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Living labs in 'Maturation': Experimentation and Design of Innovations in Urban Sustainability

Abstract

Living labs attract much attention from innovation scientists and policymakers, thanks to the participative design in sustainability innovation, real-life settings, including open processes in learning and design of solutions. Despite large popularity, recently, several studies reveal important tensions in Living labs' practice and lack of understanding of effectiveness of the tool, affecting knowledge development, establishing of networks, and collaboratively designing of innovative solutions. As the tool's application started more than 20 years ago, this paper forwards the question whether it has matured over the course of time, and whether some evident gaps in maturation would still exist. To this purpose, we present *a scoping literature review* on the development and 'state-of the art', and conclude that the application of Living labs has reached a certain maturity. Next, after forwarding a pragmatic definition of maturation, the paper presents a tentative set of seven criteria in maturation of Living labs. Important examples are clarity in means-aim logic and design, stronger standardization, and more attention for effectiveness in evaluation. Furthermore, by adopting a *means-aim logic,* the paper identifies practical challenges for stronger maturation today and near future.

Key words: Living lab, retrospective analysis, maturation definition, maturation framework, means-aim, effectiveness, stakeholder complexity.

1. Introduction

1.1 Living labs as an innovation methodology

Living labs (LL) are conceived in this paper *as a methodology* (tool) through which citizens (users) can actively participate with other stakeholders in collaborative learning processes and design of innovative solutions (e.g. Voytenko et al. 2016; Bulkeley et al. 2019; Schuurman and Leminen 2021). There are many definitions of Living labs, ranging from large systems to a project level. The European Network of Living Labs (ENoLL), a globally working umbrella organization, defines Living labs somewhat broad, as "user-centred open innovation ecosystems based on a systematic user co-creation approach, integrating research and innovation processes in real-life communities and settings" (openlivinglabs.eu/aboutus); EC 2024). In addition, there is difference in application of Living labs between the public policy domain, and the business innovation domain. Likewise, there is difference between aims to solve distinct local sustainability issues in housing and traffic on the short term versus the short and long term (transformation) (e.g. Amenta et al. 2019; Von Wirth et al. 2019) and whether 'responsible' innovation is involved (Van Geenhuizen 2019).

Alongside differences, Living labs share two common and intertwined characteristics that set them apart from 'adjacent' experimentation tools, like test-beds, field-labs and citizen consultation. These characteristics refer to the real-life and real-time environments of learning and design that ought to represent the involved challenge and citizens. Also their participatory nature (from start) and open character of learning and design of solutions set Living labs apart (Steen and Van Bueren 2017; Van Geenhuizen 2025).

The current paper has a focus *on living labs in (large) cities*, in a context of public policymaking. Large cities are generally strongly affected by sustainability issues, because of high-density living and production activity, and sometimes vulnerable location in low lands bordering the sea (delta's). Urban living labs typically deal with *multi-scalar* influences, like from national and broader regional/urban circumstances, and macrotrends in economic and social activity (e.g. Bulkeley et al. 2019). This situation complicates identification of factors that determine success (failure) of Living labs, their upscaling, and taking steps towards transformation (Nevens et al. 2013; Voytenko et al. 2016).

Living labs as a tool has been applied from about 2005, with strong commitment among local initiators and researchers for many years. Openness on *tensions* in Living lab practice and comments on lack of large-scale ex-post evaluation emerged around 2020, while early studies had developed a focus on critical performance factors (CPFs), practical handbooks (with do's and don'ts) and action-based research in case studies, however, without the opportunity of testing and generalization. This situation has become the breeding ground for many *knowledge gaps* on causal relations, multicausality, non-linearity, etc. regarding effectiveness of the tool, and also on social dynamics and learning needs in practical use of the tool.

In this vein, the aim of the paper is to explore whether Living labs – as a policy tool - has reached a certain maturity in application and results, and which activities (attitudes) of maturity are involved and can serve as criteria to identify and measure maturation. As there is scarce research on maturation of policy tools (instruments) in general, we propose and use a set of criteria derived from literature on change and effectiveness of Living labs.

1.2 A Pragmatic Approach to Maturation

What *maturation* of policy tools would encompass, is difficult to determine, due to differences in the intended role of tools – like to facilitate necessary processes, or directly reach end-results as a change - and due to many external influences (Capano and Howlett 2020; Howlett 2022; Belcher et al. 2020, 2024). In general, research on policy instruments (tools) development is seen as very relevant, just because to date a lot has still remained unknown (Capano and Howlett 2020). Pragmatically, we take maturation of Living labs as a relatively stronger realization of effectiveness relations, given the aims, means, processes, expected (and not-expected) results, and factors beyond control.

In more detail, it includes stronger standardization regarding concept and terminology, dealing with different types of causal influence (e.g. linear/non-linear, multiple); dealing with data collection and database creation; and derived from evaluation (monitoring), a better understanding of *effectiveness and strength of impacts*. Note that using the terms of 'stronger/better' in this context is normative, namely, intuitively indicating a move to the amount/level where quality is sufficient to contribute to higher levels of effectiveness of the tool.

Regarding effectiveness in sustainability inventions, it needs to be noted that these emerge in larger socio-technical systems that are characterised by strong stability, connected to lock-in mechanisms, such as costs impacts and vested interests by large stakeholders, all of them causing resistance to change (Geels 2014; Van Geenhuizen et al. 2018). In weakening resistance, Living labs by themselves may serve as an important tool in learning about acceleration of innovation and transformation. Despite the focus on *urban* living labs, we mention that selected studies on Living labs in agricultural systems and water management are also included in the paper, in particular where lessons can be learned from them (Beaudoin et al. 2022; Berberi et al. 2023; Bhatta et al. 2025).

We develop a tentative framework of Living lab processes of maturation, and next, we explore recent practical literature on Living lab projects to identify obstacles to maturation in reality signalled in literature over approximately the past five years.

1.3 Research Questions, Method and Contribution

Against the above background, the research questions are as follows:

(1) Which are the past trends and dynamics that underly Living labs' popularity in urban innovation today?
(2) What can be considered as 'maturation' of Living labs in designing a tentative framework, and which criteria (activities) can be taken?
(3) Which challenges of Living labs have been signalled as obstacles to a further maturation, given learning, networking and innovation, in an overall aim to increase *effectiveness* of the tool?

The paper is largely a *'Scoping Review'* of existing literature, and takes as a point of departure that new planning/policy tools evolve over time, and may mature. Accordingly, the review addresses the strong popularity of Living labs but also the critical questions that emerged later on. In detail, the selected literature focuses on recent tensions in practice, and as an implication, pays attention to effectiveness of the tool and how Living labs management (can) deal with that. The collection of literature for the review by the first author started in 2015, and the period reviewed altogether lasted until early 2025. Regarding type of literature, a majority is *published literature (journals*). In addition, some 'grey' literature is used that presents novel insights or application, and novel policies, like conference proceedings, reports of policymaking organisations, and of universities and research institutes. Study of the literature for this paper essentially also includes a broader

perspective on Living labs, for example, through discussing theory of change (Belcher et al. 2020, 2024), and socio-technical and policy system views (Geels 2014; Enserink et al. 2022). *Pragmatically, maturation of Living labs is conceived as the development of better conditions serving intended processes and results in terms of increased effectiveness.*

The paper runs as follows. We develop a tentative framework of maturation of Living labs, and next, we explore recent practical literature on Living lab projects to identify obstacles in a further maturation in reality, signalled over approximately the past five years. The paper's *contribution* is the following. A systematic identification of early and late maturation of Living labs, using the literature, is new (Section 2) and designing of a related framework of maturation, following a means-end logic and effectiveness, to pinpoint the state of maturation, is also new (Section 3). Developing understandings of a further maturation in Living lab practice, in particular ex-ante stakeholder analysis and ex-post evaluation is relatively new in the framework of maturation (Section 4). Next, the concomitant results lead to advising several strategies to be adopted in designing and organizing of new Living lab projects, e.g. of effectiveness that can be generalized, all of which is relatively new (Section 5). The paper is also one of the first in which Living labs are discussed in policy tool mixes, i.e. matching with the EU technology-driven 'Research Infrastructures' (EC 2024), as major scientific equipment, scientific data and archives, computing systems etc. to conduct the newest research and foster innovation.

2. Trends: Increased Popularity but Limits in Practice

2.1 Supporting context in recent history

The time-line of Living lab methodology (tool) starts around 20 years ago. The start refers to first experiments at Massachusetts Institute of Technology in Boston, US (2003), adoption of ICT-services where products were tested with end-users in Europe, and the connected establishment of the European Network of Living Labs in 2006 (ENoLL) (Schuurman and Leminen 2021). Use of the concept has been broad, e.g. including intermediation and coordination platforms of network partners in innovation (e.g. Katzy et al. 2012), this aside from single living lab projects, all at different spatial scales, like entire city (region) areas, university or large firms' campuses, and small single site projects. Over time a stronger focus developed on creation of localized innovation projects, managing real-life experimentation and design with participation of local end-users.

The popularity of Living labs is a response to and matches with several (novel) trends in policymaking, fitting 'good governance' and innovation, and matching with the use of ICT technology (e.g. Nesti 2018). Five important supporting trends are discussed below. The *first* trend – attention for active citizen participation – is connected with the emergence of a kind of policymaking that better responds to new quality needs in local governance. Solving (urban)

problems and designing adequate public services became urgent matter after a long time of monopoly by officials with users acting as passive consumers (e.g. Ostrom 1996; Nabatchi et al. 2017; Nesti 2018). As a result, active user participation by citizens started to be seen as a way of increasing public service quality and delivery, and broader, as a kind of democratization in better implementation of policies (e.g. Ansell et al. 2017; Torfing 2019). There is also a historical link with the Scandinavian workplace democracy movement in the 1970s, emphasizing a move to participatory design by citizens (Rizzo et al. 2021). *Secondly*, important changes in the relation between science and society played a role with increased attention for citizens' initiatives, starting in the early 1990s. In those years, knowledge production began to become more socially distributed, application-oriented, and transdisciplinary (Gibbons et al. 1994; Nowotny et al. 2001), also manifesting itself in important attention to citizens in university-centred Triple Helix thinking, including firms and policy institutes (Carayannis and Campbell 2009). These changes were reinforced recently by a more prominent position of private and public sector and civic society actors in knowledge production, including citizens (Trencher et al. 2015; Hecker et al. 2018). In this vein, universities became active in establishing Living labs at their campus, like the University of Manchester (UK) (Evans et al. 2015), with applications like biking circulation and CO_2 free buildings, but also considering large sections of campuses as a Living Lab, where several sustainable solutions are designed and tested, like at the University of Utrecht (NL) (Stuckrath et al. 2025).

Acknowledging the value of citizens/laymen not only took place in public policy, a *third* and related change happened in business innovation studies, in which end-users (or customers) have become recognized as an important information source on innovation design. Subsequently, the customer-active paradigm fostered models of customer/user co-development and co-creation (Prahalad and Ramaswamy 2004; Kantola et al. 2014; Von Hippel 2017). In addition, open innovation became popular, meaning that organizations intended to become more flexible and permeable in networks, to enable the exchange of ideas with outsiders, thereby crossing disciplinary and other boundaries, and achieve better innovation performance (Chesbrough 2003; Schuurman et al. 2015).

Fourth are new trends in information and communication (ICT) as *enabling* technologies for Living lab activities and as innovations in themselves. We mention as illustration of enabling technology, real-time data transfer between (sensors of) citizens in measuring environmental quality (air, noise, radio-activity, etc.) in a distributed way (e.g. Berti-Suman and Van Geenhuizen 2020). Broadly speaking, most trends in collaboration and participation are supported by sharing information over the internet, including social media tools. Further, as illustration of the innovative technology itself, we mention Living labs on public protection and safety in streets and squares, co-ordinating traffic flow and car use, and use of AI in creating and elaboration of databases. Functions like these have come together in so-called *'smart cities'* and their ambition - through

digitalization and data integration - to increase local communities' quality of life (e.g. Caragliu and Del Bo 2018; Bauer et al. 2021; Habibipour et al. 2024).

Living labs application turned out to be very appealing since about 2010, in enabling stakeholders to design innovative solutions, thereby reflecting strong democratic value and citizen empowerment (Almirall et al. 2012; Katzy et al. 2012; Ballon and Schuurman, 2015; Leminen et al. 2015; Schuurman et al. 2015; Claude et al. 2017; Hossain et al. 2019). Sectors in which early Living labs were applied have often been *ICT-based*, like in monitoring in elderly healthcare, and broader safety and security issues in cities (e.g. Ballon et al. 2018), rehabilitation of hospitals and public places like shopping centres, in particular serving mobility and social integration of disabled people (e.g. Mazer et al. 2015; Spinelli et al. 2019; Verbeek et al. 2023), new housing retrofitting from the viewpoint of sustainable energy, avoiding fossil fuel use and enhancing energy saving (e.g. Bulkeley et al. 2016; Voytenko et al. 2016; Engels et al. 2019; Von Wirth et al. 2019; McCrory et al. 2020; Molinari et al. 2023). *New applications* are currently developed in coastal areas, focusing on sensor systems, sea-defence works, novel green energy production (wave-based) and sea-farming (Vervoort 2021; Bhatta et al. 2025; Van Geenhuizen 2025).

2.2 Early Signs of Maturation

Despite euphoria, much has remained unclear in the application of Living labs, like the relation between inputs to Living labs and short- and longer-term output effects (impacts). Question marks have also emerged concerning dynamics in process characteristics and best ways of steering on them, like manifold learning between stakeholders, defining their roles, and timing of the creation of mutual understanding and trust (e.g. Hakkarainen and Hyysalo 2013; Nystrøm et al. 2014; Mastelic et al. 2015; Bhatta et al. 2025). Most networking and learning is internal between participant stakeholders, while part of the learning processes also works in interaction with external stakeholders and networks. Challenges connected to the last, refer to small embeddedness of Living labs in the city, i.e. functional as providing input to the Living lab at hand, like learning about other innovation tools in the city, and knowledge on location- or site-specificity of Living labs, in other words, which part of the site characteristics is generic and which part is specific and may seriously matter in replicating Living lab results and upscaling (Dijk et al. 2019; Van den Broek et al. 2020; Scholl and De Kraker 2021).

With regard to *causal relations*, many *early* studies emerged about inputs (means), intended processes, in particular about *critical performance factors* (CPF), the last being assumed to influence Living lab processes and outcomes (e.g. Guldemond and Van Geenhuizen 2012; Ståhlbröst et al. 2012; Veeckman et al. 2013; Ballon et al. 2018). In a similar vein, important do's and don'ts have been addressed in practical handbooks (e.g. Evans et al. 2017; McCormick and Hartmann 2017; Habibipour et al. 2020). Publications of conceptual frameworks for evaluation of Living lab results followed, using system thinking (input-throughput-output) and/or Theory of Change (ToC) (e.g. Van Geenhuizen 2018; Belcher et al. 2020, 2024; Forbat et al. 2025; Leminen et al. 2025).

It needs to be mentioned that an important broader context for understanding Living labs' processes and results, is so-called *system theory*, specifically applied to socio-technical systems. In a nutshell, in such systems, like in energy, healthcare, materials recycling, etc., systematic change to higher levels of sustainability is usually hampered and delayed. This development follows from so-called *regime* factors that are firmly anchored in mainstream social and economic behaviour, and in institutions concerned (e.g. Smith and Raven 2012; Geels 2014; Fuglsang et al. 2021). Regime factors include vested interests, existing regulation, pricing and behavioural routines of the main stakeholders, etc., causing resistance to change, including the project level.

Furthermore, the character of planning models and traditions used in cities (countries) may influence Living labs' application. Such influence, which can be seen as external influence beyond control, holds true for differences in openness and flexibility in planning, namely in requiring a set of prior defined steps and outcomes; this in contrast to emerging and open steps and open decisions on processes (e.g. Nystrøm et al. 2014; Leminen and Westerlund 2017; Hossain et al. 2019; Compagnucci et al. 2021). Evaluation methods may differ accordingly (Crosby and Noar 2011; Walker et al., 2013; Ahmed et al. 2017; Dewulf and Biesbroek 2018).

2.3 Later Signs of Maturation

Openly addressing tensions and obstacles in Living labs' professional practice can be seen as *later* signs of 'maturation' of Living labs, and this started in literature around 2020 (e.g. Dijk et al. 2019; Companucci et al. 2021; Rizzo et al. 2021; Scholl and De Kraker 2021; Nguyen and Marques 2022). The resonation of this particular literature resulted in forwarding urgent needs for systematic evaluation of Living labs and for statistical generalization using larger datasets (e.g. Bronson et al. 2021; Paskaleva and Cooper 2021; Beaudoin et al. 2022; Forbat et al. 2025). One of the reasons forwarded for largely absence of such evaluation, is the problematic comparison of Living labs, due to different size and time-duration, different technical and institutional sector dynamics, different sets of stakeholders and application of different learning and management models. This brings our focus on standardization.

Early attention has been paid to more precise definitions and typologies of Living labs, like type of innovation processes (tools) and stakeholders' roles, since about 2015 (e.g. Leminen et al. 2015; Leminen and Westerlund 2017), and this has been reinforced in a call for *standardization* later on (2021) and recently accomplished for the health sector. Accordingly, to prevent negative impact from large diversity among Living labs and to improve interoperability between Living labs and other tools or methodologies, a project started in 2021 with the aim to design a standardization framework, including common aims and methods of Living labs, and terminology, etc. (VITALISE PROJECT) (Konstantinidis et al. 2024). This attempt to harmonization would enhance opportunities for better monitoring and for ex-post evaluation, and would make upscaling of Living lab results more realistic.

In the meantime, attention also emerged for *instrument mixes*, including other participative approaches like citizen science and citizen consulting, and other experimentation like in field labs, and Triple/Quadruple Helix instruments (Carayannis and Campbell 2009; Capano and Howlett 2020; EC 2024), and the use of Living labs seems to broaden in mixing and merging with other tools.

The above findings in the literature enables to design a preliminary framework of Living labs maturation in the next section.

3. Maturation: Framework and Practice

3.1 Exploration of maturation

What maturation of a policy tool in general would encompass, is difficult to determine, as above indicated, due to differences in tools' roles and in stage of development, and many different external influences (Capano and Howlett 2020; Howlett 2022). *Pragmatically, we take maturation of Living labs as the developing of better conditions for improving intended processes and results in terms of effectiveness.* The eight tentative criteria (as activities (attitudes)) include the following:

(1) Clarity in design of means-aim or input-throughput-output
(2) Effectiveness and evaluation
(3) Doubt on results in practice (perceiving tension and obstacles)
(4) Need for Standardization (conceptualization and terminology)
(5) Willingness to learn continuously
(6) Embeddedness in urban setting and clarity about upscaling
(7) Connection with transitional change
(8) Overall reflection and positioning.

First, importantly, the above criteria partially overlap due to causal relations, like between increased emphasis on tension and challenges, and increasing attention for effectiveness and broader impact.

Our search for maturation in Living labs, is structured using a framework with inputs (I), throughput processes (II) and output/outcomes (III). We have labelled the several conditions accordingly in Table 1. We also include exogenous influences (IV). Overall, maturation tends to affect all elements in the input-throughput-output framework (Table 1, first column).

Table 1 Tentative criteria (activities/attitudes) in LL maturation and elements

Activity/attitudes (in brackets: place in input-throughput-output chain etc.)	**Elements (main examples)**
1. Increasing emphasis on aims and links with results, and unicity of tool (I-II-III-IV)	-Aims, means, processes, expected results -Differences with other tools -Critical performance factors and assessment frameworks -Ex-ante, monitoring and ex-post evaluation
2. Emphasis on tension and challenges ((I-II-III-IV)	-Emphasis on *realistic* thinking -Focus on problematic situations
3.Increasing attention for standardization (I-II-III)	-Concepts, terminology, dealing with causalities, data selection and collection; also, needs for some flexibility
4.Increasing attention for effectiveness and broader impacts, in more quantitative evaluation (I-II-III-IV)	-Understanding of means-aim rationality (input-output), and influences *beyond control* -Attention for quantitative evaluation (generalization)
5.Willingness to learn continuously (in more or less open ways) (I-II-III-IV)	-Learning between stakeholders in Living labs to enable trust-building and collaborative design of solutions
6. Increasing attention for embeddedness in urban setting (I-II-III)	-Connect with other urban innovation projects -Understanding of site-specificity in upscaling of results -Understanding of mutually reinforcing policy mixes
7.Increasing attention for LL contribution to transitional change (all)	-Connect with development scenarios and early warning signals
8. Overall reflection through own history writing and characterization (by ENoLL) (all)	-New attention to evaluation of effectiveness, or other criterion -Positioning towards other policy tools

4. Recently Perceived Challenges

4.1 Introduction

We present recent case study evidence on challenges in application of Living labs. Such challenges are important to signal, as it is assumed that maturation, like other system changes, takes place at different times, and in different pace and intensity. The evidence is ordered and detailed in Table 2. Subdivisions in the table are made according to learning (knowledge), networking, and innovation

4.2. Detailed Challenges in Current Stage of Maturation

Though maturation has taken off, there are still important challenges in practice, as apparent in recent literature, with a focus on *public* living labs. First, recent writings have put emphasis on short in *anticipative learning* before or during start of the Living lab (Table 2, point I.1 and I.2) (e.g. Dijk et al., 2019; Van den Broek et al. 2020; Bhatta et al. 2025; Van Geenhuizen 2025). Such a situation holds in particular for Living labs' intended contribution to transitional change, different stakeholders' roles in the problem and in potential solutions, and Living labs' *site-specificity* and upscaling potentials. Benefits from systematic learning are specifically addressed more recently by Bhatta et al. (2025).

A weak anticipative learning specifically refers to *stakeholder analysis* (point I.1). In general, it is a difficult task for Living labs' managers at start of a living lab, to select relevant stakeholders that represent different sides of the problem/challenge. There is not only the danger of 'self-selection' by action-oriented stakeholders, potentially undermining representativeness of results (e.g. Michels and De Graaf 2017; Dijk et al. 2019; Companucci et al. 2021), but also of 'ignoring' (sharp) differences in power position between stakeholders, if a 'consensus' living lab model is used in practice (Van Geenhuizen 2025). Such circumstances would influence legitimacy and democratic value, and may cause smaller (perceived) *policy relevance*. What is also often missing, is learning about an adequate duration of Living labs (number of years) and matching with the intended changes, given potential system resistance and delay.

Importantly, several practical challenges have been signalled in the core learning (co-creation) processes at project level (Table 2, point II.1) mainly among participants, concerning *short in time* for e.g. consensus meetings, short in capabilities and motivation, and concerning missing guidelines and shared understanding of the Living lab methodology (Nguyen and Marques 2022; Bhatta et al. 2025).

The challenge of Living labs is also to keep momentum in internal networks, after a good start, maintain high levels of participants' involvement and motivation, and prevent open processes turning into *closed* processes. Several 'dangers' have been observed, similar to '*older'* literature, like diminishing motivation of stakeholders and diminishing trust. Avoiding such situations requires adequate understanding of practical social dynamics and management approaches, e.g. to create (repair) inclusiveness and features like trust, openness, multidisciplinary, and iteration (Liedtke et al. 2012; Hakkarainen and Hyysalo 2013; Nystrøm et al. 2014; Mastelic et al. 2015; Schuurman et al. 2015).

Next, we address that maturation could be delayed if interests of involved municipalities differ between cities and within cities (quarters), some being closely interested and active as managers of a set of living labs, and others remaining more off-side. Table 2 (point III) indicates that dependent on processes in Living labs' practice, results may be different in convincing power and legitimacy towards municipalities. In view of dissemination, an active municipality is preferred,

as it makes an integration of the Living lab results with other innovation projects/programs much easier and also potentially more fruitful (Kronsell and Mukhtar-Landgren 2018; Nesti 2018; Dijk et al. 2019).

In particular in energy sustainability, the role of municipalities can be comprehensive, like in Living labs on municipal buildings (offices) aimed at decarbonization (through solar energy; city heating), improvement of energy efficiency, and use of smart energy services. In an organizational sense, such municipal experimentation could also involve collaboration in practical application of innovations developed at local universities, through spin-off firms, eventually in Triple or Quadruple Helix context (Van Geenhuizen and Nejabat 2021; Van Geenhuizen and Nejabat 2023). Municipalities' acting as a 'launching customer' accelerating market introduction, is another example.

Regarding Living lab's results (point III), upscaling of Living lab results tends to be more an exception than a rule. Oftentimes, it has *not* been included in planning of the different Living lab activities. Upscaling - in the sense of application of the results at other (similar) places - requires understanding of site-specificity, both in a social sense (local network/tissue, stakeholders) and concerning built environment, incl. physical infrastructures. Such understanding is often fragmentary or missing, or is still in development (e.g. Vreugdenhil 2010; Dijk et al. 2019; Engels et al. 2019). A weak understanding of what hampers upscaling, points to important remaining issues in maturation (e.g. Von Wirth et al. 2019; Ersoy and Van Bueren 2020; Bronson et al. 2021; Scholl and De Kraker 2021). Consequently, upscaling may be seen as too ambitious for the time and state of maturation, and not as an aim. Accordingly, a more realistic approach can be provided by solid communication of Living lab results, like using a web-portal, share test sessions with demonstration and prototypes exhibition, sharing newsletters, etc. (Compagnucci et al. 2021). Such approach can support in decreasing several lock-ins (technology, institutional, legal), better anchoring results and take Living labs further into daily routines of urban policymakers and speed-up maturation (Rizzo et al. 2021).

And finally, Table 2 indicates that small attention has been given to external *influences beyond control* of Living labs' management (point IV), while originating from the broader socio-technical situation where 'regime factors' may block change (Geels 2014). Such cases of limits set at the system level, need to be recognized and understood, and incorporated in collaborative learning and co-creation in design of solutions. A similar attention is also required for spatial systems and influences from higher urban level to the local level, like in the hierarchy of services.

The challenges addressed above are still considerable and point to limited maturation. This situation prompts the question whether maturation can be accelerated, and which ways would be most effective.

Table 2. Recently Signalled Challenges in Maturation of Living labs (LL)

	***Challenges* in practice/action**
I (1) 'Inputs': Preparation incl. *Anticipative* learning)	*Anticipative learning*, in particular: -Stronger reflection on intended transitional change (socio-technical and policy systems), specifically testing and upscaling of LL results and required time. -Stronger learning on 'factors beyond control'; on stakeholders' positions and the problem (stakeholder analysis*)*; on needs for representativeness in stakeholder and site selection (short in standardisation) -Stronger preparation of monitoring and dealing with early warning signals *Networking in broader policy context:* -Stronger embedding in and learning about past/on-going broader urban (municipality) research programs -Stronger match of duration of LL projects with comprehensiveness of subject matter and need to continue projects in view of more solid results.
I (2) 'Inputs': Real-life environment	*Learning/knowledge* -Stronger understanding of site-specificity and relevance in upscaling -Better dealing with rules and regulation concerning accidents, privacy etc.
II (1) Co-creation, design processes	*Networking and learning (internal in LL)* -Participants need more time, better match of capabilities (e.g. language and understanding different culture) and stronger motivation to participate; also, their learning potentials need to be better used (short in guidelines and understanding of methods). -Participants ask for quicker decision-making by management -Specific stakeholders hesitate and require more motivation to participate -Trust among participants need to increase and preserved *Networking and learning on the way* -Citizens/users need to increase motivation and prevent abandoning if intended LL results are not quickly achieved -Open projects need to be prevented turning into closed projects with aversion against disruptive/ undermining of established stakeholders' interests -Discontinuity needs to be prevented in participants (when moving to new projects/employers) -Managers need to prevent facing tension and short in resources for continuation
II (2) Participation in broader context	*Networking (broader context)* -Relevant stakeholders have to increase motivation to participate with broader relevance and appreciation of LL learnings (e.g. indifference of municipality) -Living labs should be better connected to other innovation projects in the city/region -Constraints from regulation and business (market) environment need to be better identified and dealt with.
III. Outcomes: Policy/Innovation relevance; Dissemination and Upscaling	*Innovation* -Outcomes may be incidental, without structural impact in broader urban policy/planning; emergence of weak democratic value and relevance needs to be prevented -Existing power structures may be reproduced (not challenged), not matching citizens' expectations on improvement/innovation - Small testing and upscaling (dissemination), because not-included in formal project aims -Innovative solutions need to be better embedded and anchored in city quarters -Municipality could be stronger involved

	-Results would be better linked with intended translational change
IV. External influences beyond control	*Networking and knowledge* -Stronger awareness on diversity and fragmentation among *external* stakeholders and institutions, and on strong and firmly established power relations (lock-in) (system constraints) -Preventing that decision-making remains *traditional* and/or *planning models* do not match new ways of policy design, causing delay in practical use of LL results -Budget constraints may arise, hampering next LL steps towards upscaling -Unforeseen events (change) elsewhere in cities may influence LL processes -Disturbance of projects by activity on a different spatial level of city services.

5. New Understandings and Needs

5.1 Stakeholder Analysis

In general in policymaking, it is important to gain understanding of different intentions of stakeholders involved in the challenge at hand, given their different problem perceptions, interests and power to respond to challenges (Enserink et al. 2022), and this also holds for application of living labs (Steen and Van Bueren 2017; Imset et al. 2018; Nesti 2018; Dijk et al. 2019; Leal Filho et al. 2023). Using ex-ante analysis of the roles and different strength of involvement of stakeholders, dynamics and temporality can be explored (identified), and eventually, anticipated.

Also, network analysis is helpful, which may reveal increasing conflicts and polarization between different stakeholders, or the reverse, relaxing in controversial relations and finding common ground for fertile coalitions (Enserink et al. 2022). Owning such knowledge provides a better basis for ex-ante developing of problem definitions, for getting the relevant (representative) citizens/users on board in the Living lab, and for designing strategic paths in experimentation and design (e.g. Companucci et al. 2021).

According to Imset et al. (2018), the following features are worth investigating in stakeholder analysis, namely, their different potential influence on the Living lab, e.g. power/authority held by them, their type of use (way of participation), their overall interest and interest in specific projects, and their attitude (as blocker or backer). In stakeholder analysis, the aim is to identify common ground and potential coalitions between stakeholders, but also conflicts and fault lines, thereby ensuring that all stakeholders are known and involved, and their values and arguments understood. Easy to use methods are standard interviews on motivation and abilities, as well as policy games. In contrast, open interviews e.g. following Q-methodology, require more research time as the aim is gaining sets of richer results. The methodology uses a structured, both qualitative and quantitative, approach to identify the variety of perspectives in a group (e.g. Enserink et al. 2022). It allows for an open, bottom-up exploration of perspectives, rather than pre-defined categories. What also deserves more attention today is the creation of practical conditions to achieve mutual

understanding and trust between participating stakeholders. Language differences and cultural challenges are prominent examples (e.g. Klotz et al. 2023).

5.2 Ex-post evaluation

With regard to ex-post evaluation, thinking about living lab results started to grow with (theory- and/or cases inspired) design of *critical performance factors (CPF)* since about 2010. What is striking to date is that lists of such critical performance factors have seldom been tested on actual causal links with Living lab results, using representative samples that would enable statistical generalization (e.g. Ballon et al. 2018; Bronson et al. 2021; Paskaleva and Cooper 2021). Examples of most recent studies signalling this challenge are a bibliographic review of evaluation studies (Berberi et al. 2023) and an actual quantitative modelling of Living lab results (as open innovation) (Leminen et al. 2025).

In existing evaluations the focus is often on *action-research* to increase in-depth qualitative understanding of critical learning in practice (e.g. Dell'Era and Landoni 2014; Logghe and Schuurman 2017; Imset et al. 2018). In this approach, which makes use of participant observation, researchers and participant stakeholders act and learn together using a *holistic* view with strong attention to complexity and the multi-dimensional character of problems, thus producing highly valuable evidence. Ex-post evaluation aimed at statistical generalization of effectiveness has remained behind, and this is connected to the following situations (e.g. Prota 2019):

- *Heterogeneity of living labs*. The situation of manyfold differences between Living labs, comes with the question which categories can reasonably be compared and which not. Of course, this is connected to weak standardization in the use of Living labs to date.
- *Multiple visions on what (matter) should be evaluated.* The focus on *effectiveness* can be manyfold, like on implementation of inputs (interventions) and specific learning results gained on the way, but also or longer term impacts on transitional change (Beaudoin et al. 2022; Von Wirth et al. 2019). Assessment frameworks have been designed by e.g. Bouwma et al. (2022) and Forbat et al. (2025).
- *Openness in Living lab comes with fuzzy results*. Open and co-creative learning make evaluation to a certain extent 'fuzzy', with somewhat 'moving' aims and outputs to be evaluated Much depends on the underlying planning models, namely, strict in perceiving causality links, or more flexible (Enserink et al. 2022).
- *Evaluation as a participatory task.* In collaborative problem-analysis and co-creative design, evaluation is preferably organized on participation, providing perspectives that are credible in framing key evaluation questions (Van Geenhuizen 2018; Beaudoin et al. 2022). Such approach may come with delay.
- *Causal complexity.* Such complexity is evident in multiple causality, non-equilibrium, non-linearity, chains of causation, circular causation, etc., and tends to be particularly true for

dynamic multi-stakeholder situations in governance and interaction with external influences (e.g., Walker et al. 2013).

- *Specific data characteristics.* Part of Living lab data on processes and results is vague, imprecise and biased, and follow from partial/fragmentary opinions among stakeholders. Such information is often measured on rank or categorical level, thereby limiting choices in statistical analysis (Leminen et al. 2025). However, use of AI (self-learning methods; data-mining) provides new opportunities to overcome limitations.

With regard to *techniques of analysis*, regression analysis and structural equation analysis are important 'candidates', but data characteristics of Living labs may set limits. Alternatively, self-learning (AI) techniques are a solution in matching with the often skewed distributions and low level (measurement) data etc., for example, in *rough-set analysis*. This technique focusses attention on identification of decision rules (e.g. Stefanowski 1998; Ragin 2006) or more advanced pattern-recognition, drawing on data-mining (Viertl 2011; Jiawei et al. 2012). Rough-set analysis is recognized as a useful technique, particularly in comparative analysis in domains like urban revitalisation, university incubation of spin-off firms. Rough-set analysis can be easily applied given standard software (e.g., Abbas and Burney 2016). Increasingly, more advanced techniques are available (e.g. Lee 2014), e.g. fuzzy set qualitative comparative analysis (fsQCA), which enables to disentangle multi-causality and critical values after or below which Living labs' performance significantly changes. At the same time, using *advanced* regression analysis and reaching statistical generalization may also overcome above-indicated limitations (like STATA ERMs 2023).

Given the complexity involved, it seems reasonable that (large scale) evaluation of Living labs is a task to be taken up by overarching organizations, like ENoLL and specialized university departments. As Living labs have often been performed as single projects with attention to short term results and limited management capacities, the more recent development of platform Living labs is promising. In such platforms for co-creation, multiple co-creation projects on diverse social issues are promoted through mutual interaction among them. The long-term operation of *platform living labs* is important for achieving social innovation and transformation through the Living lab approach. However, adequate methods and tools in sustainable management and operation of the platforms (Living lab platform canvas) have not yet received sufficient attention in practice. The EU SOILL Hub initiative (2025) is one of the first platforms to enable above-indicated large-scale evaluations.

6. Concluding Remarks

We explored the maturation of Living labs as an innovation methodology over time, principally in a framework of effectiveness in processes and producing results. In addition and supporting maturation, important new initiatives are recently taken to improve the situation, like development of standardized approaches and large scale implementation of Living labs as a platform innovation tool. In more detail, a stronger *anticipative learning* has been addressed, specifically the analysis

of dynamic stakeholder situations (Dijk et al. 2019; Bhatta et al. 2025). Also, it has been forwarded that critical performance factors' relative importance in effectiveness still have to be assessed ex-post, preferably enabling statistical generalization (Engels et al. 2019; Bronson et al. 2021). Challenges of using rough-set analysis have also been emphasized in attempts to increase maturation of Living labs.

This paper is largely a scoping review. A weakness that is difficult to avoid in such review, is the often merely 'touching upon' relevant issues. A challenge that has been addressed but not elaborated, is management of Living labs, given sometimes low motivation for participation, and short in resources (time) and capabilities, frustrating the necessary learning activity. Future research is needed on best practice solutions and best methods involved.

Strong leaps forward in maturation can be taken by several strategies. First, extending standardization while not neglecting needs for some flexibility; secondly, better understanding of upscaling issues e.g. site-specificity and anchoring Living labs within municipalities; and thirdly, by testing effects of causal factors and models, alongside the rich combination with action-based approaches to Living Labs' results over time. These strategies particularly hold also for the currently developing large-scale platform-based Living labs, as well as the bonding with 'adjacent' tools of Living labs, and role of AI in planning and evaluation techniques.

Further, several important research questions on maturation of Living labs have remained unanswered. Most important seems the choice in a conceptual sense adopted in this paper which has been *effectiveness* in an input - throughput (processes) - output (results) framework. The criteria selected to identify/measure maturation over time, are accordingly. However, other underpinning models or mixes of models are also possible, e.g. focussing on increased citizen democracy or responsible innovation, coming with (partially) different criteria (Van Geenhuizen 2019). In addition, the questions can be posed to what extent maturation can be enhanced and accelerated? And, which stakeholders would be involved in such adaption?

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