aspect is that the circular living lab is open to the public during its testing phase, ensuring <b>people can learn about CE and experience first-hand</b> the future possibilities of modular living”
	(Cuomo, 2022)	“ILs have stimulated relevant initiatives in all the 10 Rs of the CE, namely, <b>refusing, reducing, reusing, repairing, refurbishing, remanufacturing, repurposing, recycling, re-mining actions</b> ”
	(Meath et al., 2022)	“CoLab provides rare empirical evidence of how a multi-level collaboration, and meso-level <b>collaboration led by industry and academia and incorporating government, was developed, and how the specific design addresses known drivers, barriers and enablers of shifting to CE.</b> ”
(Coskun et al., 2022)	“Having a trusted and reliable <b>network of circular makerspaces (CMSs) would allow the cities to exchange experiences and learn from each other.</b> ” All strategies need to be tailored to the specific context of each city. The insights should be mainly used as a reflection on the method cities can apply to tackle challenges linked to CMSs.	
Social environmental awareness: mediation, education	(Helal et al., 2017)	IL “provides a <b>collaborative platform</b> to unite research and main societal across to commonly develop and <b>apply practical solutions</b> faced to different challenges around the <b>society needs</b> .” “Actions to <b>sensibilize</b> population in schools, universities and others to participation issues to different <b>projects on the protection and valorization of the environment.</b> ”
	(Fasoli & Tassinari, 2017)	“The different labs offer a <b>multilevel service</b> that answers to a variety of <b>social needs</b> from different segments of the society from the young age to elders, and creates an inclusive and interdisciplinary infrastructure of knowledge, in which citizens can <b>share experiences and experimenting new practices with advanced technological tools.</b> ”
	(Braun et al., 2022)	“Our data show that the context in which Social Labs were set up was of crucial importance to the role they played in terms of <b>learning and mediation.</b> ”
	(Callaghan & Herselman, 2015)	“The social process of meeting like-minded people to engage with and in the research of <b>evaluating educational apps</b> across the curriculum is undeniably meritorious.”
	(Pugliese et al., 2021)	“Coupling the IL experience with <b>effective territory control</b> , through the implementation of complementary <b>socio-institutional actions</b> , could <b>improve the stakeholders’ awareness</b> limiting the different perceptions of heterogeneous stakeholder groups”

	(Berberi et al., 2023)	“Living labs hold great potential as a novel method for innovating technologies or practices that might help us <b>address the grand social and environmental challenges</b> of our time”
	(Merino-Barbancho et al., 2023)	“Opening the creative space to citizens who normally do not participate in planning, creation or design activities is necessary not only to enrich the creative process but to raise awareness of innovation and increase stakeholders’ acceptance demands”
	(Klooker & Hölzle, 2023)	“We conclude that a <b>sociomaterial perspective</b> is essential to fully grasp the phenomenon of <b>developing collaborative innovation space</b> as an effective workplace for collaborative innovation”
<b>Environmental conservation: multidisciplinary issues, sustainable innovations</b>	(Zermeño & Alemán de la Garza, 2020)	“The evidence and analysis results demonstrated the capacity of open laboratories for social innovation to promote the <b>exchange of experiences and best practices of education for peace and sustainable development</b> ” “participants became actively involved in the generation of collective knowledge”
	(Zivkovic, 2018)	“Incorporates and synthesizes all of the key features recommended for addressing wicked problems: it will focus on <b>addressing complex problems</b> , take a place-based <b>transition approach</b> , enable coherent action by diverse actors, involve users as co-creators, support a networked governance approach and recognize government as an <b>enabler of change</b> ”
	(Turku et al., 2022)	“The idea was to use an open and collaborative approach that follows the principles of a CE to <b>coordinate activities and generate ideas for the new urban</b> district.”
	(Arnould et al., 2022)	“ <b>Sustainability</b> develops as an emergent normative property of the Hiedanranta Urban Living Lab”
	(Trivellas et al., 2023)	IL “objective is to bring together forest owners to pool their resources in order to create <b>more coordinated management units for wood harvesting</b> ” “the main positive impact observed concerns governance in the forestry sector”
<b>Governance sustainability focus</b>	(Bevilacqua et al., 2020)	IL “demonstrates the possibility of an <b>effective urban governance</b> through a <b>new dynamic organizational</b> pattern based on a <b>horizontal multi-sectoral collaboration</b> ”
	(Meister Broekema et al., 2022)	“The potential added value of the concept perhaps does not lie in its newness or uniqueness, but in its power rather <b>to transform static institutions</b> , such as governments or universities, into <b>more outward facing institutions</b> , by including external stakeholders and/or work in a novel way.”
	(Del Vecchio et al., 2017)	IL could play a role to promote knowledge sharing and exchange for regional innovation by integrating university, public institutions, government, firms and end-users. “The collaborative interaction among all the participants focused on generating an <b>innovation policy</b> ”
	(Ascione, 2021)	“The city, through a multi-stakeholder management setting, has guaranteed a <b>public and democratic participation</b> of a wide range of interests. Moreover, with the ULL, the city has reinvigorated the public interest towards the purpose of limiting the depletion of scarce resources, and it has played an active role in <b>promoting a factual change in the regulation</b> not only for the benefit of the project but also for all the private actors operating in the backfilling soil market.”
	(Bulkeley et al., 2016)	ILs “are doing more than simply fostering learning and innovation, they are <b>part of the ways</b> in which urban responses <b>to sustainability challenges are governed.</b> ” IL “as part of the <b>shifting governance</b> landscape, a means through which interventions are increasingly pursued in order <b>to realize urban objectives</b> ”
	(Rehm et al., 2021)	“How to develop resilient organizational models for urban experimentation platforms. ... these considerations centered on three key facets, (1) <b>facilitating urban ecosystem governance</b> , (2) <b>empowering co-creation</b> , and (3) <b>qualifying local innovation</b> . Based on a discussion of case insights, along these three facets, we propose a set of objectives and measures supporting the set-up of Urban Experimentation Platforms, along with the roles municipalities could play.”
<b>Spatial planning sustainability focus, Sustainable cities</b>	(Dupont et al., 2014)	IL allows us to <b>consider</b> the skills and knowledge of <b>all actors</b> in relation to urban projects and thus to confront different visions and develop <b>new urban projects</b> . IL to support co-design of eco-neighborhood
	(Nevens et al., 2013)	IL “as the locus within a city where (global) <b>persistent problems are translated</b> to the <b>specific</b> characteristics of the <b>city</b> and where multiple transitions interact across domains, shift scales of operation and impact multiple domains simultaneously (e.g.

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	energy, mobility, built environment, food, ecosystems)” “There is growing acknowledgment that cities can actually accelerate transitions to sustainability, <b>provided that new governance structures emerge to achieve this.</b> ”
(Larios et al., 2016)	“The main goals driving the creation of the Living Lab including the ability to develop and <b>transfer</b> solutions to the municipalities at Metropolitan Area, <b>explore public policies</b> that foster the development of Smart City applications, and <b>reduce political risk</b> by informing authorities about potential solutions to implement in the city.”
(Leminen et al., 2017)	“This study not only illuminates four collaborative innovation modes but also contributes to the growing literatures of open innovation networks and living labs by <b>describing the ways Living Lab networks are exploited in the city context.</b> ” The city can be seen as a provider, a neighborhood participator, <b>a catalyst or a rapid experimenter.</b> The innovation generated will be different.
(Rodrigues & Franco, 2018)	IL “allows the setting up of small firms and multinationals in the region and the <b>creation of a business network</b> , where resource-sharing is crucial for the success of the entrepreneurial and innovative ideas of <b>citizens</b> motivated to do <b>business</b> and <b>collaborate</b> actively in the <b>region's management and growth.</b> ”
(Cerreta et al., 2020)	“Process of adaptive reuse of cultural heritage through the implementation of a Living Lab can not only aim at identifying a new function by <b>evaluating possible scenarios</b> and outcomes, but can itself <b>generate new values</b> during the path of reuse, with <b>repercussions for the entire urban context.</b> ”
(Bartelt et al., 2020)	“This study demonstrates the ability of IL to <b>break down silos, improving collaboration and innovation</b> , while also creating new challenges such as potential reallocation of funding across departments.” IL “also proved a useful tool for initiating a <b>long-term shift</b> towards a collaborative culture and for <b>identifying synergistic opportunities</b> within the smart city program and across departments within the city”

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These analyses demonstrate the role of ILs in contributing to the five concepts of sustainable territory development. Innovation labs create new forms of governance and develop cooperation between various actors in the territory to create new knowledge or new supply chain (Trivellas et al., 2023). Moreover, they can function as intermediaries because of their access to many actors. They can raise awareness of the entire local territory. The variety of profiles present in these places can create innovations that are multidisciplinary, systemic, increasingly original, and thus in line with societal and environmental issues. Innovation labs individually support many territorial dynamics and, thanks to all their innovations, they can be a source of job creation, entrepreneurship, etc.

#### 4.2. Networks of innovation labs support territorial dynamics

To manage the impacts of territorial dynamics on the territories, all their actors must be concerned and involved. All the stakeholders of a territory (industrialists, policymakers, civil society, academics) are present in these ILs (Moradi & Dokhani, 2020). Public authorities (state or region) could connect all parts of the local territory through these different ILs. Thanks to the large number of innovation labs in the territory, they could be an interesting intermediary to mobilize every stakeholder. The network of ILs could therefore be part of territorial issues and strategies.

Networks make it possible to create industrial symbioses (Simboli et al., 2020) or ecosystems (Gamidullaeva et al., 2022). These dynamics could make it possible to support sustainable territorial development (Gamidullaeva et al., 2022). For those reasons network of ILs can potentially develop sustainable territory or circular economy. Some authors (Coskun et al., 2022; Prendeville et al., 2017) have initiated a reflection on circular makerspaces, though they do not address the interest for the whole local territory. People would come from different regions and have different points of view and skills, which would make it possible to address certain issues through innovative systemic (multidisciplinary) solutions. Indeed, the association of various skills and knowledge from all the organizations of the territory allows the realization of multidisciplinary solutions (Zivkovic, 2018). The more varied the skills and knowledge are, the more radical the innovations can be. These innovations can produce value for the territory. “More than knowledge itself, the creation of value comes from the exchange and linking of knowledges; hence the importance of the network concept”<sup>6</sup> (Silberzahn et al., 2007). Networking ILs would

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<sup>6</sup> Translation in English from the authors

therefore allow them to spread their knowledge and specificities on a larger scale over a territory thanks to their geographical distribution. Moreover, (Zivkovic, 2018) shows that each type of IL has its own specificities and responds differently to current issues, so they can be complementary. These places are sources of creativity and innovation locally. Creative capital contributes to the strategy of sustainable development (Sokół & Mempel-Śnieżyk, 2022). According to (Turku et al., 2022), “despite ephemerality, local sustainability innovations can help sustainability pathways emerge and thus accelerate local transitions.” Reconfigurations are necessary conditions for all transitions (Turku et al., 2022). This study assumes that reconfiguring closely located innovation labs in a network could bring much added value to its ecosystem, through:

- Sharing of material and skills.
- Allowing an actor to come to one of the ILs to express his need and then be redirected to the one most adapted to his needs.
- Sharing the knowledge produced locally with other parts of the territory to have a homogeneous network of knowledge on the territory.
- Share costs and risks between several innovation labs.
- Develop dynamics like a circular economy. The waste of one could become the resources of another and knowledge could be disseminated without any competition or other constraints (reuse of manufactured product, sharing of energy used, etc.) (Kasmi et al., 2021; Tyl & Allais, 2021).
- Having simultaneous real-world experimentation fields, multi-actor processes and resources between several geographical or industrial sectors (Scholl et al., 2022; Turku et al., 2022).

This reconfiguration will allow us to limit the impact on the environment. Also, providing a means for public decision-makers to monitor and evaluate the dynamics put in place is important for understanding the effects of their funding in IL.

Only (Memon et al., 2022) proposed a framework to structure an IL network as an innovation process shared between IL. Moreover, they do not propose an approach for setting up this type of network and no means of monitoring its development and impact.

All these elements validate our assumption that a network of ILs could bring more value to the territory. Indeed, they will be able to bring even more value by creating dynamics such as a circular economy or a short supply chain (Kasmi et al., 2021). Thus, a detailed analysis of these dynamics has been carried out to identify the tools, methods, and approaches that exist to study and monitor these dynamics.

### **4.3. Comparison of impact assessment approaches**

Due to the lack of IL impact assessment, RE3 was used to identify several approaches. As the analysis of the territorial networks of innovation labs is very complex, it is important for public authorities and people who support these places to gather all the elements used for the systemic analysis in a single document. This literature review shows the different types of indicators already established to analyze territorial dynamics. Twenty articles present the indicators used. Moreover, the combination of indicators is not new and has already been carried out. This table identifies the different elements that make up a set of indicators (dimensions, indicators, visualization of the indicator results) as well as the steps to build it (combining indicators, comparison of indicators, selection process, concrete tool to build it). This step identified:

1. The dimensions that correspond to the major themes that need to be assessed.
2. The possibility of combining indicators from different domains, and whether any of them had been compared (to identify which indicator is the most appropriate).
3. Selection processes to justify the approach used to select certain indicators.
4. Concrete and operational tools to build the framework.
5. Ways to visualize the evaluation results from the indicators.

Only ten articles combine indicators and present the selection process (cross in brackets in Table 6). However, the concrete tools to implement the approach are rarely presented (five articles) (Table 6).

Note that in this analysis we want to identify what is possible when using indicators, to select them, combine them, etc., but we are not yet interested in the scales to use to measure each indicator.

Table 6. Literature review on impact assessment approach.

Authors	No. of citations	Indicators	1 - Dimensions	2 - Combines indicators	2 - Comparison of indicators	3 - Indicator selection process	4 - Concrete tool or approach	5 - Visualization of indicators
(Xijie et al., 2023)	0	X	X				X	
(Lepenies et al., 2023)	1		X			X		
(Latif et al., 2023)	0	X		(X)		(X)		
(Pitkänen et al., 2023)	1	X	X	(X)		(X)		
(Ricciolini et al., 2022)	16		X					
(Halla & Merino-Saum, 2021)	1		X		X			
(Mengistu & Panizzolo, 2022)	4	X	X			X	X	
(Bote Alonso et al., 2022)	6	X	X	(X)		(X)	X	
(Valls-Val et al., 2022)	14		X	X	X			
(Bianchi et al., 2022)	10	X	X					
(Panchal et al., 2021)	63	X	X	X				
(Wang et al., 2021)	5	X	X					
(Al-tekrete et al., 2021)	5		X			X		X
(Veyssièrè et al., 2021)	13		X					
(Londoño-Pineda et al., 2021)	4	X	X	(X)		(X)	X	
(Tolstykh et al., 2020)	44						X	
(Assarkhaniki et al., 2020)	26	X	X					
(Lütje & Wohlgemuth, 2020)	31	X	X	X				
(Jing & Wang, 2020)	61	X	X	X				
(Völker et al., 2020)	65	X	X					
(Silva et al., 2020)	50	X	X	(X)		(X)		
(Kristensen & Mosgaard, 2020)	438	X	X					
(Shi et al., 2019)	38	X	X	(X)		(X)	X	
(Avdiushchenko & Zajaç, 2019)	82	X	X	X				
(Huovila et al., 2019)	401		X		X			
(Rahma et al., 2019)	55		X			X		
(Kozma, 2019)	6				X			
(Hong et al., 2019)	15		X	(X)		(X)		
(Janoušková et al., 2018)	133				X			
(Avdiushchenko, 2018)	37		X			X		
(Musa et al., 2018)	49	X	X	(X)		(X)	X	
(Li & Mathiyazhagan, 2017)	142	X	X			X		
(Lopes & Franco, 2017)	26		X					
(Allen et al., 2017)	122	X	X			X		X
(Mantese & Amaral, 2017)	4			(X)		(X)		X
(Felicio et al., 2016)	81		X	X				X
(Huang et al., 2014)	1	X	X	(X)		(X)		
(Pülzl et al., 2011)	43	X	X			X		
(Singh et al., 2009)	937	X	X			X		
<b>Sum</b>		22	33	16	5	19	6	4

The literature shows that to build a system of indicators, methods are needed to select the most relevant indicators and to not get confused (Avdiushchenko, 2018; Hong et al., 2019; Janoušková et al., 2018; Mantese & Amaral, 2017; Musa et al., 2018; Silva et al., 2020; Veleva & Ellenbecker, 2001). Through this literature review different methods could be identified. Only five methods were used to select indicators without having a prior quantitative value. Moreover, further research is needed to develop a visualization of the indicator results to be accessible to all types of actors present in an IL.

Thanks to Table 6, processes to select and to combine indicators have been identified (Bote Alonso et al., 2022; Hong et al., 2019; Latif et al., 2023; Londoño-Pineda et al., 2021; Musa et al., 2018; Pitkänen et al., 2023; Shi et al., 2019; Silva et al., 2020). To establish our system of indicators, we can draw inspiration from the most cited (they have been recognized as interesting by the community) or recent (to keep a current vision). By comparing these eight processes, six main steps were identified:

- Context analysis (identify stakeholders and experts, issues, etc.)
- Brainstorming and/or analysis of literature and/or reports to identify reference indicators.
- Identify the objectives of the local context.
- Select indicators based on and through the above elements (objectives, stakeholders to be considered in the selection) or through previous assessments conducted with the indicators to identify those that best represent the reality.
- Verification of the relevance of each indicator by different means (correlation analysis, Pearson analysis when there is previous data or merely simplification, clarification, and aggregation).
- Definition of the means to collect the necessary data.

To identify relevant indicators, we selected the most cited articles because they propose indicators that have been used, applied, and verified many times. We chose papers with more than sixty-three citations. This allowed us to gauge the standards and also to use indicators that are potentially less applied so that we could maintain a broad view. We also included very recent papers to keep a current vision. Their low number of citations may simply be due to their recent publication. The indicators most used to analyze territorial impacts are the SDG indicators (Allen et al., 2017; Huovila et al., 2019; Janoušková et al., 2018; Li & Mathiyazhagan, 2017), indicators to measure the circular economy (Avdiushchenko & Zajaç, 2019; Kristensen & Mosgaard, 2020; Völker et al., 2020), or, in less recent articles, those analyzing industrial symbioses (Felicio et al., 2016). As the circular economy and sustainable development are closely linked (Panchal et al., 2021), it is consistent to combine these indicators. However, the large number of indicators linked to the SDG makes them difficult to apply and it is often complicated to identify which ones best represent a local situation (R. E. Kim, 2023). Indeed, often the indicators derived from the SDGs allow us to evaluate the progress of SDGs at an international level and not at a local level (Sharaf, 2023). Usually, the choice of SDG indicators is made at the policy and government level (Lepenes et al., 2023). In the case of an IL network, it is necessary to be closer to the territory and its actors in order to align with the philosophy of ILs. Because of a very large number of SDG indicators, only the targets that can be achieved by the ILs were selected thanks to the framework used in Sub-section 4.1.

To facilitate the task of future researchers, we have identified reference indicators that can be applied to a local context and to ILs. Indicators to assess sustainable development and CE which can be used in a network of ILs are presented in Table 7.

Table 7. Selected indicators to analyze the five concepts.

Concepts	Adapted Indicators
<b>Circular economy</b>	Number of projects to promote the repair and reuse of material goods (investment...)
	Quantity of recycled materials
	Generation of waste by the network
	Recycling rate for all waste excluding major mineral waste
	Recycling rate for packaging
	Recycling rate for plastic packaging
	Recycling rate for wooden packaging
	Recycling rate for electrical and electronic waste
	Recycling rate for biowaste
<b>Social environmental awareness: mediation</b>	Number of training courses on sustainable development for national policies, teachers, students, and children.
	Number of projects promoting reintegration
	Number of jobs created / number of volunteers
<b>Environmental conservation: multidisciplinary issues, sustainable innovations</b>	Number of projects related to supporting clean energy research and development and renewable energy production
	Level of water resource management at the inlet and outlet of the network
	Type and quantity of resources shared
	Level of awareness of issues related to sustainable consumption and production
	Number of projects co-constructed with public policies



	Number of innovation projects to mitigate climate change
	Total research budget allocated to marine technology research
	Number of projects on ocean exploitation
	Total research budget allocated to forest management
	Number of projects promoting biodiversity, soil protection, and forest adaptation to climate change
	Number of inclusive projects involving diverse people
<b>Spatial planning sustainability focus, sustainable cities</b>	Number of innovation projects related to sustainable and resilient infrastructure
	Number of partnerships with sustainable and/or inclusive industry
	Number of projects oriented toward green spaces, biodiversity, forests, etc.
	Number of mediation events, awareness of the environmental impact of cities
	Amount of use of local materials
<b>Governance sustainability focus</b>	Number of new collaboration opportunities to develop projects around technology and innovation
	Frequency of sharing information, knowledge, materials...

Sub-section 5.1 proposes a portfolio of indicators which brings together all the indicators needed for our analysis. Each IL has different objectives in their specific context, which is why it will be necessary to make a selection among all these proposed indicators. To identify and select indicators that can analyze the expected impact, Sub-section 5.2 will present an approach to select the most relevant indicators with local stakeholders.

In Section 6, on the main steps identified in the literature, an important element is to take into account the context and the stakeholders. When an evaluation of territorial impacts is conducted, all the actors must be involved from the very beginning of the creation of the framework (Gertler et al., 2010; Halla & Merino-Saum, 2021), but this is not always the case. Therefore, a complementary literature review to identify methods to take stakeholders into account was realized (cf. Table 8).

Table 8. Methodology to select indicators with stakeholders.

Approach (references)	Description	<ul style="list-style-type: none"> <li>• Advantages</li> <li>○ Disadvantages</li> </ul>
<b>Delphi</b> (Y. H. Kim & Kim, 2013; Musa et al., 2018)	Iterative method of confronting points of view with surveys to obtain a tool shared and validated by all actors. Iterations continue until a convergence of views is reached.	<ul style="list-style-type: none"> <li>• Consider the actors in an anonymous or non-anonymous way; iterative overview</li> <li>• No approximation</li> <li>○ Repeated mobilization of actors</li> </ul>
<b>Fuzzy Delphi Method</b> (Mengistu & Panizzolo, 2022)	Method based on a survey like the Delphi method but the answers to the questions are qualitative. During the analysis, a number will be assigned to each answer according to a curve defined at the beginning (triangular, trapezoidal or Gaussian).	<ul style="list-style-type: none"> <li>• Faster convergence than with the Delphi method</li> <li>• Based on the importance of the participating actor from his level of experience in the field</li> <li>○ Defining the adapted analysis curve is not always obvious, approximation can be wrong</li> </ul>
<b>BETA-EvaRIO</b> (Bach & Wolff, 2017)	Allows for a combination of qualitative and quantitative indicators. Uses several data collection methods (interview, specific data with survey...)	<ul style="list-style-type: none"> <li>• Mixed approach; focuses on all activities performed and not just on one actor</li> <li>○ Specific for evaluating research projects</li> </ul>
<b>PIPA</b> (van Drooge & Spaapen, 2017)	Allows us to gather all the stakeholders of a project in interdisciplinary collaboration to define the objectives and then create a system of adapted indicators. The objective of the indicators is not to compare projects or measure scientific excellence but to understand the collaboration dynamics and the societal changes achieved.	<ul style="list-style-type: none"> <li>• Interdisciplinary context; stakeholder participation</li> <li>○ Remobilization of the actors</li> </ul>
<b>SWARA</b> , analysis of the weighted evaluation report by stages (Zolfani & Saparauskas, 2013)	SWARA gives decision-makers and policymakers the chance to select their priority based on the current situation of the environment and economy. The role of the experts is very important in this method. The	<ul style="list-style-type: none"> <li>• Questionary</li> <li>○ Remobilization of the actors</li> </ul>

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SWARA method is simple and experts can easily work together.

### 3S methodology

Cloquell-Ballester et al. (Mantese et al., 2016)

Specific questions for the choice of indicators (Conceptual coherence; operational coherence; utility)

- Easy and clear approach (similar to SMART method to validate a goal)
- Long: a questionnaire with 12 questions for each indicator

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Following this analysis, certain methods were identified as relevant. The use of the Delphi method allows iterations to keep the anonymity of the participants, which in some cases contributes to the removal of barriers and therefore to ascertaining needs, difficulties, and issues close to reality. Whereas the PIPA method is not anonymous or iterative and does not allow for validation of the framework defined after the definition of the objectives. The involvement of stakeholders in the process is very important to create an indicator framework that is as close as possible to their objectives and ambitions. Some authors (Londoño-Pineda et al., 2021; Rigo et al., 2020) have shown that the weighting of indicators is important to define or quantify the importance/relevance of the selected indicators to prioritize certain indicators and to strike a balance between different perspectives or objectives. The Delphi process seems to be one of the most adapted. In addition, the 3S method can be a complementary method that the creator of the system of indicators can use to start the selection. The BETA-EvaRIO impact evaluation method combines different approaches to assess research projects. Our proposal will be inspired by the latter. The proposal presented in Sub-section 5.2 combines quantitative and qualitative indicators and assesses not only input-output indicators but also the process and considers activities and interactions between actors.

#### 4.4. Identification of complementary indicators to analyze a network of ILs

Our objective is to provide the means to analyze the territorial impacts of this IL network. In the previous section, the indicators for evaluating territorial impacts were selected. However, it is necessary to have indicators to monitor the evolution of the network in order to adjust its functioning if the targeted impacts are not achieved. In previous studies, some indicators to also assess collaborative network performance were identified (Govindan et al., 2021; Graça & Camarinha-Matos, 2017; Pruvot et al., 2022). Indicators are:

- Related to identifying whether the collaborative success factors are met: communication, management skills, reward, clear and flexible IP policy, environment, membership characteristic, process/structure, purpose, resources, competitiveness, trust and commitment to mutual benefit, value creation, strategic partnership, sustainability, decision-making (Bryson et al., 2006; Draghici et al., 2017; Mattessich & Monsey, 1992; Ramli & Senin, 2021).
- Related to network performance: To assess the network quality some indicators can be used (Graça & Camarinha-Matos, 2017; Pruvot et al., 2022): Number of actors, Number of connections between actors; Density, Types of interactions, Centrality, Reciprocity, Transitivity, Direction, Distance between nodes.

Regarding collaboration or network indicators, very few articles consider the ecosystem or the local territory in their analysis (Pruvot et al., 2022; Seres et al., 2019). Moreover, few publications analyze IL impacts (Bronson et al., 2021). It is for this reason that we will use the indicators identified in the previous section.

## 5. Results

### 5.1. Proposal of a portfolio of indicators to assess a collaborative network of ILs in a territory

The objective of creating a system of indicators is to have a dashboard to follow the evolution of a collaborative network of ILs in a local territory. This battery of indicators is original because none exists in the literature with this combination of collaborative network indicators, impact indicators, and indicators of the development of IL. This reference system should be a support tool for the development of the network of innovation labs and to benefit a local territory (Table 9).

A point of attention brought by (Baslé et al., 2018) to indicators is that they don't always measure the entire impact chain. Indeed, it requires a list of categories that should reflect the specific characteristics of the object being measured (Halla & Merino-saum, 2021). In this case, the nine key dimensions to analyze an IL network on a territory defined by (Pruvot et al., 2022) was used. The large number of indicators in this portfolio could be sorted according to these eight dimensions. The dimensions "objectives of the network" will be considered during the selection of indicators, using the Kano method presented in Sub-section 5.2. In addition, the indicators are also sorted by level of analysis: micro at the IL level, meso at the network level and macro at the territory network level.

This repository of indicators is intended to be adapted to each local territory developing IL networks (Coskun et al., 2022). To adapt it, the use of the approach proposed in Sub-section 5.2 can facilitate this selection. Normally, most indicators from network- or collaboration-related sources are relevant to analyze a collaborative network in any context. Some indicators, identified in Sub-section 4.4, that appear to be similar have been combined. Table 10 in the appendix is the combination of all the indicators selected in the previous parts to monitor the evolution of an IL network in a territory. To use this portfolio, a selection must be made among them using the approach proposed in Sub-section 5.2. Moreover, a thorough analysis must be conducted to identify the appropriate scales for assessing each indicator in the local context.

### **5.2. Proposal of an approach to design a system of indicators**

The approach proposed is an original one because it allows us to consider the stakeholders upstream of the evaluation. This framework will allow public decision-makers to have a global vision of the dynamics created in the territory through the IL network. Phases of selection of indicators must be set up by iteration to obtain an accessible, efficient impact assessment system.

The first phase is to identify indicators in the literature. In this case, Sub-section 5.1 summarizes all the indicators needed in a portfolio of indicators. This simplifies the first step. Then we must consider every stakeholder. Stakeholders are all types of actors present in an innovation lab and in their local territory. The second phase will be to define what the network should address, when the needs of the different actors (Aragonés-Beltrán et al., 2022) can be considered with the Kano method. The (Kano et al. 1984) method was used to define the performance, attractiveness, and basic and neutral needs (ben Rejeb et al., 2008) of the collaborative IL network, by means of a survey with functional and dysfunctional questions. This stage enables us to propose objectives for the network. The third phase is to link indicators, identified in the literature, with needs and expectations. Each indicator will be selected using the questioning method set up by (Mantese et al., 2016) and the needs identified.

Then, the Delphi method or the fuzzy Delphi method can be used to consider the views of all stakeholders. If possible, it is better to use the traditional Delphi method, which is more accurate because there are no approximations, even if the process is longer.

The Delphi process is used when there is no precise information available (Musa et al., 2018). Steps 4, 5, and 6 are to be performed iteratively until a consensus is reached.

The generic and adaptable approach developed is (cf. Figure 6):

1. To take a portfolio of indicators or to identify relevant indicators in scientific literature.
2. Identification of expectations and needs, carried out anonymously (Kano method).
3. Selection of indicators in the portfolio by comparing the evaluation objectives and the needs identified in Step 2. The selection can be supported by the 3S methodology (Mantese et al., 2016).
4. Verification and validation workshop with stakeholders (adaptation of the Delphi process, such as previous work (Beaudoin et al., 2022)) or anonymously.
5. Adapt or refine according to the feedback from previous steps.

## 6. Validation with stakeholders with an anonymous survey.

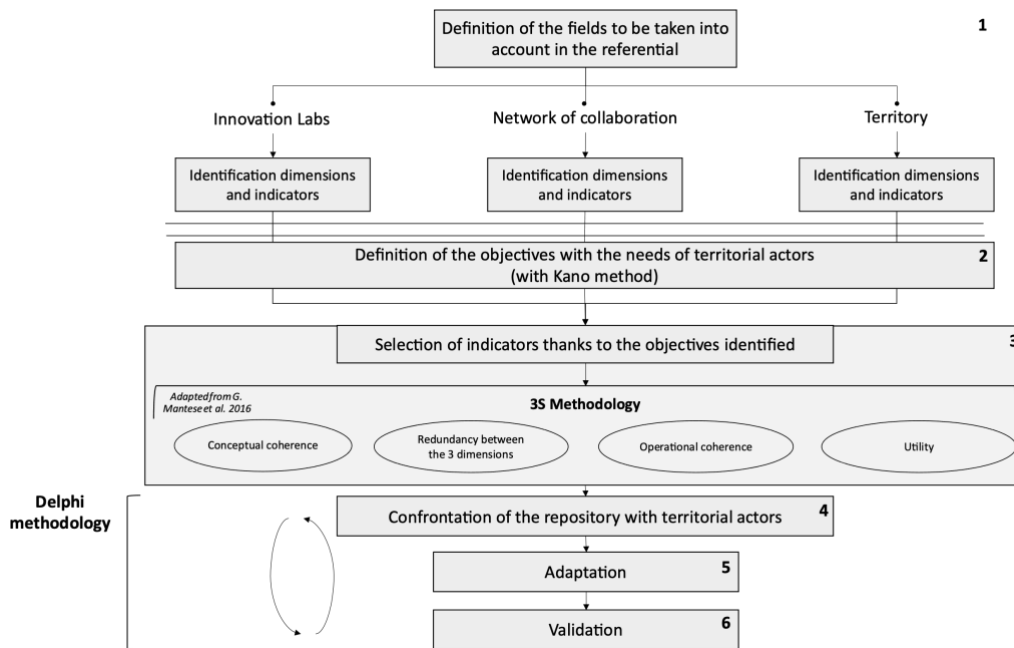


Fig. 6. Generic process for selecting a combination of indicators.

Following this approach, the system of indicators will then be used as a support to carry out case studies and improve the dynamics present in a local territory. This system of indicators could allow us to adapt the functioning of ILs and their network to have an extended optimized impact on the local territory.

When applying this process, certain problems may be encountered. During the application of this approach, the stakeholders may change and thus modify the previously selected indicators. A discussion may be needed to understand previous choices and new inputs from new stakeholders. Another difficulty could be the failure to involve all the stakeholders who are involved in the IL network in the territory. A strategic analysis of the actors can be carried out in order to select the most relevant stakeholders. Moreover, it will be necessary to present in a clear and detailed manner the real benefits that selecting the right indicators can bring to each stakeholder. Furthermore, one person will be needed to manage this process over a long period of time. Indeed, the iteration proposed by the Delphi methodology can be performed over a period of up to six months. However, the shorter the period of time, the easier it will be to implement and the more the selected indicators will be consistent with the current situation.

## 6. Conclusion

### 6.1. Key findings and research implications

The literature review confirmed the initial assumptions. These places can support sustainable territorial dynamics and a network of innovation labs can contribute even more to sustainable development in a local territory. Network analysis is often analyzed in the literature, but few apply this to IL (Memon et al., 2018) and rarely apply it to a local territory to analyze its impacts (Seres et al., 2019). The literature review leads to the proposal of a practical contribution: a portfolio of indicators that will make it possible to analyze the operation of the network and the network's impact on ILs and the local territory. We assume that this portfolio will help the evaluation team to save time both when selecting indicators and when analyzing an IL network in its territory. To help evaluators to select the relevant indicators in the portfolio and thus correctly analyze their network, a selection process has also been developed. This process has the specificity of considering the stakeholders involved in the network.

Once this selection has been made, the evaluation scales for each indicator need to be defined to create a system of indicators. Through this system of indicators, the evaluation team could see if these ILs are less in competition and more open to sharing or whether or not their service offerings are of better quality (Memon et al., 2018). This system of indicators will allow the members of a network to assess their method, their functioning, and their results. It will allow them to identify the weak points to work on to improve the collaboration. This first result highlights other questions that need to be answered, such as: How do you operationalize a collaborative network? How do you collect information? Which actors should use the framework?

## **6.2. Limitations and discussions**

The main limitation of this article is that it is still very theoretical, even if this thorough analysis of the literature has identified all the necessary elements to be considered. The next phase will be the application of all these proposals to strengthen our own proposal and identify potential improvements to be made.

Moreover, some keywords may have been omitted and therefore some indicators may be missing. Because of the combination of three areas of analysis, a selection of indicators had to be made so that there would not be too many indicators.

Another limitation is that the basis is not operational yet; there are some elements which need further research to determine how to measure certain indicators or to know which indicators are the most suitable.

The limitations are:

- After the selection of indicators, the system of indicators needs to be validated by confirming that no element has been omitted and that the resulting analysis is representative of a network of innovation labs supported by collaborations.
- Moreover, the system of indicators must be accompanied by an operational approach to implement the evaluation.
- Currently, the portfolio proposal includes many indicators, so it may seem a little fuzzy. The literature review phase having been completed, future managers will be able to pick and choose from this selection to analyze their network. In fact, our literature review has enabled us to identify an initial selection of indicators that could potentially be applied in the case of an IL network in a territory. To facilitate the use of these indicators, they could be sorted according to their objectives. However, we have not yet tested this portfolio and this approach, so there may be unforeseen circumstances.
- Once the relevant indicators have been selected, evaluators will need to define the scale for measuring/evaluating each of them. Identifying them could be part of future research.

The originality of our portfolio is that it combines three levels of analysis. However, this feature can become a weakness, as it requires a lot of data and can therefore be difficult to implement. The richness of this portfolio makes it highly generic and therefore applicable in a variety of contexts. This article may seem highly theoretical, but it provides a starting point to speed up the implementation of future network analysis.

## **6.3. Future Research**

The lifespan of these places is scarcely treated in the literature. It would be interesting to identify the causes of failure, or closure of these places. There are often questions about the weak sustainability of these organizations but there is little in-depth analysis to understand these phenomena. Even the authors who address this subject do not clearly establish the average lifespan, the survival rate of these places, the triggers, etc. (Mastelic et al., 2015; Ondiek & Moturi, 2019). The system of indicators could help to understand these phenomena and networking ILs could allow them to be more complementary and thus have a longer lifespan.

Further analysis may show that a network could facilitate the creation of sustainable business models and address other issues (lack of local resources, lack of space, human resources, funding, etc.).

Further research is needed to demonstrate that the definition of indicators for monitoring the functioning of a network of ILs would enable the creation of small-scale dynamics. Some additional research needs to be conducted to define how to evaluate subjective indicators (trust, involvement, satisfaction, communication, etc.).

Moreover, scientists have shown that when there is interaction and innovation between the private and public sectors and civil society, this leads to systemic innovation processes (Bevilacqua et al., 2020). These ILs are places where these types of interactions exist. The use of a system engineering approach or representation would be

relevant. The dashboard which represents the evaluation results needs to be accessible to all types of actors, for example derived from system dynamics (Chen et al., 2018; Graça et al., 2019).

It would also be interesting to apply this framework on a local-scale dynamic. To see if this model allows us to manage and maintain an IL network in a local territory.

Further research is also needed to define the characteristics (structure, good practices, etc.) of a network with the expected impacts on the territory. Moreover, further research will be necessary to create a tool, approach, and methodology to develop interaction between innovation labs and to implement and operationalize the collaboration.

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## 9. Appendices

### Appendix 1

Table 9: Example of Innovation Labs which address the five concepts.

Sustainable territorial development concepts (5 concepts)	Sources	Example of ILs that address the concepts
<b>Circular Economy (CE)</b>	(Prendeville et al., 2017)	Fab Lab London, Buda::lab
	(Tyl & Allais, 2021)	RECYLUSE
	(Weber & Heidelmann, 2019)	Sustainability innovation lab: Sustainable Canteen
	(Del Vecchio et al., 2017)	20 Living Lab City of the Future Living Lab; Cortereggio; Cross-Border Living Lab on Territorial Marketing (CBLTM)...
	(Engez et al., 2021)(Turku et al., 2022)	Hiedanranta Urban Living Lab (2 sources)
	(Cantù et al., 2021)	The Circular Living Lab
	(Cuomo, 2022)	U- Lab; RePair; proGiReg; Stapeln living lab
	(Meath et al., 2022)	The Infrastructure CoLab (ICL)
	(Coskun et al., 2022)	Circular Maker Space (Project Pop-Machina)
<b>Social environmental awareness: mediation, education</b>	(Helal et al., 2017)	Monastir Living Lab
	(Fasoli & Tassinari, 2017)	Roma Makers
	(Meister Broekema et al., 2022)	Public Sector Labs
	(Braun et al., 2022)	Social Labs
	(Callaghan & Herselman, 2015)	Living Lab for Innovative Teaching Research
<b>Environmental conservation: multidisciplinary issues, sustainable innovations</b>	(Pugliese et al., 2021)	Isar River Restoration
	(Zermeno & Alemán de la Garza, 2020)	OPENLAB_SI
	(Zivkovic, 2018)	Systemic Innovation Lab
	(Turku et al., 2022)	Hiedanranta Urban Living Lab
	(Arnould et al., 2022)	Forestry Living Labs
<b>Governance sustainability focus</b>	(Bevilacqua et al., 2020)	MONUM
	(Ascione, 2021)	proGReg Living Lab
	(Bulkeley et al., 2016)	Governing the city through ULL
	(Rehm et al., 2021)	Urban Living Labs
<b>Spatial planning sustainability focus, Sustainable cities</b>	(Dupont et al., 2014)	La Fabrique
	(Nevens et al., 2013)	Urban Transition Labs
	(Larios et al., 2016)	UDG Living Lab
	(Leminen et al., 2017)	Third-Generation Living Lab Networks
	(Rodrigues & Franco, 2018)	Cova da Beira Living Lab was
	(Cerreta et al., 2020)	SSMOLL
	(Bartelt et al., 2020)	Denver Living Lab
	(Turku et al., 2022)	Hiedanranta Urban Living Lab

## Appendix 2

Table 10. Portfolio of indicators: list of relevant indicators to evaluate the functioning of a network of ILs in a territory (to be adapted to each context).

Level	Indicators	Description	Source theme
MICRO / MESO	Quality of communication	Evaluate how communication is perceived	Collaboration
		Level of knowledge of other innovation labs (location, equipment, key competencies...)	
MICRO / MESO	Types of exchanges	Number of shared materials and frequency	IL, Collaboration
		Number of shared spaces and frequency	
		Formal or informal exchanges	
MICRO / MESO	Inspiration	Measured by the number of new ideas that have emerged between 2 or more network members and the attractiveness of the network	IL
MICRO / MESO	Consistency	Level of consideration of the "operating" cycles of each of the innovation labs	IL
MICRO / MESO	Satisfaction	Level of satisfaction with the contribution of the other IL	Network
MICRO / MESO	Involvement	Level of involvement in the network	Network
		Level of satisfaction with this involvement in the network	Arnstein's Ladder 1969
MICRO	Direct relations	Number of direct relationships with actors X	Network
	Indirect relations	Number of indirect relations with actors X	Network
Number of intermediaries in exchanges with actor X			
MICRO	Reciprocity	Number and types of resources shared	Network; Collaboration
		Number and types of resources received	
MICRO	Innovation Process	Level of definition of the stages of the innovation process	IL
MICRO	Resource management	Number of resources reused, between members	CE; Target SDG 12.2 ;12.4 ; 12.6 ; 11.5 ; 11.6
		Quantity of waste	
		Number of recycling materials	
		Type and quantity of resource exchanges	
MICRO	Reputation of the space	Number of users of the space	IL
		Means of communication of IL	
		Level of user satisfaction with the IL's service offering	
MICRO	Financial resources	Amount of resources of each innovation lab for the network	Collaboration
		Amount of financial resources shared within the network	Target SDG 8.4 CE
MICRO	Markets	Number of new markets reached by members through the network	IL, Territorial development
MICRO	Experience	Number of collaborations carried out and description of their progress	Collaboration
MICRO	Network / Openness	Number of other networks in which the innovation labs are involved	IL
		Level of openness of the innovation lab	
MICRO	Production	Number of innovation projects carried out within the network	IL, Collaboration
MESO / MACRO	Citizen involvement	Level of citizen involvement in the network's activities	Target SDG 12.7 ;12.8 IL
MESO	Allocations	Evaluates the distribution of roles and responsibilities	Collaboration
		Level of clarity of each person's responsibilities	
MESO	Objectives	Level of definition of shared objectives and values	Collaboration
MESO	Innovation process	Level of definition of the steps of the innovation process within the network	Collaboration
MESO	Management	Number of projects that meet the deadline	Collaboration
		Number of projects within budget	
MESO	Projects	Number of projects developed in relation to sustainable energy production and consumption	

		Number of projects promoting biodiversity, soil protection, forest adaptation to climate changes (to preserved ecosystem services)	Target SDG 6.4; 7.3 ; 7.A, 9.1 ; 9.2 ; 9.5 ; 11.2 ; 11.3 ; 11.5 ; 11.6 ; 11.7 ;
		Number of projects on ocean exploitation and on marine technology	13.1 ; 13.2 ; 13.3 ; 14.a ; 15.1 15.2 ;
		Number of innovative projects to mitigate climate change	15.4
MESO	Dynamics	Number of people entering and leaving the network	Network
MESO	Contribution	Number of new relationships/collaboration opportunities created through the network	Target SDG 17.17
MESO	Financing	Amount of funding received for the network thanks to interactions between members	Network CE
MESO	Governance	Presence of a pivotal structure	Collaboration
		Adequacy of governance with members' expectations	
MESO	Policy	Formalized rules: for the management of results (IP), for the distribution of roles (flexibility and adaptability)	Network, Collaboration
MESO	Decision-making	Use of decision support tools	Collaboration
		Variety of actors in decision-making	
MESO	Frequency of exchanges	Frequency of exchanges within the network	Network, Collaboration
		Intensity of exchanges	
MESO	Projection	Ambition of the network defined at 1 month, 6 months, or 2 years	Network, IL
MESO	Common identity	Level of definition of the common ambition	Collaboration
		Level of consensus	
MESO	Entry and exit strategy	Defined process of network entry and exit	Network
MESO	Coherence	Level of consideration of individual strategic intentions	IL, Collaboration
MESO	Sharing	Number of ways to share knowledge and experience between members	Collaboration,
		Frequency of sharing knowledge, competencies, skills between members	SDG 17.6
		Types of sharing resources made available	Collaboration,
		Level of satisfaction with knowledge sharing among network members	Collaboration
MESO	Production	Promotes the creation of knowledge about climate change (recycling, biodiversity...)	Target SDG 13.1 ; 13.2 ; 13.3
MESO	Human	Valuation and sharing of human resources in innovation labs	IL, Collaboration
MESO	Trust	Measuring the level of trust between the ILs	Collaboration
MESO	Conflict management	Number of conflicts encountered	Collaboration
		Number of conflicts resolved	
		Means of conflict resolution	
MACRO	Territorialization	Level of integration of the network in the territory (integrated policy, distributed production, territory, and similar network strategy, filière development...)	Territorial development
MACRO	Social development	Number of innovation projects involving citizens	Target SDG 4.7 ; 17.6 ; 11.3 ; 9.1
		Number of projects that improve the well-being of citizens	
MACRO	Sustainable urbanization	Number of innovation projects related to sustainable and resilient infrastructures developed within the network	Target SDG 7.3 ; 11.2 ; 11.3 ; 11.5 ; 11.6 ; 12.6 ; 9.1 ; 12.2 ; 12.4 ; 12.6 ; 12.7 ; 12.8 ; 9.1
		Number of abandoned infrastructures redeveloped	
		Number of projects related to supporting clean energy research and development and renewable energy production	
		Number of projects on water-use efficiency	CE
MACRO	Impacts	Promotes the development of a resilient territory: innovation, anticipation, prospection, adaptation	Target SDG 9.1
MACRO	Territorial attractiveness	Number of partnerships with sustainable and/or inclusive industries	Target SDG 9.2 ; 9.5
		Number of new events organized in the territory	Territorial development
		Number of newcomers to the territory in the network	
MACRO	Economic development	Number of new jobs, new companies/startups created...	Territorial development SDG 8.2 ; 8.3

MACRO	Politics	Level of integration of public decision-makers and public policies in the projects	Target SDG 8.3 ; 13.2
MACRO	Openness	Frequency with which the network opens to the territory	Territorial development, Network, IL
MACRO	Territorial strategies	Level of knowledge of territorial strategies	Territorial development
MACRO	Knowledge sharing	Number of training courses supported by the whole network for all actors of the territory	Target SDG 12.2 ; 12.4 ; 12.6 ; 12.7 ; 12.8 ; 4.7 ; 17.6
		Number of mediation events, awareness of the environmental impacts of cities or awareness of issues related to sustainable consumption and production	11.3 ; 11.5 ; 11.6