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Living Labs in science-industry collaborations: Roles, design, and application patterns

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ABSTRACT

Living Labs (LLs) are now well-recognized in the development and commercialization of science—that is taking emerging discoveries from research labs to the industry. Whereas their widespread interest seems encouraging, it has been complicated by some inconsistencies regarding what LLs actually are, what types of activities they (should) support, and under what conditions. We conduct a meta-synthesis of 41 LL application patterns, supplemented by an in-depth empirical case study—the application of a MedTech LL in healthcare—to examine effective practices for organizing collaborative innovation within the science-industry nexus. By studying what worked best and under what conditions, we present a typology of eight design elements that underlie four unique LL models. Our analysis reveals that although these different models do fit under the same umbrella concept, they vary in the roles they serve in the collaborative innovation process. Most notably, we find that organizations need to navigate between these models as the collaboration moves from idea inception into impact. Our results offer relevant insights for understanding new forms of organizations for science-industry relations. We discuss practical implications for LL managers, researchers, and sponsoring institutions and conclude by outlining promising areas for future research.

1. Introduction

The journey from research labs to the market is replete with challenges and complexities. While many scientific discoveries, such new technologies, novel drug compounds, or new concepts with potential commercial applications may emerge from research laboratories, successfully transitioning them into viable, customer-facing solutions is a multifaceted process (Haessler et al., 2022) that is shaped by the (inter) actions of different agents, including entrepreneurs (e.g., scientific researchers and specialists), industry actors (e.g., businesses and investors), and intermediaries (e.g., technology transfer offices, business incubators, and science parks) (Johnson et al., 2022). To streamline this process, organizations have expanded the ways in which they engage with researchers and entrepreneurs (see e.g., Clayton et al., 2018; Doorn et al., 2014). Setting up living labs (LLs) is a relatively recent, yet promising approach that organizations have begun using to help bridge the science-industry nexus.

Broadly defined as user-centered innovation ecosystems,[1] LLs represent physical or virtual *spaces* for co-creating, testing, and validating *user-driven* innovation under presumably *realistic conditions* (Della Santa et al., 2022; Følstad, 2008; Osorio et al., 2019). Their attractiveness stems not just from their emphasis on the “end-user”, but also from their potential to foster stronger interactions and partnerships across the science and business community (Huang and Thomas, 2021). At best, they enable researchers and industry actors to work together to identify mutual interests, tackle emerging societal/business-related challenges, and conduct joint projects with practical applications and real-world impact (e.g., Schuurman et al., 2016). At worst, they represent another approach for structuring and promoting open innovation activities (Paskaleva and Cooper, 2021).

As of 2024, the number of LLs stands over 480 worldwide and has been steadily rising over the past decade.[2] They have been traditionally supported by universities and research institutions, as well as independent research hubs (e.g., Fritzsche, 2020) in an effort promote user-centric solutions through altering the distribution of roles and responsibilities between stakeholders in the innovation process (Huang

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[1] The general definition proposed by the European Network of Living Labs (ENoLL): https://enoll.org/.
[2] European Network of Living Labs (ENoLL): https://enoll.org/.

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and Thomas, 2021; Leminen and Westerlund, 2019). More recently, LLs have become increasingly popular among industry actors, such as corporate accelerators, technology companies, and business centers, as a way to support the development and commercialization of promising discoveries (e.g., Haukipuro et al., 2019). On a larger scale, entire cities have been framed as LLs. The city of Calgary, Canada, for example, has turned much of its public spaces (e.g., industrial lands, transportation corridors, and fiber networks) into experimental LL platforms to "*help entrepreneurs bring big ideas to fruition.*[3]" Despite their proliferation, empirical and theoretical knowledge on LLs in the context of science-industry collaborations remains scarce and loaded with inconsistencies over what might be called a "Living Lab", which activities they (should) support, and under what conditions.

To date, the literature has addressed a variety of research questions pertaining to their defining features and characteristics (Dell'Era and Landoni, 2014; Van Geenhuizen, 2018), the types of services they provide (Schuurman et al., 2019; Thees et al., 2020), and their unique contribution to the innovation process (Dekker et al., 2020; Schuurman et al., 2016). While informative, this research does not go in-depth on how to actually organize and manage collaborative innovation activities in such spaces (Akasaka et al., 2023). As Hossain et al. (2019) point out in a recent review of the literature, "*stakeholders wishing to set up a living lab and its activities, as well as firms considering developing one, find limited reference models for developing and managing a living lab*." (p. 986). As a result, the design of these interaction spaces has been mostly considered a "trial and error" process rather than a systematic and professionally-managed endeavor (Perez Mengual et al., 2023).

The purpose of this paper is, therefore, to explore *how organizations can design and manage LLs in science-industry collaborations.* Our point of departure is practice-oriented, yet theoretically-driven—we want to understand the different approaches in which innovation activities can be organized in a LL format; that is through open innovation principles with a strong emphasis on user-centric solutions and real-use product development/testing. While the application of LLs is not solely limited to the development and commercialization of science (e.g., Chronéer et al., 2019), we focus particularly on their application in such context given both, the considerable resources invested to align science and development efforts with pressing innovation challenges (Sarpong et al., 2023), as well as the pertinence of the LL model for taking innovative ideas from research labs to the market (Engels et al., 2019; Schuurman et al., 2019).

To this end, we engage in a meta-synthesis of 41 LL applications in science-industry collaborations. A meta-synthesis is a systematic integration of qualitative research evidence to gain a more comprehensive insight on a contemporary organizational phenomenon (Hoon, 2013). The design elements that emerged from these studies are synthesized and grouped into four LL models, each underpinned by a unique value proposition driving their roles and application patterns in the innovation process. This analysis is further substantiated by an empirical case study (Siggelkow, 2007) tracing the evolution of a MedTech LL in Montreal, Canada as it navigates between models to facilitate the collaboration between researchers and industry actors. This empirical illustration allows us to draw concrete conclusions on the distinctive features of each LL model described in the literature and introduces a dynamic dimension to our organizational design framework.

In doing so, we complement recent discussions on new actors and forms of organizations in science-industry relations. First, we present LLs as a promising approach for coordinating collaborative innovation within the science-industry nexus. We categorize their diverse application patterns under coherent models, providing a foundation for future research to explain variations in the innovation outcomes emerging from LLs (Schuurman et al., 2016), thereby addressing some of their core criticism in the literature (Paskaleva and Cooper, 2021). Second, we respond to recent calls to acknowledge the heterogeneity in approaches for supporting the development and commercialization of science (e.g., Clayton et al., 2018; Li-Ying et al., 2022) by illustrating the different kinds of spaces needed to facilitate productive interactions between research-based and business-driven communities. Third, we advocate for a more adaptive and responsive approach for (re)designing intermediary spaces for addressing emerging innovation-related challenges (Agogué et al., 2013), complementing the static portrayal of such spaces in the literature (Osorio et al., 2019; Perez Mengual et al., 2023).

2. Theoretical background

2.1. The logic behind "Living Labs"

Over the past decade, LLs have been increasingly recognized for their potential to address the challenges (and frequent failures) of science commercialization that often struggles to move beyond basic research and development stages (Leminen and Westerlund, 2019; Van Geenhuizen, 2013)—a phenomenon often exemplified by the "valley of death" metaphor (Auerswald and Branscomb, 2003). They are premised on the belief that the real value of innovation is not in superior technical qualities, but rather in their alignment with the needs, capacities, and aspirations of end-users (Veeckman et al., 2013). This resonates strongly with the broader concept of innovation ecosystems, which acknowledge "*that concerted action by a group of actors may be needed for an innovation to create value in the eyes of the users.*" (Baldwin et al., 2024, p. 2). Yet, LLs tend to be more confined to a specific geographical region, industry, or institution where experiments and co-creation activities can occur. Recognizing the importance of the demand-side of innovation, studies have also employed similar approaches to explore the interplay between science and industry with notable work on "triple-helix" (and later "quadruple-helix") framework (cf., Etzkowitz and Leydesdorff, 2000; Miller et al., 2018), open-innovation networks (Beck et al., 2022), and smart city governance (Mora et al., 2023).

A very useful aspect of this literature has been the recent focus on innovation intermediaries, such as technology transfer offices, accelerators, and science parks as a way to facilitate multistakeholder collaborations (Clayton et al., 2018; Siegel et al., 2023). Consistent with open innovation principles, which reflect the process of managing the knowledge flows within and across organizational boundaries (Chesbrough, 2007; Chesbrough et al., 2018), these intermediaries "*facilitate the identification of external knowledge providers and make external knowledge accessible*" (Agogué et al., 2017, p. 20) by providing dedicated spaces for researchers and (academic) entrepreneurs to co-create innovative solutions (e.g., products, services, and technologies) together with end-users, suppliers, and other industry actors (Binz et al., 2014). In effect, such spaces now play a crucial role in shaping collaborative innovation efforts (Klooker and Hölzle, 2024) and scholars have attempted to discern their unique contributions to the dynamics and outcomes of the innovation process (Leminen et al., 2024; Yström and Agogué, 2020).

At the most basic level, LLs represent experimental, co-creation spaces for organizing open innovation activities around concrete challenges (Del Vecchio et al., 2017; Leminen et al., 2020). They are essentially designed to allow real-time development based on active learning and user feedback (Engels et al., 2019). In contrast to other forms of co-creation spaces, such as testbeds, FabLabs, or Maker Spaces, LLs focus less on physical tools and machineries, and more on multidisciplinary collaborations and joint research and development initiatives (Fritzsche, 2020). While their application has not been limited to technology transfer (i.e., bringing promising discoveries to the market), their emphasis on the needs, preferences, and concerns of end-user has been key for reducing the risks associated with advancing innovation that may not eventually find market acceptance (e.g., Leminen et al., 2017; Nesti, 2018).

[3] https://www.calgary.ca/general/living-labs/living-labs.html.

2.2. Living Labs in practice

Despite the apparent similarity among the various conceptualizations of LLs in the literature, they have shown to be anything but clear in practice. The term was first presented to practitioners simply as a way of developing new customer-facing solutions through user involvement (Bergvall-Kåreborn et al., 2009; Lehmann et al., 2015). Early attempts to implement this approach have resulted in technologies being developed separately by researchers and then tested by users in a well-designed real-use environment (Ballon and Schuurman, 2015; Schuurman, 2015). Whereas users were in fact treated as key components in the innovation process, their role has remained rather passive and mostly relevant in later stages, such as in testing and validation[4].

Over time, the concept was further developed into a more detailed methodology for managing and structuring open innovation activities (Edwards-Schachter et al., 2012; Veeckman et al., 2013). This has motivated the launch of the European Network of Living Labs (ENoLL) in 2006 as a European-led initiative to promote the concept of LLs and facilitate its diffusion around the globe. As they became more popular, they have inspired a surge of interest across disciplines leading some scholars to label the phenomenon as the "Living Lab movement" (e.g., Hossain et al., 2019; Huang and Thomas, 2021) that is fueled by a proliferation of studies with the sole purpose "*to frame concepts about LLs and set them into action*" (Leminen and Westerlund, 2019, p. 251), prompting calls for more rigorous evaluation and monitoring criteria (see e.g., Paskaleva and Cooper, 2021).

While research suggests that the way these labs are organized internally influences how the collaborative innovation process unfolds (Schuurman et al., 2013; Van Geenhuizen, 2018), efforts to relate different LL applications with underlying innovation outcomes has remained largely descriptive and exploratory in nature (Hossain et al., 2019). We, thereby, build on and complement this work by proposing an organizational design framework to study LL applications in science-industry collaborations. This framework is particularly suited for unpacking the diversity of organizational models used to manage collaborative innovation activities and distinguish the value that each provides to the stakeholders involved (Pauwels et al., 2016).

2.3. An organizational design lens for studying Living Labs

Organizational design is simply a framework for explaining how entities organize their activities, processes, and communication patterns to achieve a desired outcome (Greenwood and Miller, 2010). The renewed interest in organizational design within innovation management studies stems from the prevalence of highly distributed forms of innovation governance that transcend individual organizational boundaries (Ollila and Yström, 2016). Consequently, researchers have increasingly turned to organizational design as a lens to study emerging forms of co-creation spaces and outline their roles, activities, and practices (e.g., Osorio et al., 2019; Perez Mengual et al., 2023), offering a fresh perspective on the range of intermediaries operating within the science-industry nexus (Siegel and Wright, 2015).

In line with this research, we draw on Zott and Amit's design framework (Zott and Amit, 2010, 2013; Zott et al., 2011) as our starting point for studying the application of LLs in such context. According to Zott and colleagues, two main design parameters define how organizations structure their activities: (1) *design elements*, which describe an organization's architecture in terms of its content (i.e., the selection of the activities), structure (i.e., the link between them), and governance (i.e., the roles of key stakeholders involved), and (2) *design themes*, which are distinct configurations of design elements that depict how these elements can be connected based on a given value proposition (Fig. 1). The integration of design elements into coherent themes illustrates how different LL models help create and capture value in the innovation process.

Indeed, similar design frameworks has been used to study different forms of intermediaries involved in supporting innovation-related activities, including accelerators (Cohen et al., 2019), incubators (Bruneel et al., 2012), science parks (Ng et al., 2019), and more broadly physical interaction platforms (Perez Mengual et al., 2023). Despite the significance of organizational design for distinguishing LL application patterns and justifying their impact on the innovation process (Dell'Era and Landoni, 2014), this view has not led to an abundance of studies at the intersection between both streams of research (Hossain et al., 2019).

3. Research method

To this end, we start by reviewing the literature on LLs in science-industry collaborations with a particular emphasis on their defining features, distinguishing characteristics, and envisioned outcomes. We considered a range of possible approaches to make sense of the range of available LL applications and opted for a meta-synthesis for the purpose of this study as it seemed to offer the most productive way forward (Hoon, 2013). A meta-synthesis is a form of literature review that involves using qualitative studies developed by other researchers as our main source of data and synthesizing the main themes and issues that emerged from the authors' own description of these studies (Dixon--Woods et al., 2004; Sandelowski et al., 1997). The "aggregation of qualitative studies" can therefore result in the construction of larger narratives and more generalizable models for explaining a certain phenomenon than those obtained from any single study (Simpson et al., 2013). Given the constraints that are typically prevalent in developing a set of examples that is large enough to allow policymakers and practitioners to evaluate and compare different LL applications, a meta-synthesis was deemed appropriate for "putting together" empirical insights on what worked, what worked best, and under what conditions. Table 1 provides a summary of our research design, combining both a meta-synthesis for deriving overarching LL models and an empirical case study for illustration.

Step 1 - Identifying relevant papers: We started with a preliminary search in the Web of Science (WoS) database for studies containing either the term "living lab*", "innovation lab*", "test beds", or "real world laboratories" in the title, the keyworks, or the abstract. These terms are all used (often interchangeably) to denote experimental, user-centered approaches to innovation management under real-world testing conditions (Engels et al., 2019). This initial search yielded a total of 637 contributions. With the absence of a unified definition of LLs and the plurality of meanings embedded in the term (Leminen and Westerlund, 2019), we considered LLs as intermediary spaces designed to facilitate the co-creation of innovation-driven solutions involving users and other relevant stakeholders under presumably realistic conditions.

As we became more familiar with this literature, we started to detect relevant terms that were also used to denote similar co-creation spaces dedicated to supporting science-industry collaborations (e.g., Fritzsche, 2020; Leminen et al., 2024; Perez Mengual et al., 2023). Accordingly, we performed another search involving related keywords, including: "university-industry lab*", "Do-it-yourself science", "DiY science", "science--based open-lab*", "company-university lab*", "innovation ecosystem hubs", and "collaborative innovation workplaces". All these terms have been well-recognized in the literature on technology transfer (Adegbile et al., 2021) and have been also used for studying the relations between researchers and industry actors (Hu and Fritzsche, 2021). This search further resulted in 21 additional papers.

[4] Schuurman (2015) labelled these early labs as "American Living Labs" where the focus is mostly on the infrastructural aspect which is modeled on based on a real living environment and users are studied in this environment, which can be considered natural but not real.

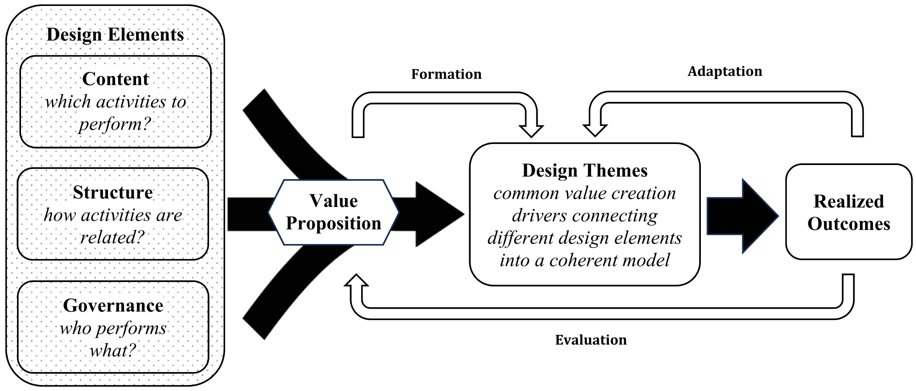

Fig. 1. An organizational design framework for studying the application of Living Labs.

In order to ensure we covered appropriate data material to capture different applications patterns of LLs in science-industry collaborations described in the literature, we complement this basic search by cross-reference checking the sample of articles that were covered in recent reviews on the topic (i.e., Akasaka et al., 2023; Bronson et al., 2021; Dekker et al., 2020; Hossain et al., 2019; Paskaleva and Cooper, 2021; Sarpong et al., 2020). Four more articles were identified that had not already been covered by our database search, resulting in an initial sample of 662 papers.

Step 2 - Inclusion criteria: For any paper to be considered relevant to our study, it must (1) focus on one or more LLs as the main unit of analysis; (2) provide sufficient details on the key characteristics of the LL under study, including its purpose, underlying activities, and operations; (3) address their usage in the context science-industry collaborations, and (4) discuss how the collaboration was accomplished or is expected to be accomplished within a LL format. By applying these basic criteria, we manually screened the abstracts, introductions, and methods (if the introduction made no references to the method used), and automatically excluded studies that were either quantitative or purely conceptual in nature and studies that use the term LLs (or its derivatives) as examples to explain other phenomena, such as open-innovation or co-creation. This initial screening generated a sample of 88 potentially relevant publications.

We further engaged in a second round of screening to exclude studies that (1) do not address the application of LLs in the context of science-industry collaborations or (2) do not provide the basic information to make judgement about the activities, outcomes, or innovation project being carried out in the LL. This refined screening resulted in the exclusion of 58 papers, which mainly focused on the application of LLs in other innovation-related context, such as in generating creative solutions to address urban design planning (Van Waes et al., 2021), preserving a city's cultural heritage (Cerreta et al., 2020), or tackling social integration challenges (Dekker et al., 2021) that do not necessarily require the involvement of both researchers and actors from the industry. Consequently, our final sample comprised of 30 pertinent papers, covering 41 LL application patterns. Fig. 2 illustrates the sample development and selection process. Appendix A provides a journal breakdown of our sample papers.

Step 3: Description and validation: The content of the assembled studies was then analyzed to identify key parameters (i.e., design elements and underlying configurations) that distinguish one LL application from another. For this purpose, we developed a standardized database to describe and compare each of the LLs covered in our sample. This was managed using Microsoft Excel, with each application assigned to a specific row and the columns containing relevant LL description.[5] While not unique to the context of science-industry collaborations, there was often limited information about the effectiveness of each LL approach. This was partly due to the absence of established indicators to monitor the actual performance of LLs in relation to defined innovation outcomes (see e.g., Paskaleva and Cooper, 2021). However, one aspect that made a meta-synthesis particularly helpful to our objective is that all studies described successful (and often ideal) examples of LLs and thereby, have been presented as best-practices to managers and policymakers for structuring collaborative innovation activities. Hence, our selected studies provided an opportunity to learn from these LL applications. Appendix B provides a description of all the 41 LL applications covered in our study.

Consistent with qualitative research best practices, all studies included our sample explicitly report a detailed description of each LL, the methods employed for gathering and analyzing data, and the major findings (with respective contributions). Not surprisingly, almost all papers rely on interviews with key stakeholders, including project managers, researchers/entrepreneurs, user participants, and to a lesser extent the sponsoring institutions (e.g., Nguyen and Marques, 2022). Some influential studies also reflect on the authors' own involvement in the LL project (e.g., Logghe and Schuurman, 2017), providing an insider perspective into the dynamics of LL activities. While the bulk of this literature remains centered around Europe, accounting for approximately 90% of the sample, there is a noticeable emergence of studies exploring the application of LLs in other regions, such as South America and Africa.

However, most of these studies focus mainly on one specific aspect of a LL's design structure, such as the role of end-users (Almirall et al., 2012; Leminen et al., 2014), the importance of enabling spaces (Della Santa et al., 2022), and its broader strategic orientation (Engels et al., 2019). Even the few studies that seem to investigate the application of LLs more holistically (e.g., Van Geenhuizen, 2018) do not go far to outline the realized innovation outcomes. This concern was also echoed by other scholars in their critical analysis of this literature (e.g., Hossain et al., 2019; Paskaleva and Cooper, 2021).

Step 4: Identifying key design elements: At this stage, we began examining the available data for each LL by noting the type of projects

[5] Details include a LL's: name, country of origin, year established, mission statement, industry or sector in which it operates, sponsoring organization(s), and outcomes achieved (if applicable).

Table 1
Research design: Living Lab models in science-industry collaborations.

	Purpose	Description	Key Activities
Step 1: Identifying Relevant Papers	Establish an initial sample of relevant studies from the literature	Gathering a comprehensive set of literature on the applications of LLs in the context of science-industry collaborations	Conducted a preliminary search in the Web of Science database using related terms; Refined the search through additional keyword searches and cross-reference checks
Step 2: Inclusion Criteria	Ensure that only relevant studies are considered in the analysis	Defining a specific set of criteria or guidelines for selecting papers to include in the meta-synthesis	Screened papers to exclude studies that were quantitative or purely conceptual, as well as those examining a different phenomenon or the same phenomenon but in contexts unrelated to science-industry collaborations
Step 3: Description of each LL application	Provide a detailed overview of each LL in the sample	Documenting the characteristics, methodologies, and purpose of individual LL applications	Developed a standardized database to describe each LL application as a basis for subsequent analysis
Step 4: Extracting design elements	Identify the main building blocks of the LL model	Analyzing the content of assembled studies to outline key elements distinguishing one LL application from another	Defined key design elements that are general to all innovation-support organizations (e.g., founding purpose and sponsors); Integrated elements that are specific to LLs (e.g., user involvement, services, and membership)
Step 5: Analyzing application patterns	Derive overarching LL models	Synthesizing the different design elements from various LL applications into common themes, each based on a unique value proposition	Categorized different LL applications based on their founding objective; Linked each objective to one of the four stakeholder categories introduced by Leminen et al. (2012); Defined a value proposition for each category; Integrated the content of the design elements under each value proposition
Step 6: Validating design parameters	Enhance the credibility of the LL design framework	Gathering the perspectives of experts and researchers to validate key LL design parameters (i.e., elements and themes) that emerged from the meta-synthesis	Consulted experts and researchers on LLs for validation and feedback; Presented research findings at conferences and workshops
Step 7: Empirical case study - iTMT	Provide an empirical illustration of LL application patterns	Complementing the broader findings of the meta-synthesis by illustrating how collaborative innovation can be (re) designed in LLs	Conducted a case study tracing the evolution of a MedTech LL in healthcare; Described how it was actively (re) designed in response to emerging needs and priorities in the innovation process; Outlined key challenges for organizations implementing LLs in healthcare

they support, the roles they assume in the innovation process, and their governance structure. Our objective was to identify the specific characteristics that make it possible to distinguish one LL application from another. We started our analysis by identifying the founding purpose (value proposition) for each of the 41 LLs covered in our sample. For example, the objective of the KTH Living Lab is *"to open up buildings for real-life experiments, conduct research projects, and share validated results with different decision makers in order to accelerate innovation and change"* (Molinari et al., 2023) and that of UNaLab is to "*develop smarter, more inclusive, more resilient, and increasingly more sustainable societies through innovative nature-based solutions*" (Chronéer et al., 2019).

Once objectives were defined, we began identifying the main sponsoring institutions that govern (fund or manage) these LLs. These sponsors typically comprised of universities, research institutions, consulting firms, local municipalities or a partnership between these actors. We also noted whether each LL relied predominantly on project-based funding with a specific timeframe or had established mechanisms for long-term sustainability, such as revenue-generating activities, partnerships, or diverse funding sources for supporting an ongoing project portfolio. This aspect was pivotal for understanding the governance aspect of the LLs.

We then turned our attention to content of the assembled LL applications, focusing on the nature and stage of the innovation projects being carried out (e.g., basic research/validation, development, and/or implementation/commercialization), the services offered by the LL for supporting these projects, and the manner in which users were involved in this process—whether users actively participated in ideation, testing, and refinement processes and at which stage. Oftentimes, assumptions were made about how LLs ought to operate, what innovation-related challenges they are best suited to address, and why a LL approach was the chosen mechanism for addressing them. Hence, we had to revert to the LL's own website to make sure we correctly reflected the LL's founding objectives, services, and key stakeholder involved. This triangulation helped validate the key insights we derived from the authors' own description of their case.

Hence, our analysis covered design elements that are general to all innovation-support organizations, such as general focus, funding structure, and temporality, as well as those that are specific to LLs, such as stage and degree of user involvement, project selection criteria, services offered, and membership (Fig. 3). These design elements represented the building blocks of the LL model and provided the foundations to further explore how different LL applications can be integrated under common themes.

Step 5: Analyzing application patterns: From this vantage point, we proceeded by comparing the different LL applications covered in our sample. Consistent with Hoon (2013)'s recommendations, we began examining our sample in terms of which elements are common across all studies, which are likely to appear together, and under what

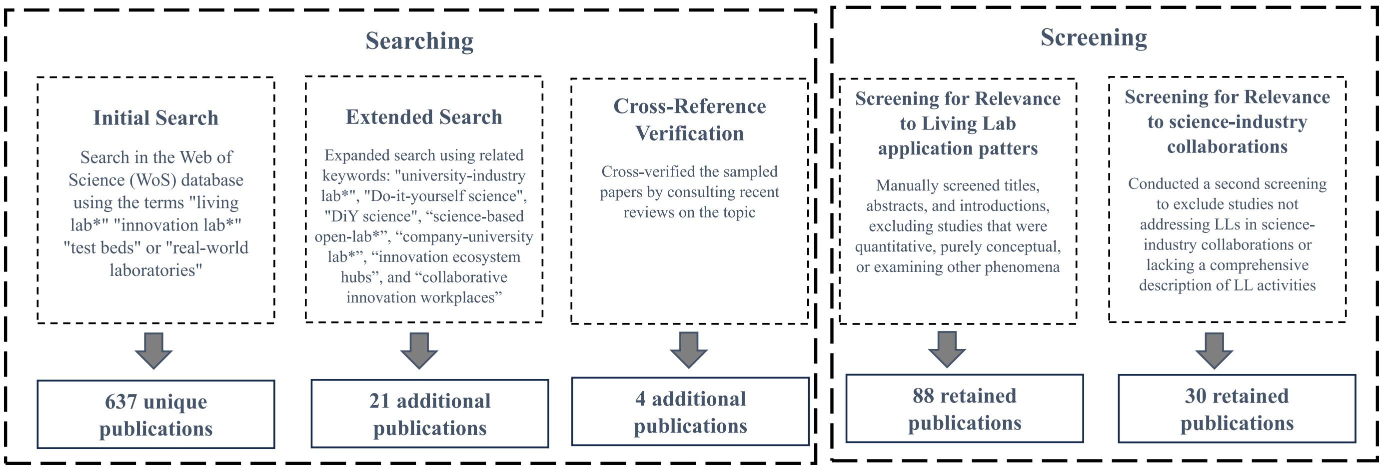

Fig. 2. Sample selection and screening process.

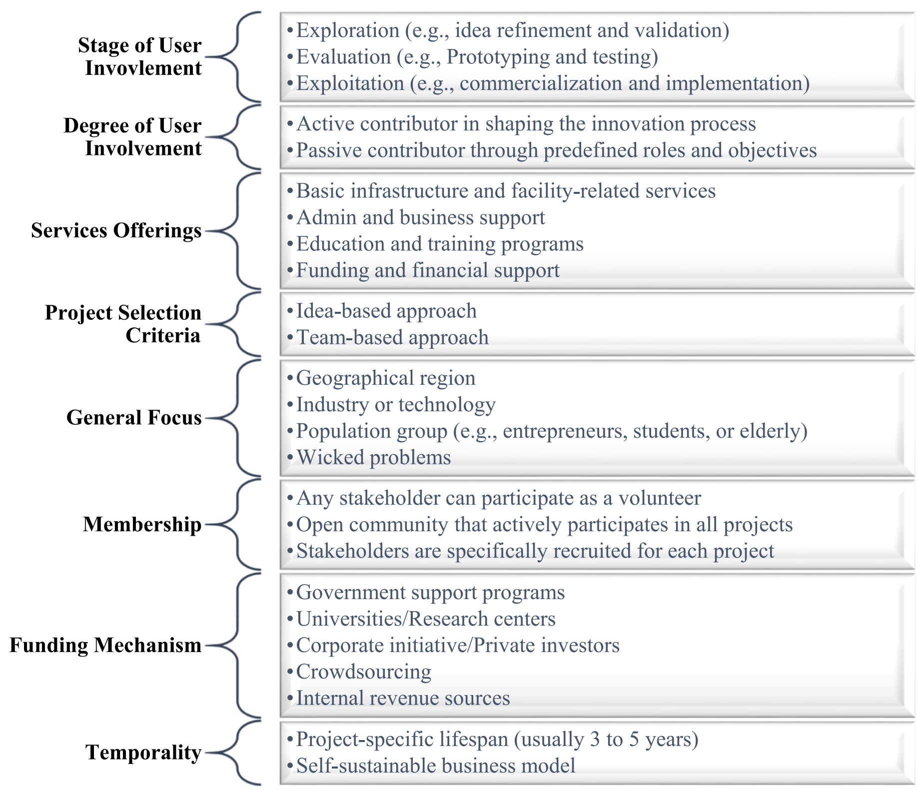

Fig. 3. Living Lab design elements.

conditions. The idea was to move away from treating each LL as a single entity to consider them more as a heterogeneous set of data suitable for pattern analysis; moving from the actual description of each of the 41 applications to identifying commonalities/differences between those descriptions—what do the 41 applications say about LLs when looked at as a whole?

We took Leminen et al. (2012)'s categorization of LLs as our starting point. According to Leminen et al. (2012), LLs can be differentiated according to the group of stakeholders that holds the most influence over their activities. This includes: utilizers (i.e., organizations that launch and promote LLs to develop their businesses), enablers (i.e., governmental or community actors that support LLs to pursue societal improvements), providers (i.e., universities and institutions that manage LLs for promoting research and knowledge creation), or users (user communities that focus on solving everyday-life problems). Applying this categorization to our dataset places the LL's "value proposition" at the center of our analysis. The value proposition reflects the unique contribution that a LL creates to its stakeholders, and in effect the role it assumes in the innovation process.

Building on Leminen and colleagues'' framework, we began linking each of the reported LL objectives to relevant stakeholder categories. For instance, LLs with a goal to detect marketable solutions were linked to the utilizers category, those seeking to address local societal challenges were associated with the enablers category, LLs focusing on fostering stronger ecosystem relations were aligned with the providers category, and those prioritizing technological advancement were associated with the users category. The linkage between LL objectives and stakeholder categories informed the derivation of overarching value propositions. This value proposition encapsulated the collective goals and objectives of each LL category. It also helped contextualize different LL applications based on concrete innovation outcomes (i.e., goals they are set up to achieve).

Accordingly, we proceeded by comparing the content of the eight design elements that we identified in Step 4 under each category. Not surprisingly, all LL applications under the same category involved very similar approaches to funding, project selection, user involvement, temporarily, among others. This consistency within categories suggests a convergence of the objectives and priorities of each group of stakeholders. By synthesizing the common elements within each category into broader themes, we were able to derive four overarching LL models for organizing collaborative innovation within the science-industry nexus. Each of these models is defined by a unique value proposition guiding its purpose and design structure.

Following our derivation of these models, we presented our framework to two experts in innovation management who have worked extensively with LLs to ensure that it resonates with established perspectives in the field. This external consultation highlighted some emerging trends in LL applications, such as a notable increase in the agency being assigned to end-users and the expanding reach of LLs beyond the European context. It also provided an additional layer of validation to our findings from the literature. We further presented our research at an academic workshop with peers well-versed in LL research to enrich the robustness of our analytical framework and strengthen the credibility of our findings.

4. Living labs: an organizational design framework

4.1. Design elements

The design elements represent the main components of an organization's business model and collectively describe its content, structure, and governance (Zott and Amit, 2010). From our analysis, we identify eight design elements that distinguish one LL model from another. These elements were derived from an in-depth comparison between the 41 different LL applications contained in our sample. A summary of these design elements is presented in Fig. 3 and described more fully in this section.

Stage of user involvement: A first key element that emerged from our analysis relates to the stage of user involvement in the innovation process. In general, all LLs involve some form of user involvement, however they differ in the specific stages[6] in which these users are involved. Some LLs tend to engage users at every stage of the innovation process, while others seem to prioritize user involvement only in particular stages. Botnia Living Lab, for example, attempts to involve users at every stage of its innovation process so that each project becomes customized to the unique requirements for that particular user group (Bergvall-Kareborn and Stahlbrost, 2009). In contrast, JOSEPHS® LL in Germany tends to prioritize user engagement only in the testing and prototyping stages so that the feedback gathered from users could be presented to innovators to make any needed adjustments (De Vita and De Vita, 2021).

Degree of user involvement: User involvement is not only a matter of stages, but also a matter of degree. The degree of user involvement generally ranges from passive participation where users' role in a LL is limited to providing feedback on specific technologies, products, or services (e.g., Torvinen and Jansson, 2022) to a more active involvement where users become co-creators and leading contributors (e.g., Gascó, 2017). Leminen et al. (2014), for instance, highlight four roles that can be attributed to end-users in LLs: informants, testers, contributors, or co-creators. Each of these roles is based on the level of agency assigned to users in shaping the outcomes of the innovation process. The degree of user involvement in the innovation process is therefore the second key design element shaping a LL's model.

Service offerings: LLs also differ in the services they offer to their participants. Based our analysis, almost all LLs seem to provide the basic physical infrastructure in terms of localities, equipment, and facility-related services. While these amenities are relatively common, they can vary based on the kinds of spaces available (e.g., prototyping rooms, co-working spaces, and testing facilities). In addition to the physical infrastructure, many LLs also provide business and administrative support such as consulting, financial analysis, and legal advice (e.g., Haukipuro et al., 2019). Some LLs even offer educational and training programs, such as workshops, events, and lectures given by experts and industry leaders in the field (e.g., Cantù et al., 2021; Torvinen and Jansson, 2022). Others also provide incubation services for specific projects and/or new ventures (e.g., Budweg et al., 2011).

Project selection criteria: Project selection refers to decisions concerning which projects to accept and which to avoid. Project support activities occupy the bulk of a LL's operation portfolio and therefore, the specific criteria used for selecting projects represent the basis for effective resource allocation and an important design element of a LL. In general, selection strategies usually follow one of two approaches. The first is a solution-based approach where a project is evaluated based on the viability of its proposed idea, that is the specific technology, product, or service that defines the outcome of the project (e.g., De Vita and De Vita, 2021). The second is a team-based approach where evaluation decisions are based on the team's expertise that is most relevant to a LL's mission and objectives (e.g., Torvinen and Jansson, 2022).

General focus: A fifth design element that characterizes a LL pertains to their general focus. In most cases, a LL's general focus is directed towards a specific industry or population group (cf. Della Santa et al., 2022; Van Geenhuizen, 2018). Others, such as NovaGob.Lab in Spain (Criado et al., 2021) or Energy Avantgarde Anhalt LL in Germany (Engels et al., 2019) are more geared towards a specific geographical region. Increasingly, more LLs are being set up to deal with wicked problems, such as environmental degradation, food insecurity, pollution, and other sustainability issues created by urbanization. As an example, the FloodCitiSense was initiated as a LL to address the urban hazards caused by intense rainfall and insufficient drainage systems through applying a Citizen Science approach to collect data about rainfall in Belgium and develop solutions to urban flooding accordingly (Veeckman and Temmerman, 2021).

Membership: Membership denotes the approach used for selecting and integrating stakeholders in LL activities. It typically ranges from an open collaboration strategy where anyone with a vested interest can participate (e.g., the Hiedanranta Living Lab in Finland), to a fairly more restrictive strategy where stakeholders are pre-selected and invited to participate in specific projects (e.g., the Apollon Living Lab) (cf. Särkilahti et al., 2022; Ståhlbröst and Holst, 2017). Other LLs, such as the UEREF Lab in Berlin (Engels et al., 2019) tend to have a more targeted membership approach where a defined group of stakeholders actively participates in all projects. The unique governance features for managing membership are likely contingent on the specific attributes of the project in terms of the innovation capabilities required for identifying, selecting, and implementing relevant ideas.

Funding *mechanism:* LLs also differ in the way they receive funding. The rapid proliferation of LLs particularly in Europe, has been largely attributed to the range of government-supported initiatives for promoting multidisciplinary collaborations in research and development (Leminen and Westerlund, 2019). Hence, many LLs originate with regional or national policy objectives in mind. Increasingly, LLs are being set up by universities and research institutions as a way to effectively commercialize scientific research and expand their outreach (e.g., Della Santa et al., 2022; Van Geenhuizen, 2018). In the private sector, LLs have been created as in-house innovation units designed to boost the

[6] These stages usually cover: (1) the exploration stage—the co-creation of new ideas, opportunities, and solutions; (2) the evaluation stage—the validation, prototyping and testing of co-created concepts in real-life settings, and/or (3) the exploitation stage—the development and implementation of the most promising ones.

company's innovation capacity and speed up its product development lifecycle (De Silva and Wright, 2019; Haug and Mergel, 2021) or as part of a business center to help facilitate business incubation (Guzmán et al., 2013) and some have also started to leverage crowdsourcing initiatives to expand their activities over time (Ståhlbröst and Lassinantti, 2015).

Temporality: A final design element that distinguishes LL application patterns pertains to their temporal lifespan. Indeed, some LLs are driven by predefined projects and therefore tend to have a relatively short-term lifecycle (usually between two to five years) depending on the specific outcome and funding structure (e.g., Dupont et al., 2019). Others, such as the CitiLab in Spain or the iMec Lab in Belgium, tend to have much longer lifespans. These LLs usually pursue a sustainable business model by relying on internal revenue sources while strategically managing their dependence on external funding.

4.2. Design themes

The design themes constitute the second set of parameters that characterize the LL model. They represent unique configurations of design elements that capture an organization's main value creation driver (Zott and Amit, 2010). Our analysis revealed four overarching design themes (summarized in Table 2), each representing a unique model for organizing science-industry collaborations within LLs: (1) Technology sponsor, (2) Opportunity spotter, (3) Network orchestrator; and (4) Community anchor.

4.2.1. Technology sponsor

A "technology sponsor" is a LL created specifically for the purpose of catalyzing the development of new technologies and facilitating their adoption in the market. It is usually engaged in markets defined as "transactions for the use, diffusion, and creation of technology" (Arora et al., 2001, p. 423) and is set up by large universities or research institutions in partnerships with governmental agencies and/or relevant industry actors. Technology sponsors frequently engage in organizing workshops and events to attract new stakeholders, forge partnerships with science-based communities, and reinforce their legitimacy in the absence of key performance indicators. This type of LL is, therefore, established as a means to accelerate the development of scientific research and promote academic entrepreneurship by providing a range of services, guidance, and resources for supporting the development of emerging technologies.

Technology sponsors work closely with researchers to overcome information and resource asymmetries by providing personalized services pertaining to intellectual property (IP) rights, technical and ethical standards, as well as helping navigate clinical trials specifically in the life sciences. Given the high costs and uncertainties associated with the commercialization of scientific research, this type of LLs is usually involved at every stage of the innovation process and is often accompanied by a selected groups of users and specialized participants who actively contribute to the advancement of the project. Hence, the LL's network is almost exclusively geared towards stakeholders with relevant knowledge and expertise in a specific area and concentrated in a specific industry or discipline. While these forms of LLs are typically funded through fixed-term public mandates, their track record and accumulated expertise can open up new opportunities to generate alternative revenue sources and help maintain a sustainable business model.

As an example, the imec.livinglabs,[7] a separate division within the iMec research institute in Belgium, was set up to help researchers and entrepreneurs co-develop and test new products, services and business models (related primarily to the fields of nano- and digital technologies) with user groups (Schuurman et al., 2019). Over the years, iMec has accumulated extensive expertise in managing diverse open innovative projects and has developed its own panel of users who are invited to participate in different projects (Logghe and Schuurman, 2017). Through hosting various successful interdisciplinary collaborations, iMec has created a trusted environment where researchers, users, suppliers, policymakers, and regional industry actors can come together to overcome systemic gaps in the innovation process. Similarly, the Apollon LL initiative, initially launched in Finland as an effort to promote the acceptance and diffusion of technologies related to monitoring energy consumption, was scaled to other regions for promoting these technologies at a broader scale (Ståhlbröst and Holst, 2017).

4.2.2. Opportunity spotter

The "opportunity spotter" represents a LL whose primary purpose is to detect the most promising ideas and turn them into viable, customer-facing solutions. They are usually run by corporations or business centers as a means to boost their innovation capacity without hindering day-to-day business operations. Opportunity spotters can also act as "listening posts" for gaining access to strategic market knowledge and facilitate the identification of emerging consumer trends. As a result, these forms of LLs have inspired much interest among businesses around the world and are often perceived as a way to reflect the management's commitment to foster a stronger culture of innovation and entrepreneurship among employees.

Opportunity spotters typically operate with a for-profit motive and are closely monitored using a defined set of performance metrics, such as indicators for tracking the number of ideas generated, the number of successful products launched, and the level of engagement among stakeholders. Hence, the project selection criteria are usually based on an idea's likelihood to turn into a viable business opportunity. The focus is, therefore, not only on solving a particular problem, but also on generating a broad pool of marketable ideas and promoting their adoption process. Users are typically preselected to co-design, test, and validate products or services that are being developed in the LL. However, the innovation process is almost entirely coordinated and controlled by the sponsoring organization.

One prominent example is the LL division of the European Energy Forum (EUREF) campus in Berlin. EUREF is proclaimed as a real-world laboratory designed to facilitate the shift to renewable energy in Germany by hosting leading actors in the fields of energy, mobility, and building technologies (e.g., engineers, businesses, and research institutions) and motivating them to work together to develop and test new solutions under quasi real-world conditions (Engels et al., 2019). EUREF's LL model has been essentially geared towards the development of the most viable projects that best reflect EUREF's innovativeness vis-à-vis investors, policymakers, potential partners and customers. Its LL approach is thus conceived not just as a "neutral site" for the co-creation and testing of new technologies, but also as an indicator of feasibility and commercial success (Engels et al., 2019).

4.2.3. Network orchestrator

A "network orchestrator" is a LL whose main role is to coordinate partnerships between stakeholders with complementary resources and capabilities. These LLs help organizations and nascent entrepreneurs connect to key market actors, policymakers, mentors, and other potential resource providers. They are usually set up through partnerships between two or more research institutions in order to expand their network reach and provide incentives for faculty to engage in industry-oriented research. In this regard, a network orchestrator not only facilitates the innovation process at the individual-level, but also addresses the innovation gaps at the level of the ecosystem by shaping the relational dynamics within and across industries (Magas and Kiritsis, 2021). They are open to all stakeholders and user groups that are able to contribute in one form or another to a specific project. Their success highly depends on the relations and structures within their ecosystem as well as their ability to manage informal knowledge spillovers that may arise in the process.

As an example, the L3 Lab defines itself as an open, participatory,

[7] Previously known as iMinds: https://www.imec-int.com/en.

Table 2
Living Lab design models.

Value proposition	"Technology sponsor"	"Opportunity spotter"	"Network orchestrator"	"Community anchor"
	Catalyze technological advancement	Detect the most promising marketable solutions	Foster stronger relations in an ecosystem	Address local societal challenges
Design Elements				
Stage of User Involvement	Heavily involved in the testing and validation stages. Prioritize scalable testing procedures to ensure that technical feasibility is attained	Mainly involved in the very early and/or late stages of the innovation process after technical feasibility is attained	Prioritize concept evaluation and validation to help detect barriers associated with knowledge transfer	Involved uniformly across all stages of the innovation process with a particular emphasis on defining challenges and proposing practical solutions
Degree of User Involvement	Users typically play a passive role in the innovation process, primarily focused on validating the technical aspects of a given technology	Users are preselected and mostly involved in providing insights to refine/validate ideas and prototypes	Users participate as part of a broad network, contributing at various levels based on their expertise	Users are active contributors to the innovation process
Services Offerings	Services related to the proper validation and implementation of emerging technologies	Services related to idea conception, refinement, and market validation	Services related to the formation of new networks and partnerships across science-based and business communities	Services related to the co-creation of relevant and practical solutions
Project Selection Criteria	Projects contributing to the advancement of a certain technological domain. Favors teams with a proven track record in a specific area or industry	Projects aligned to the sponsors' interests and objectives. Favors ideas with the strongest potential to succeed in the market	Projects supporting the transfer of scientific research conducted in universities or research institutions	Projects prioritizing the welfare of a society. Favors ideas that are considered important to certain groups of a community
General Focus	Technology development in a specific sector	Building viable customer-facing solutions	Forging new partnerships and stronger collaborations	Economic development and social welfare
Membership	Established network of stakeholders, users, and specialists with frequent access to workshops and events	Access restricted to a selected group of participants often within the same organization. Users are chosen based on their potential as prospective clients	Open to specific user groups with a defined set of criteria that vary with each project	Open participation to concerned members of a community or group
Funding Mechanism	Mix between public funding and internal revenue sources	Corporate/Private investors	Universities/Research centers	Government support programs
Temporality	Based on the viability of the underlying technologies	Based on the performance of the innovation outcome	Based on active network participation	Based on renewable project mandates
Examples	iMec LL (Belgium), Apollon LL (Finland), Bauhaus.MobilityLab (Germany)	EUREF Berlin (Germany), JOSEPHS® (Germany) and LLs run by corporate entities	L3 Lab (Spain), Botnia LL (Switzerland), LineGov Brazil (Brazil)	CitiLab (Spain), GENS LL (South Africa), and Urban Living Labs in general

experimentation and co-creation space situated in a public library in Barcelona with the aim of reinforcing the links between culture, technology and society (Nguyen and Marques, 2022). It is driven by the desire to foster multi-stakeholder collaborations as a way of transferring research outcomes faster to the real world. In effect, L3 has been the result of a bottom-up network initiative that emerged between local residents, businesses, the municipality, and a research center, which is coordinating the LL activities. Similarly, NovaGob.Lab was set up in Spain to accelerate innovation in the public sector by fostering networks and collaboration spaces between public sectors organizations, academic institutions, private organizations and the civil society (Criado et al., 2021). It primarily operates by leveraging the academic knowledge generated by researchers in order to design innovative public policies and services. The outcomes generated from the adoption of the policies and services emerging from the LL would then provide feedback to enrich academic knowledge by informing researchers and political scientists about the validity of their theories.

4.2.4. *Community anchor*

The "community anchor" represents a LL created to address emerging societal challenges, either within a specific geographical region or within a target population group. It is typically funded by local municipalities or regional governmental entities with the aim of fostering sustainability, economic growth, and social welfare. Hence, it focuses heavily on open and active participation from concerned citizens and motivated members of the community. As such, stakeholders are usually very diverse and come from a range of different backgrounds and disciplines. All stakeholders are admitted as long as they are able to contribute to the LL's defined mission. Because the majority of supported projects tend to be in their very early stages, a community anchor is mostly involved in the idea evaluation phase of the innovation process.

Urban LLs generally tend to fall under this category. They distinguish themselves from other models by their explicit focus on societal issues and their heavy dependence on public support. Community anchors are usually deeply embedded in their society making it possible to identify and mobilize relevant stakeholders and monitor the direct impact of their actions. While many of these LLs tend to prioritize local sustainable solutions for addressing wicked problems, they can also be oriented at promoting economic growth or enhancing social cohesion. The support they derive from municipalities and members of their community enables them to use specific areas of the city to develop and test emerging solutions.

One example of such a LL, is the Energy Avantgarde Anhalt (EAA) lab launched in Germany as part of a regionally tailored initiative to accelerate the sustainable conversion of the local energy system in the Anhalt region (Engels et al., 2019). It functions as a non-profit organization by bringing together multidisciplinary groups of energy experts, researchers, suppliers, utility companies, municipalities, as well as individual citizens to enable the co-creation of new ideas related to sustainable energy transitions. Another example is CitiLab founded in Barcelona to help promote social and digital innovation (Gascó, 2017). It operates with a particular focus on fostering digital awareness among citizens, facilitating the democratic access to information, and promoting open-innovation principles, thereby prioritizing a way of innovating much more focused on the needs of its community.

5. LLs in science-industry collaborations: an empirical illustration

The above meta-synthesis lays the foundation for understanding the diverse applications of LLs in science-industry collaborations. From this vantage point, we selected an empirical case study for an in-depth examination, and one LL was analyzed by considering its entire life cycle, starting from an analysis of the motivations for its establishment, through an assessment of its activities, up to its current stage where a sufficient level of maturity was realized and operational feasibility was attained. By doing so, we argue that innovation models are not so much built into rigid organizational structures, but are actively shaped by what organizations do (activities/practices), who they interact with (key stakeholders), and what roles they assume in the innovation process. This case study is intended to enrich and exemplify these theoretical insights and complement the broader findings of our meta-synthesis by illustrating the different ways in which LLs can support science-industry collaborations (Siggelkow, 2007).

The case traces the evolution of a Medtech LL (henceforth referred to as iTMT) that was created specifically to foster innovation in the medical technology sector in Montreal—that is, to transform medical research into practical solutions that can be readily integrated into the existing healthcare system (e.g., hospitals and clinics). This case was particularly relevant for our purpose as it provided a unique opportunity to delve deeper into the dynamics of LLs in science-industry collaborations. First, being among the first Medtech LLs in Montreal, iTMT has played a crucial role in pioneering this concept (i.e., user-driven innovation under real-use conditions) in healthcare in the region. Second, iTMT's extensive project portfolio[8] showcases its versatility and adaptability in addressing a wide range of healthcare innovation challenges. Each project represents a unique combination of stakeholders, objectives, and outcomes, offering an opportunity to observe the various LL models in action. Moreover, our extensive case material enabled us to conduct a comprehensive life cycle analysis of the organization, providing a detailed understanding of how its LL operations were set up, how they evolved, and what internal and/or external factors influenced this evolution.

5.1. Case overview: iTMT

iTMT was initially created in 2017 by Polytechnique Montréal in collaboration with three leading hospitals in the region with the aim to support the development and diffusion of new medical technologies across three categories of diseases: cancers, cardiovascular diseases and musculoskeletal. To achieve this objective, iTMT explicitly defines itself as a LL around which a growing network of researchers, clinicians, entrepreneurs, students, and industry leaders can meet to co-create, validate, and test new medical solutions in an actual hospital setting. In effect, all innovation projects supported by iTMT are undertaken in a "*living lab format where new [medical] solutions are co-developed with partnering hospitals*" (Deputy director, iTMT). Its strategic positioning within a leading university hospital in Montreal allowed it to serve as a vital bridge between scientific research and industry application.

Data collocation: Our work with iTMT was part of a larger project aimed at identifying common principles and best practices for organizing innovation spaces in healthcare. A total of 85 interviews were conducted throughout this project with different actors from the healthcare innovation ecosystem in Montreal, including: 10 interviews with senior managers from iTMT, 23 with medical researchers and hospital representatives, 22 with entrepreneurs and industry actors, 16 with innovation researchers, mentors, and policymakers, and 14 with other regional intermediaries (e.g., incubators, accelerators, and innovation centers). This diverse range of informants facilitated data triangulation and provided a comprehensive understanding of iTMT's role and impact from multiple perspectives.

The interview process spanned a year and a half, starting in July 2020 and concluding in early 2022. The interviews delved into various aspects of iTMT's LL approach, including its mission, stakeholders, activities, and outcomes, with a specific focus on how it identifies and supports innovation projects, manages collaborations, and contributes to technology development and commercialization. We also covered the primary barriers to healthcare innovation, especially in the context of the COVID-19 pandemic, alongside the growing role of iTMT within its broader healthcare innovation ecosystem. Appendix C summarizes the key themes we covered during our interviews.

As part of our data collection, we also undertook constant visits to iTMT's premises to discuss the organization's evolving business model, inquire about emerging challenges, and confirm/refine our findings. We reviewed in parallel supplementary organizational reports and updates in order to validate key themes and discussion points covered during our interviews. This also allowed us to keep track of the new activities being organized by iTMT. Hence, our involvement with this case enabled us to identify key phases in iTMT's LL life cycle, including its inception, prominent challenges, evolving priorities, and impact. The insights derived from this study were further culminated in an action report for iTMT's management team and were further condensed into practitioner workshops on the roles of LLs in healthcare.

Data analysis: Our initial aim was to understand the influence of "living labs" on facilitating the development and integration of new medical technologies (Abi Saad et al., 2024; Cohendet, 2022). However, as we started to engage more with the literature, we noticed a variety of approaches for organizing science-industry collaborations within LLs, as well as differences in their roles, networks, and governance structures. This has prompted us to delve deeper into the different application patterns of LLs in such context, and perhaps equally importantly, how these patterns can be organized in relation to a specific innovation outcome (i.e., value proposition). The four LL models that emerged from our meta-synthesis (opportunity spotter, technology sponsor, network orchestrator, and community anchor) formed the basis for examining the role(s) of iTMT and the way it was (re)designing its LL model over time.

Indeed, each of iTMT's projects involved unique objectives, challenges, and stakeholder requirements. For some projects, particularly those involving complex technical development and strict regulatory procedures, we observed a more centralized innovation approach, where iTMT takes a lead role in coordinating activities and engaging stakeholders (discussions with project managers). Other projects tend to be more decentralized as users (e.g., clinicians and patients) take a more active role in co-creating and validating emerging solutions. Similarly, projects also differed in their scope and complexity. Some focused on the development of digital health software, such as telemedicine platforms for remote consultations or mobile applications aiding patients to manage chronic diseases. Others integrated both hardware (e.g., medical scanners or wearables) and software algorithms to facilitate the early detection of serious medical conditions. Yet, a smaller but growing category of projects involved only direct medical interventions, such as music or sound-based therapies for pain relief (project reports).

As a first step, we squarely focused on iTMT's evolution, mapping out the key milestones in its LL journey, including the initial motivation behind its LL approach, notable achievements, key stakeholders, and position within its broader healthcare innovation ecosystem. Not surprisingly, discussions with project managers validated some of the defining features of a LL, such as *"end-user involvement", "real-world development and testing",* and *"multidisciplinary innovation*" with the ultimate goal to accelerate the diffusion of new medical solutions in healthcare (project managers, iTMT). However, further interviews revealed that each of the different stakeholders (e.g., researchers, clinicians, industry actors, and entrepreneurs) perceived the role of iTMT differently depending on their own needs and priorities.

Most notably, nearly all stakeholders agreed that the role of iTMT is essentially "*a translator between research and practice*" (Professor and senior consultant). However, their individual perspectives varied on how this "translation" is being achieved. For instance, medical researchers and entrepreneurs primarily engaged in LL projects to "*help in identifying risks, validating strategies, (and) providing networking opportunities*". Hospitals, on the other hand, prioritized LL projects that shed

[8] As of 2024, iTMT has supported more than 135 LL projects

light on *"the main barriers to technological adoption, including regulatory, procurement, and cultural"* (Head of innovation, University Hospital Center). Moreover, iTMT's LL activities were also praised for their contribution to enhancing the responsiveness of the local healthcare system by helping "*validate, test, and obtain required ethical approvals more efficiently*" (Senior innovation advisor, Quebec region).

Hence it quickly became evident that each of these roles required a unique approach to organizing collaborative innovation. Notably, when we first presented our LL design framework to the managers at iTMT, they unanimously agreed that the organization was effectively navigating between all four models, adapting its approach based on the nature of the specific project being carried out. As iTMT's founder explains "*the major strength [of iTMT] has been its agility and ability to constantly adapt to emerging changes and projects requirements*". Hence, we revisited our data in relation to the application patterns of LLs we derived from the literature and accordingly, began narrowing down our focus to capture how iTMT was strategically re(designing) its LL model over time.

5.2. (Re)designing LLs for emerging healthcare innovation challenges

Technology sponsor*:* Since its inception, iTMT has performed traditional "*Technology* sponsor" roles, prioritizing services related to the proper development and validation of new technologies by helping researchers/entrepreneurs tailor these technologies to end-users (e.g., hospitals, clinics, and physicians). As such, iTMT's LL model has been essentially geared towards technology development focused on "*translating the value of the technology to the patients*" (Medical researcher). The role of iTMT here was to "*provide the right mechanisms and infrastructure that are crucial for the development of new (medical) technologies*" (Professor and senior advisor, iTMT).

This approach prioritized working with specialized teams of researchers capable of thoroughly assessing the technical feasibility of specific technologies and ensuring their alignment with existing hospital systems. "*Because iTMT is situated inside an actual hospital, it already understands the barriers [to technology development] that can be regulatory, procurement, or cultural*" (Senior hospital representative). Hence, the initial "target market" for iTMT's LL activities comprised of physicians, medical researchers, and local entrepreneurs. End-users (e.g., clinicians and patients) were in fact involved in the innovation process but their role remained mostly focused on testing and technical validation rather than actively engaging in their actual development.

Opportunity spotters: Despite iTMT's efforts to mitigate the challenges arising during the technology development process, a recurring concern that was frequently expressed by our informants was "*how to convince healthcare institutions to buy the technology*" (Senior hospital representative). The growing awareness of this challenge prompted iTMT to reorient its LL model to involve elements associated with "*opportunity spotters*". In effect, iTMT has employed a range of mechanisms designed for *"scouting promising innovation projects"*, *"customizing* support *services"*, and *"broadening areas of expertise to accommodate for emerging technologies"* (Project manager, iTMT). For example, it started collaborating more closely with other intermediaries in the region, including business incubators, accelerators, and science parks to help move promising medical solutions to the market.

"How to do research is not the same as to launch a company … this needs institutions like iTMT to help researchers change their mindset … we should all support them in testing, developing prototypes, and accessing local markets" (CEO – Business center for innovation and entrepreneurship).

Target segments have further expanded over time. Most notably, iTMT began catering to international entrepreneurs that are seeking to develop and validate their solutions in North America (case notes and project reports). This required iTMT to diversify its areas of expertise and provide more personalized support for enhancing the market feasibility of the technologies emerging from its LL—"*ensuring that these technologies have value and can be safely integrated into the existing health system if developed further*" (Deputy director, iTMT).

Network orchestrator: For other projects, iTMT has taken an even broader role as a "*network orchestrator*" around which diverse stakeholders from both the research community and the industry can work together on solutions for addressing persistent innovation challenges. As "*network orchestrator*", its key objective was to facilitate collaborations that help direct and promote the transfer of academic research towards the needs and priorities of healthcare institutions. Accordingly, the LL model underlying such projects focused on the provision of the right infrastructure for fostering multidisciplinary collaborations.

"On the one hand iTMT is an institute that does multidisciplinary and collaborative research, but it also reflects best-practices in collaborative innovation, making it an expert on how to transfer research into commercial technologies" (Senior innovation advisor, Quebec region).

For instance, iTMT started integrating regular networking events, workshops, and trainings to motivate researchers to work together and share ideas (discussions with deputy director). In many cases, new opportunities emerged by introducing researchers and nascent entrepreneurs to industry leaders. As one entrepreneur explains, *"iTMT is engaged with all major hospitals in the region … and knows who the key decision makers are … so they did not only help us with developing our technology but more so with connecting us to potential clients and investors"*. The goal was not to facilitate the development or implementation of certain technologies *per se*, but rather to forge new partnerships between researchers and industry actors.

Community anchor: Over the years, iTMT became recognized as a flagship initiative for fostering healthcare innovation in Montreal. Many of its LL projects began to share notable characteristics with a "*community anchor*". In effect, these projects have been carefully designed as regionally tailored solutions for addressing local challenges raised by the healthcare community.

"The integration of new innovations is one of the major challenges in Montreal healthcare system … the solution is to show the value of the innovation, meaning that to put them in the hands of the users and to measure their effectiveness, the living lab approach solves the first issue, but it's underutilized in the sector" (Physician and medical researcher).

iTMT's "*community anchor"* approach strongly resonates with the notion of regional co-creation (e.g., De Silva et al., 2023) and has focused heavily on ensuring broad membership and diversity in stakeholder representation, including patients, clinicians, hospitals, and specialists in the innovation process. "*This diverse expertise in our network enables us to rapidly respond to the evolving needs of [medical] researchers*" explains one senior project manager at iTMT, it is this multidisciplinary representation that "*allows us to provide new solutions to concrete healthcare challenges*" she continues.

Indeed, iTMT's ability to adapt the collaboration process within its LL to the unique requirements of each project has made it a reference point for supporting healthcare innovation in the region. *"It takes someone to do it this way so that other organizations become convinced to adopt these practices"* notes Quebec's senior innovation advisor.

5.3. Overcoming challenges to Living Lab implementation in science-industry collaborations

While our analysis of the literature reflected successful LL application patterns, delving into the iTMT case has also revealed notable challenges involved in implementing LLs within the science-industry nexus. These challenges, we observed particularly in the MedTech sector, suggest a constant need for (re)designing LL activities to address the evolving priorities in the innovation process. It is important to note that these challenges were derived from our analysis of a LL embedded in the healthcare innovation ecosystem in Montreal[9], and therefore

[9] For an overview of the healthcare innovation challenges see Hermes et al. (2020); Massaro (2023); Santarsiero et al. (2023).

might not capture the specificities of other industries or ecosystems. Moreover, our fieldwork coincided with the COVID-19 pandemic, which may have influenced the types of projects supported by iTMT, potentially amplifying LL implementation challenges. Although the context may vary, these challenges underscore the importance for organizations to consider the potential hurdles when applying LLs in science-industry collaborations and recognize the need for constant adaptation.

First, the *broad nature of the projects* supported by iTMT spanning across the whole healthcare innovation lifecycle drove the organization to seek alternative LL approaches to accommodate a wider range of stakeholders (including patients, healthcare professionals, researchers, entrepreneurs, and hospitals). While some projects had well-defined objectives (e.g., testing/validating a new medical intervention, gaining quality certification, and accelerating a research project), others were more ambiguous, especially those involving an AI component (e.g., helping medical entrepreneurs navigate clinical trials and overcoming key barriers to adoption in hospitals), requiring more personalized and hands-on support (project reports and discussion with project managers).

The initial LL approach adopted by iTMT has focused predominantly on the early stages of the technology development process, prioritizing "*the provision of relevant technical expertise*" and "*helping researchers navigate clinical trials*" (Project manager, iTMT). It has been indeed successful at mobilizing key stakeholders and has helped deliver promising solutions to concrete challenges faced by the medical community (fieldnotes and interviews). Despite notable successful projects, focusing on the technology itself has shown to be insufficient for generating value for the different stakeholders involved. As one informant puts it:

"Research and (technical) innovation are not well integrated with the healthcare perspective, they are anchored in economic growth while healthcare prioritizes patient wellbeing … So the cycle doesn't stop in commercialization but also require assessment to ensure that value is realized. Hence, supporting healthcare innovation is about ensuring the continuity of this cycle" (Director, Quebec national institute of health and social services).

For instance, we noted that many promising solutions being developed in the LL remained stuck in the innovation pipeline without ever being integrated into the existing health system. This has been largely due to the complexities inherent in the diffusion of new medical innovation, including stringent procurement criteria, long legal approvals, reimbursement issues, and restricted access to patient data (interviews with medical entrepreneurs).

Thus, iTMT's main challenge became "*to take the technology all the way to patients*" (Physician, University hospital), a process that could not be codified as it is highly dependent on the needs of each project. Hence, the diversity of innovation projects posed a significant challenge to relying on a single LL model, prompting iTMT to seek alternative approaches in order to accommodate the evolving priorities of its stakeholders.

The second factor is attributed to the dynamically evolving *nature of the (healthcare) innovation ecosystem*. In recent years, healthcare innovation in Montreal has experienced significant growth, fueled by substantial public investments and a surge in new innovation support initiatives. The COVID-19 pandemic further accelerated this trend as increased funding and attention were directed towards promoting digital health solutions. This has led many intermediary organizations (e.g., business incubators and science parks) in the region to coordinate their efforts (e.g., seek strategic partnerships, initiate joint pilots, and collaborate on cross-disciplinary projects) to maintain a cohesive and coordinated approach to healthcare innovation.

There have always been political challenges while allocating resources between different medical innovation niches, but the strength of Montreal's healthcare ecosystem has been the strong collaboration between partners (CEO, Montreal's life science and health technology cluster).

For iTMT, being part of this rapidly growing ecosystem drove it to take on a more proactive role in orchestrating networks within the science-industry nexus and ensure a strong alignment between the different innovation efforts to avoid redundancies. Hence, much of its LL operations have been directed towards providing a common platform for sharing best practices, identifying common goals, and coordinating efforts to address pressing healthcare innovation challenges. "*It's not just the co-creation process that is valuable, but how the intersectoral collaborations unfolds in an experimental context … such Living Lab models need to be documented and replicated across other industries to help address emerging challenges faced by our society*" (Committee member, Quebec's research funding institute).

Third, as iTMT evolved over time, the need to *balance between its local focus and desire for scalability* became more apparent. Initially, its LL approach placed strong emphasis on the local context, fostering intentional engagement of researchers and entrepreneurs with local stakeholders, such as hospitals, universities, funding institutions, and community members. "*Our message to all companies is that every technology needs to be developed in collaboration with the local hospital for it to be aligned with our existing (healthcare) system*" (Deputy director, iTMT). This focus on the local context ensured that the solutions emerging from its LL address a specific challenge encountered by the local healthcare community.

At the same time, the organization's ambitions for scalability drove it to expand its LL activities to a wider and more international audience. This was a purely strategic move towards broader outreach and a desire to render its operations more sustainable by reducing its dependency on public funds (case notes and discussions with managers). Since then, iTMT began engaging with new categories of clients, including international organizations, researchers, and entrepreneurs wishing to access new market opportunities by tapping into Montreal's vibrant healthcare innovation ecosystem. Hence, many medical technologies that emerged from the lab have been "*developed and validated in Montreal, but implemented elsewhere*" (Senior director, Montreal life science and health technology cluster) and were mostly catered to foreign researchers, namely from Europe and Israel wishing to "*gain access to real-time data*", "*gather feedback from actual users*", and "*test their technologies in an actual hospital setting*" (Deputy director, iTMT).

Indeed, iTMT's reputation as "*a leading model in the region about how to evaluate new medical technologies*" (Senior innovation advisor, Quebec) has been built over the years upon successful project outcomes, positive testimonials from partners, and an impressive track record (case notes). "*The most valuable aspect of iTMT is that they have accumulated a strong expertise in these areas, they are exposed to many stories so when we have a strategic choice to make, we always ask them what to do and where the risks are?*" explains one entrepreneur. This strong reputation has helped the organization to *"sell its LL approach"* internationally and in a way, "*these [international] collaborations have been key to broadening the market for locally developed technologies*" (Project manager, iTMT).

Taken together, these factors highlight the main challenges encountered by iTMT in organizing collaborative innovation in a LL. While most applicable to the MedTech sector, these challenges underscore the importance of flexibility in implementing LLs in science-industry collaborations and illustrate how organizations might need to navigate between different models as they cater to the diverse stakeholders in the innovation process.

6. Discussion

In this paper, we set out to explore the application patterns of LLs within the science-industry nexus. Through a meta-synthesis of past studies, we introduce a parsimonious framework for organizing science-industry collaborations within LLs. Each of the patterns we identified is underpinned by a unique value proposition guiding its objective and design structure. We show that despite the common elements that underlie the LL model (i.e., user involvement, co-creation, and real-world experimentation), their application in practice can vary in important ways. A good deal of attention went into describing these common elements and their importance in fostering open innovation activities. Less emphasis was placed on the distinguishing features across models. This study therefore reflects this emphasis.

6.1. Linking Living Lab applications with underlying outcomes

Existing research have outlined the defining characteristics of the LL innovation model, including the roles (Leminen et al., 2015) and agency (Nyström et al., 2014) assigned to end-users, as well as the physical lab infrastructure (Della Santa et al., 2022), strategy for coordinating participation (Leminen, 2013), and level of embeddedness in the society (Engels et al., 2019). While informative for distinguishing between LL applications, the literature frequently omits insights into their underlying outcomes (Paskaleva and Cooper, 2021). The challenge lies in the fact that most studies we have reviewed do not delve into the subsequent phases of the innovation process to ascertain whether an envisioned outcome was actually realized. Hence, the effectiveness of LLs as a tool for organizing open innovation activities has not been sufficiently addressed in the literature.

By integrating the different LL design elements described in the literature into unique coherent models, we place this outcome at the center of the LL innovation model. We show that the effectiveness of LLs extends beyond their mere defining features (e.g., user-involvement and real-world development/testing), but also depends on how well these features align with and are adapted to the specific objective (or value proposition) they are designed to achieve. For example, if the objective is to develop next-generation technologies, prioritizing more user engagement might not be as important as offering access to a state-of-the-art development and testing environment (Engels et al., 2019). On the other hand, if the goal is to develop practical solutions to existing and concrete customer challenges, then active user engagement and feedback become more critical (Dell'Era and Landoni, 2014).

Recognizing these various innovation outcomes acknowledges the possibility of fundamental differences between the needs, priorities, and perspectives of stakeholders. It underscores the critical role of the translation occurring within LLs, where divergent viewpoints must be navigated to drive the collaboration forward. As Fritzsche, A., 2018 explains, the act of translation will not necessarily result in a shared understanding, but can enable organizations to "*gain insight into the fundamental differences between their own understanding of business operations and the understanding expressed by others*" (p. 654), forcing them to review their relations to stakeholders and reflect on their own role in this exchange. The organizational design framework we present in this paper therefore offers a basis for justifying the "added value" of LLs in science-industry collaborations and provides a tool for future research to explain variations in the innovation outcomes that emerge from different LL applications. In doing so, we respond to calls from innovation scholars for more outcome-oriented focus when studying LL activities (Ogink et al., 2023; Schuurman et al., 2016).

6.2. Spaces for facilitating science-industry collaborations

We also respond to recent calls for recognizing the heterogeneity of intermediary spaces in science-industry collaborations (e.g., Clayton et al., 2018; Li-Ying et al., 2022). In traditional collaboration models, the interaction between academia and industry often follows a linear trajectory, where research outcomes are developed within the confines of the laboratory and subsequently handed over to industry for commercialization (Etzkowitz and Leydesdorff, 2000). LLs disrupt this linear process by providing a space for science and industry actors to interact closely throughout the entire innovation lifecycle (Fuglsang and Hansen, 2022).

The four identified LL models—Technology Sponsor, Opportunity Spotter, Network Orchestrator, and Community Anchor—represent distinct approaches to organizing collaborative innovation between science and industry actors. For example, the Technology Sponsor model emphasizes technical expertise and early-stage testing/validation for accelerating the development of emerging technologies. On the other hand, the Opportunity Spotter focuses on identifying and capitalizing on emerging market opportunities, hence providing novel areas for the commercialization and/or integration of these technologies. A Network Orchestrator plays a pivotal role in sourcing and coordinating efforts across stakeholders to help establish a stronger and more diverse collaborative infrastructure. Lastly, the Community Anchor model focuses on more localized opportunities/challenges, emphasizing partnerships with local community actors for developing solutions attuned to existing societal challenges.

We thereby, shed light on the diversity of configurations for organizing science-industry collaborations within such spaces. Indeed, previous work has underscored the importance of intermediary spaces for facilitating academic engagement with the industry, and *vice versa* (Leminen et al., 2024). Yet, our analysis reveals that this facilitation can take different forms. Beyond promoting interdisciplinary knowledge exchange, these spaces can also provide a context for directing research and industry efforts towards more pressing innovation challenges. This may entail orchestrating early-stage interactions to help co-create new collaboration opportunities (Autio, 2022). It could also involve establishing the necessary infrastructure for sustaining ongoing and future collaborations (Schiuma and Santarsiero, 2023). Hence, our analysis suggests that research on intermediary spaces in science-industry collaborations need to be "contextualized" (Ratinho et al., 2020) in such a way that any analysis of their underlying outcomes is interpreted in relation to what is being facilitated, for what purpose, and under what conditions.

6.3. (Re)designing intermediaries for emerging innovation challenges

Indeed, much of the LL's appeal rests on their claim of intermediating between industry, academia, and policy (Del Vecchio et al., 2017). However, very little explicit attention has been paid to how this intermediation process is organized (Paskaleva and Cooper, 2021). Recent typologies and taxonomies presented in the literature have offered valuable insights for understanding the different forms of intermediaries in the innovation process (Perez Mengual et al., 2023) and for distinguishing between one form and another (Osorio et al., 2019). Some also account for the existence of hybrid forms (Pauwels et al., 2016) combining different design features from multiple models. However, this work has considered each model as a standalone structure (Good et al., 2019) overlooking how they can be adapted over time to the evolving needs and priorities of different stakeholders (Howells, 2024; Linde et al., 2021).

We build on and complement this literature by highlighting the inherent dynamism in the design of intermediary spaces in collaborative innovation. Our analysis of iTMT's evolution illustrates how the emerging demands of the innovation process necessitate a more adaptive and responsive organizational design. While research has often focused on one specific LL approach, we acknowledge that multiple approaches can coexist and be combined to address a wide array of innovation challenges. These "multi-purpose" LLs, capable of accommodate multiple innovation-driven value propositions, can be particularly salient for tackling projects with varying levels of complexity, stakeholder engagement, and technical requirements, such as those common in the development and diffusion of healthcare innovation (Santarsiero et al., 2023). However, they may also introduce additional governance considerations, such as sourcing relevant expertise, navigating diverse expectations, and managing overlapping activities (Hakkarainen et al., 2013; Molinari et al., 2023). Nevertheless, recognizing the presence of multi-purpose LLs further underscores the adaptability and complexity required for organizing collaborative innovation, especially when dealing with a rapidly evolving innovation landscape.

Hence, in line with prior work (e.g., Ritala et al., 2023; Veeckman et al., 2013), we recognize that the starting point for orchestrating collaborative innovation activities originates from the interests and priorities of the key stakeholders involved. However, we also show that both, internal organizational factors, such as variations in the nature of projects supported (e.g., objective, complexity and stages of development), as well as external environmental forces, such as changes in the dynamics of the innovation ecosystem (e.g., the emergence of new partnership/collaboration structures and the presence of complementary innovation support initiatives) can influence this process.

6.4. Implications for practice

From a managerial perspective, the four models presented in this study provide a framework for organizing science-industry collaborations in LLs. It helps managers, policymakers, and other interested parties avoid the common pitfall of replicating best practices instead of designing appropriate environments tailored to their unique, context-driven objectives. This includes defining which stakeholders to involve, what outcomes should be achieved, and what activities are needed to achieve them.

For example, we find that LLs prioritizing the development of emerging technologies tend to rely heavily on a carefully selected group of experts and are likely to reinforce their legitimacy through organizing workshops, trainings, and events, especially in the absence of key performance indicators. In contrast, LLs with a focus on societal challenges tend to rely more on governmental funding programs, leading to a more inclusive collaboration approach directed at promoting locally driven solutions. Identifying what model to adopt should be based on the managers' high-level innovation priorities and own assessment of their organizational capabilities. Making these priorities explicit is therefore a first step for managing collaborative innovation in such spaces.

Importantly, while a major strength of LLs lies in their ability to translate promising research into real-world practical applications (e.g., products, services, and technologies), this translation does not always need to result in a unified understanding among stakeholders (e.g., Fritzsche, A., 2018). By acknowledging and leveraging the diverse needs, priorities, and perspectives of relevant contributors, LLs can create an environment where the diverse viewpoints can enable new opportunities and uncover potential challenges early in the innovation process (e.g., cultural resistance, regulatory hurdles, and procurement challenges in healthcare institutions). Activities such as joint workshops, cross-disciplinary trainings, and regular feedback loops can help foster these productive interactions. They can also enable more effective stakeholder engagement, as each group feels their concerns and priorities are being considered and valued.

Hence, the insights we draw from studying LL application patterns can guide organizations in facilitating collaborations between science and industry actors throughout the innovation process. While simple in its formulation, it remains to be seen how these models would compare across different regulatory, political, or sociotechnical contexts given the high degrees of the social embeddedness of LL initiatives (Engels et al., 2019).

7. An agenda for future research

We conclude this paper by highlighting four key areas for future research. First, as with other studies examining the roles and organizational forms of intermediaries supporting science-industry relations (e.g., Good et al., 2019; Pauwels et al., 2016; Perez Mengual et al., 2023), our LL design framework, while comprehensive at the time of our study, may not capture the entirety of evolving trends in the development and commercialization of science (Nickerson et al., 2013). Despite covering different LL applications described in the literature, the challenges confronting science-industry relations are likely to continue to evolve, especially with the rise of complex innovation priorities, such as digital transformation (Dąbrowska et al., 2022) and sustainable transitions (Van Rijnsoever, 2022). Hence, we encourage researchers to further develop and refine our model to accommodate new roles and orientations.

Another promising avenue for future research involves a deeper investigation into the roles of end-users in the innovation process. Despite the centrality of "user-driven innovation" in the LL model (Schiuma and Santarsiero, 2023), there is a notable lack of evidence of the conditions under which integrating users is most effective. Indeed, prior research acknowledges that LLs yield maximum benefit when they involve users throughout the entire innovation lifecycle from idea inception until value is realized from implementation (Schuurman et al., 2016). However, very few studies (with the exception of Huang and Thomas, 2021; Leminen et al., 2014) unpack the conditions under which involving users can be most beneficial. We distinguish in our review between the stage and the degree of user involvement in LLs. Addressing questions around how much autonomy should be assigned to end-users and at which stage could significantly advance our understanding of the influence of user involvement in the innovation process.

We also detect a need for more longitudinal studies tracking the evolution of intermediary spaces over time. Longitudinal analyses can help identify key barriers in adapting these spaces across contexts (e.g., D'Hauwers et al., 2017), shedding light on the types, root causes, and implications of these challenges at different stages. Researchers can also discern recurring obstacles associated with using LLs to facilitate collaborations between science and industry and outline the strategies that managers and sponsoring institutions can employ to mitigate them (Haug and Mergel, 2021). Such longitudinal analyses can therefore provide a nuanced understanding of how external factors, including changes in industry dynamics, technological changes, or shifts in societal preferences, influence the types and nature of support services needed over time (e.g., Rossi et al., 2022).

Critical questions also persist about the effectiveness of LLs in coordinating open innovation activities. While research has extensively explored the benefits and defining features of LLs (Dell'Era and Landoni, 2014; Della Santa et al., 2022) focusing on individual characteristics in isolation provides limited insights into how to optimally manage LL activities (Hossain et al., 2019) and offers little guidance on the main outcomes arising from this process (Paskaleva and Cooper, 2021). As we show in our study, setting up LLs in the context of science-industry collaborations involves multifaceted considerations, including which types of projects to support, what role to assign to end-users, and at which stage of the innovation process to be most involved in. Future research could thus offer a more holistic evaluation of the impact of LLs, potentially benefiting from a configurational analysis (Furnari et al., 2021) to investigate the synergistic (or inhibitory) effects between different design elements in relation to envisioned outcomes.

Our study also carries certain limitations that warrant consideration. First, our derivation of LL application patterns is bounded by a meta-synthesis of existing studies from the literature. While this approach offers reliable and systematic insights into prevalent models and practices documented in prior studies, it might have restricted the variety of LLs in we could investigate and therefore we might have overlooked other application patterns that have emerged (our could still emerge) but not covered in the literature. Relatedly, a disproportionate majority of the sample we reviewed concentrates on LL practices in Europe. This might introduce a potential spatial bias as LLs, embedded within distinct socio-economic, cultural, and regulatory environments, may exhibit unique design elements and objectives. As such, caution is warranted when generalizing our findings globally as the European experience may not fully represent the diversity of LL practices worldwide.

It is also important to recognize that LLs serve diverse purposes, ranging from pure research commercialization to broader societal impact. Our research primarily focuses on LLs within the context of science-industry collaborations. Hence, the findings may not be directly extrapolated to LLs with different orientations or operating in other contexts. These limitations underscore the need for future research to expand our methodology beyond the confines of the existing literature and possibly consider other design features that may affect how LLs operate. As the LL phenomenon continues to expand globally, a careful examination of their design features could enable stakeholders to better organize collaborative innovation in such spaces for fostering stronger science-industry relations.

CRediT authorship contribution statement

Elie Abi Saad: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Marine Agogué:** Writing – review & editing, Validation, Supervision, Formal analysis, Conceptualization.

Data availability

Data will be made available on request.

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Appendix A

Academic journals included in final sample

Journal	Academic Papers	Living Lab Applications
TECHNOLOGY INNOVATION MANAGEMENT REVIEW	6	6
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	2	5
ENVIRONMENT AND PLANNING C-POLITICS AND SPACE	1	3
JCOM-JOURNAL OF SCIENCE COMMUNICATION	1	3
GOVERNMENT INFORMATION QUARTERLY	2	2
RESEARCH POLICY	1	2
JOURNAL OF INNOVATION ECONOMICS & MANAGEMENT	1	2
INTERNATIONAL JOURNAL OF PUBLIC ADMINISTRATION	1	2
EUROPEAN PLANNING STUDIES	2	2
R&D MANAGEMENT	1	2
APPLED ENERGY	1	1
TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT	1	1
JOURNAL OF RURAL STUDIES	1	1
PRODUCTION PLANNING & CONTROL	1	1
MEASURING BUSINESS EXCELLENCE	1	1
EVALUATION	1	1
INTERNATIONAL JOURNAL OF INNOVATION AND REGIONAL DEVELOPMENT	1	1
SUSTAINABILITY	1	1
TECHNOLOGY IN SOCIETY	1	1
SMART CITIES	1	1
TECHNOVATION	1	1
JOURNAL OF CLEANER PRODUCTION	1	1
TOTAL	**30**	**41**

Appendix B

Living Lab applications in the literature

Lab Name	Purpose	Country	Founding institution (s)	Year of Inception	Living Lab Model	Publication References	Website
iMec	To support startups, scale-ups, and established companies in bringing new technologies and products to market with a strong focus on nanoelectronics and digital technologies.	Belgium	The living lab division of the research institute iMec	2009	Technology Sponsor	Logghe and Schuurman (2017); Yusubova, Andries, and Clarysse (2019)	https://www.imec-int.com/en
Citilab	To promote a knowledge society based on design thinking, computational thinking and user-centered co-creation.	Spain	The Cornellà municipality. First citizen centre in Catalonia for social and digital innovation	2007	Community Anchor	Gascó (2017); Nguyen, Marques, and Benneworth (2022)	http://citylabbcn.org/
EAA	To prioritize regional co-creation and	Germany	Association of committed citizens,	2014	Community Anchor	Engels et al. (2019)	https://www.energieavantgarde.de/

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Lab Name	Purpose	Country	Founding institution (s)	Year of Inception	Living Lab Model	Publication References	Website
	experimental implementation as foundational principles for advancing energy research, technology development, business ideas, and social organization models.		municipalities and districts of Anhalt-Bitterfeld-Wittenberg region, alongside companies and research institutions				
Engergise Living Lab (ELL)	To involve end-users in the co-design of energy service solutions to create value for the sponsoring partner.	Switzerland	Consortium of local Energy services providers	2013 till 2015	Opportunity Spotter	Dupont et al. (2019)	http://www.energise-project.eu/livinglabs
Health innovation lab (HIL) Denmark	To design methodologies in hospital renovation/refurbishment drawing on input from users in order to reach solutions that are scalable and transferable to connected hospitals in the region.	Denmark	University Hospital Center	2010 till 2012	Network Orchestrator	Van Geenhuizen (2018)	https://www.centerforsundhedsinnovation.dk/
i2Cat Catalonia Digital Lab	To democratize internet research and innovation by fostering collaboration among the public sector, businesses, and university research groups, with the goal of making these advancements accessible to society.	Spain	Non-profit foundation	2002	Network Orchestrator	Almirall and Wareham (2011); Nguyen et al. (2022)	https://i2cat.net/
LineGov Brazil	To generate innovative and strategic solutions for organizations and government, acting as an agent of change with the partners	Brazil	University of Brasília (UnB), Faculty of Economics, Management and Accounting (FACE)	2012	Network Orchestrator	Criado et al. (2021)	N/A
Doornakkers Eindhoven	To promote information communication technology (ICT) usage for home care, fitness, and home safety.	Netherlands	Municipality Eindhoven; Brainport (region)	2011 till 2012	Community Anchor	Van Geenhuizen (2018)	N/A
Living lab Amsterdam	To facilitate the acceptance using ICT tracking for living and home care.	Netherlands	Municipality Amsterdam in partnership with a university ThinkTank	2011 till 2013	Community Anchor	Van Geenhuizen (2018)	N/A
NovaGob.Lab	To become an institution for innovation by creating an environment which allows innovation in the public sector.	Spain	A spin-off from the Autonomous University of Madrid (Spain)	2013	Network Orchestrator	Criado et al. (2021)	https://novagob.org/goblab
Laboratoire d'Innovation Territorial (LIT)	To organize support for innovation projects involving farmers and other users of the territory to revitalize regional agricultural innovation ecosystem.	France	Two local research institutes, but now involves eight major actors of the regional agricultural innovation system, including a private company (linked to an agricultural cooperative), an agricultural graduate school, and an innovation cluster	2016	Network Orchestrator	Toffolini, Capitaine, Hannachi, and Cerf (2021)	https://www.lit-gca.com/
Ecospace Livng Lab	To be a regionally based initiative concentrating on	Germany	European Space Agency Centre for	2006 till 2009	Technology Sponsor	Budweg et al. (2011)	https://cordis.europa.eu/project/id/035208

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Lab Name	Purpose	Country	Founding institution (s)	Year of Inception	Living Lab Model	Publication References	Website
	business incubation. It utilizes technologies within the space and geographical information domain to foster innovation and development.		Earth Observation (ESA-ESRIN),				
Urban living lab Hiedanranta	To make life smoother for future city dweller by supporting the transfer of research into smart, sustainable, and circular economy solutions	Finland	Tampere City council	2016	Community Anchor	Särkilahti et al. (2022)	https://hiedanranta.fi/en/innovations/
Apollon Living Lab	To foster knowledge creation and the adoption of energy visualization technologies among users.	Finland	Funded by the European Commission and led by local research institutions	2010 till 2012	Technology Sponsor	Ståhlbröst and Holst (2017)	https://www.aalto.fi/en/center-for-knowledge-and-innovation-research-ckir/apollon
Fab athenaeums	To promote the democratization of production and spreading concepts related to design, architecture, and smart cities where citizens, local associations, groups, universities, and businesses collaborate in the development of social innovation initiatives.	Spain	Barcelona City Council	2014	Community Anchor	Gascó (2017)	https://www.connectionsbyfinsa.com/fabrication-athenaeums/?lang=en
Transforma Lab	To help companies co-create innovation and improve the operational efficiency.	Belgium	Private Business Center	2014	Opportunity Spotter	Santarsiero, Lerro, Carlucci, and Schiuma (2022)	https://www.transformabxl.be/innovation/transforma-lab/
UNaLab	To develop smarter, more inclusive, more resilient, and increasingly more sustainable societies through innovative nature-based solutions.	Netherlands, Finland, and Italy	Funded by the European Union Horizon research and innovation program and managed by the local municipalities and members from research, business, and industry	2017	Community Anchor	Chronéer et al. (2019)	https://unalab.eu/en
Urban Lab of Europe	To provide urban areas throughout Europe with resources to test innovative solutions to the main urban challenges and analyze how these work in practice.	France	Funded by the European Council managed by the Hauts-de-France French Region	2014	Community Anchor	Dekker et al. (2021)	https://uia-initiative.eu/en
EUREF Berlin	To help companies and researchers develop and integrate new energy, mobility, and building solutions in a well-controlled open environment	Germany	EUREF AG real estate in partnership with TU Berlin University	2008	Opportunity Spotter	Engels et al. (2019)	https://euref.de/en/science-and-research/#tu-campus
Botnia LL	To contribute to the creation of a better society through digital innovations in collaboration with municipalities, SMEs, large companies, associations, researchers and end-users.	Sweden	Luleå University of Technology	2000	Network Orchestrator	Bergvall-Kareborn and Stahlbrost (2009)	https://www.bioinnovation.se/anlaggningar/botnia-living-lab/

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Lab Name	Purpose	Country	Founding institution (s)	Year of Inception	Living Lab Model	Publication References	Website
Future Internet CHallenge eHealth (FICHe)	To develop innovative applications and businesses using the FIWARE technology.	Netherlands	The FIWARE Accelerator Programme	2011	Opportunity Spotter	Haukipuro et al. (2019)	https://www.fiware.org/2016/09/13/myfiwarestory-fiche-fulfilling-the-future-internet-ehealth-challenge/
FloodCitiSense ULLs	To apply a Citizen Science (CS) approach to collect citizen-generated data about rainfall and urban flooding, addressing the emergent urban hazard primarily caused by prolonged or intense precipitation events and insufficient drainage capacity of local systems.	Belgium, UK, and the Netherlands	Vrije Universiteit Brussel and accompanying research institutes	2017 till 2020	Community Anchor	Veeckman and Temmerman (2021)	https://jpi-urbaneurope.eu/project/floodcitisense/
L3 Living Lab	To establish connections between culture, technology, and society, operating as an open, participatory, and co-creation space within a public library in Volpelleres.	Spain	A group of active residents under the Association of Residents of Volpelleres Neighbourhood (AVBV)	2015	Network Orchestrator	Nguyen and Marques (2022)	N/A
LL JOSEPHS®	To provide companies and researchers a real-life context for the creation and study of authentic use situations	Germany	Fraunhofer Institute IIS and the University of Nurnberg-Erlangen	2014	Opportunity Spotter	De Vita and De Vita (2021)	http://www.josephs-service-manufaktur.de/en/
LiCalab	To support companies and organizations in the health and healthcare sector in co-creating, evaluating, and testing innovative solutions that are better fit to the needs and context of real end users and care professionals.	Belgium	A collaborative network organisation between the Thomas More University of Applied Sciences, the City of Turnhout, the Flemish Chamber of Commerce and a Welfare umbrella organisation of 27 local communities	2012	Network Orchestrator	De Witte et al. (2021)	https://www.licalab.be/
The GENS Living Lab	To foster applied research in the security of household energy services. It is also a learning environment for researchers, key community leaders and the community in general.	South Africa	The municipality in Groenheuwel in South Africa in partnership with a community radio station (Radio KC)	Limited project	Community Anchor	Mukama et al. (2022)	N/A
Bauhaus. MobilityLab	To offer a comprehensive platform for the creation of innovative smart city solutions, supported by an IT platform that enables customers to develop, operate, and evaluate smart city applications.	Germany	The Fraunhofer Institut Angewandte Systemtechnik (AST) research institute	2020 until 2023	Technology Sponsor	Frey et al. (2022)	https://bauhausmobilitylab.de/en/experiments/
Modena Automotive Smart Area (MASA)	To test and experimentally validate innovative solutions for intelligent urban mobility, with a focus on autonomous and connected vehicles (ACVs), Advanced Driver-Assistance Systems (ADAS), and	Italy	Major industrial players from the automotive and Information and communication technologies (ICT) sectors in collaboration with the municipality of Modena and the	2017	Technology Sponsor	Della Santa et al. (2024)	https://www.automotivesmartarea.it/?lang=en

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Lab Name	Purpose	Country	Founding institution (s)	Year of Inception	Living Lab Model	Publication References	Website
	protocols of interaction among vehicles and the surrounding urban environment.		University of Modena and Reggio Emilia				
JRC Living Lab (JRC-LL)	To serve as a testing ground for new mobility solutions based on existing or envisioned policy and regulatory approaches with the aim of supporting and improving-more open, efficient, sustainable, and smarter cities. This includes technologies and innovations related to transportation, with a focus on assessing their feasibility, effectiveness, and impact.	Italy	The European Commission Joint Research Centre in collaboration with the municipality of Ispra, in the province of Varese, Italy	2019	Technology Sponsor	Della Santa et al. (2024)	https://joint-research-centre.ec.europa.eu/jrc-sites-across-europe/jrc-ispra-italy_en
BCNLab	To combine traditional arts, science and technology by supporting both existing initiatives and new entrepreneurial proposals.	Spain	The Directorate of Creativity and Innovation within the Culture Institute of Barcelona (Barcelona City Council).	2012	Opportunity Spotter	Nguyen et al. (2022)	https://www.bitlab.cat/en/projectes/bcnlab/
Healthcare Living Lab Catalonia (HCLLC)	To support healthcare innovation bringing diverse stakeholders including healthcare centers, technological centers, and other LLs across Catalonia to facilitate the prototyping, testing, and validation of solutions efficiently.	Spain	The LEITAT technological centre, developed from the Terrassa municipality's innovation platform.	2016	Network Orchestrator	Nguyen et al. (2022)	https://healthcarelivinglab.cat/
LLH (Living Lab for Health)	To promote health for and with society through educational and participatory programmes that empower citizens with the knowledge to make decisions about health and to engage in health research and innovation projects.	Spain	Governed by IrsiCaixa AIDS, a private research centre promoted by a bank and regional government.	2014	Community Anchor	Nguyen et al. (2022)	https://www.irsicaixa.es/en/living-lab-health
UABSSC	To support the university in research, technology transfer, and societal interaction particularly in the area of mobility by adopting a framework that views the university as a LL, combining smart city technology with social innovation.	Spain	The UAB, Catalonia's second largest university	2014	Network Orchestrator	Nguyen et al. (2022)	https://www.uab.cat/web/coneix-els-labs/a-campus-open-to-experimentation-1345823398630.html
The Living Lab Florianópolis	To test and implement new ideas for innovative urban growth, using infrastructures as test environments to assess the feasibility of proposed solutions.	Brazil	The Florianópolis Innovation Network, a partnership between the City Hall and the Catarinense Technology Association (ACATE).	2018	Community Anchor	Esashika et al. (2023)	https://redeinovacao.floripa.br/en/living-lab-2/

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Lab Name	Purpose	Country	Founding institution (s)	Year of Inception	Living Lab Model	Publication References	Website
Itaipu Technology Living Labs	To contribute to the advancement of tourism, technology, and sustainable development, smart buildings, ICT and sustainable urban mobility.	Italy	The Itaipu Technology Park Foundation	2003	Community Anchor	Esashika et al. (2023)	https://www.ovtt.org/en/network/itaipu-technology-park-foundation/
Porto Digital	To serve as a hub for the development and growth of the information technology sector in Pernambuco, Brazil.	Brazil	Established initially as a public policy initiative, and has evolved to include various laboratories and initiatives aimed at fostering innovation and supporting startups	2000	Technology Sponsor	Esashika et al. (2023)	www.portodigital.org
SmartiP	To empower citizens to grow and sustain a "smart city" ecosystem which is used as an enabling environment for supporting new service opportunities.	Belgium (with similar projects in the UK, Germany, and, Finland)	Funded by European commission to promote the use of open innovation for creating internet-enabled services in smart cities and managed by local city councils	2011 till 2015	Community Anchor	Paskaleva and Cooper (2018)	https://joinup.ec.europa.eu/collection/egovernment/document/smartip-smart-metropolitan-areas-realised-through-innovation-people-smartip
Kenniswijk	To facilitate the development of broadband infrastructure and diffusion of new advanced ICT services in the city of Eindhoven.	Netherlands	A cooperative of local Internet Service Providers (ISPs) with subsidies from the city	2006	Community Anchor	Sadowski (2017)	N/A
Cova da Beira Living Lab	To complete the region's existing strategies for collective efficiency based on various territorially based cooperation networks.	Portugal	Owned by the municipality and managed as a business incubator by a professional advisory board and entrepreneurs	2012	Opportunity Spotter	Rodrigues and Franco (2018)	N/A
Linky by Makers (LbM)	To explores the development of a user-driven innovation supporting French public electricity distribution network (PEDN). It also establishes the requirements of the design of a smart PEDN supported by citizens.	France	Enedis SA (French's national electricity distributor)	2015 till 2016	Technology Sponsor	Dupont et al. (2019)	http://linkybymakers.fr/in-english/
KTH Live-In Lab	To open up buildings for real-life experiments, conduct research projects, and share validated results with different decision makers in order to accelerate innovation and change	Sweden	KTH University in Stockholm in collaboration with the Swedish Innovation Agency VINNOVA	2015	Network Orchestrator	Molinari et al. (2023)	https://www.liveinlab.kth.se/start-1.1064463

Appendix C

Summary of interview themes

Main Interview Themes	Key Discussion Points
iTMT's Role and Characteristics as a Living Lab	- Mission and objectives of iTMT -Foundational context and governance structure -Nature of activities undertaken in the living lab -Key stakeholders -Changes and evolution since inception
Innovation-Support Activities	-Processes for identifying and selecting relevant projects -Types and nature of projects supported -Services offered (or desired to be offered) -Support provided to researchers/entrepreneurs in technology development and commercialization
Healthcare Innovation Ecosystem	-The key barriers hindering innovation in healthcare -Main strengths/weaknesses of the local health innovation ecosystem -iTMT's position within this ecosystem -Collaboration dynamics between ecosystem actors -Impact of the COVID-19 pandemic on the evolution of this ecosystem
Living Lab approach in healthcare	-Managing collaborations among multidisciplinary actors -Role and importance of end-users -Evolution of iTMT's network of researchers and industry actors over the years -Importance of learning (e.g., from past projects and accumulated data) -Scalability, replicability, and long-term sustainability
Outcome and impact	-Impact assessment and monitoring criteria -Adoption and diffusion of supported technologies -Feedback collection mechanisms

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