Living labs “Coming of Age”: Experimentation in Urban Energy Sustainability

Abstract

This paper deals with a policy (management) tool aimed at enhancing innovation, introduced about 20 years ago: living labs. Living labs as a tool has attracted attention by policymakers for many years, thanks to the participative design for citizens, real-life settings and open innovation. However, recently, case studies reveal several tension in living labs' practice and lack of understanding of effectiveness of results. In the first part, the paper presents *a scoping literature review* on the ‘state-of the art’ and concludes that application of living labs has reached a certain maturity, but still calls for attention for three important conditions, namely, a stronger anticipative learning on stakeholders' different interests and problem perceptions, an extended ex-post evaluation on effectiveness; this alongside a stronger involvement of municipalities. In the second part, in view of improvements, the paper discusses causes of complexity in stakeholder analysis, and ex-post evaluation, and forwards a set of practical decisions to be taken. With regard to involvement of municipalities, the paper puts emphasis on desirability of a stronger and more coherent involvement in important steps in transitional change. This holds for experimentation and design of energy solutions concerning housing stock and wider facilities owned/managed by municipalities, for acting as launching customer, and eventually broader, for acting as one of the leaders of an innovation community.

1. Introduction

Living labs are conceived in this paper as a tool or methodology through which citizens (users) can actively participate with other stakeholders in collaborative learning and design of solutions to sustainability problems. The ‘living’ character refers to real-life and real-time environment in which the methodology is implemented. In everyday language, the term living labs is also used for the organization and physical places involved. In addition, it needs to be noted that living labs is used as a buzzword in pointing to an innovative organization or an area, without a specific meaning and boundaries.

From the beginning in the early 2000s, living labs application turned out to be appealing in driving co-creation between stakeholders to reach innovative solutions, thereby reflecting high 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 living labs are applied are (very) different, like in safety and security (digital innovation), (e.g. Ballon et al. 2018), health care and rehabilitation (hospitals, public places), in particular elderly care and reintegration of disabled people (e.g. Kehaya et al. 2014; Mazer et al. 2015; Spinelli et al. 2019). The largest application sector is energy sustainability, for example, aimed at decreasing fossil fuel use in urban housing and traffic (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 city area, focusing on sensor systems, sea-defence works, novel green energy application (wave-based) and sea-farming (Vervoort 2021; Van Geenhuizen, 2024).

The current paper has a focus on living labs in (large) cities. Cities are facing high energy consumption levels and a large share in global greenhouse gas emission (Eurocities 2020). At the same time, urban living labs deal with *multi-scalar* influences, like from national and broader regional/urban circumstances, and macrotrends in economic and social activity, but living lab management cannot or can only slightly change these *external/exogenous* influences (e.g. Bulkeley et al. 2019). This situation complicates the identification of factors that determine success (failure) of living labs. In more detail, sustainable energy inventions 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, 2002, 2014; Van Geenhuizen et al., 2018). In fighting resistance, living labs is only one tool in intended shifts towards energy transitions.

Overlooking the many studies (e.g. Steen and Van Bueren 2017; Van Geenhuizen 2018; JPI 2022), living lab methodology shares *two unique values*, as compared with ‘adjacent’ experimentation tools (test beds, field labs, citizen/user consultation), namely, early user involvement in interactive (co-creative) learning and design, and practice in real-life environment that represents the sustainability problem and stakeholders. Despite popularity, it increasingly appears that urban living labs are vulnerable to tension, calling for challenges to implement change, often connected to dynamic multi-stakeholder situations.

Since inception of living labs, many studies have been published about inputs (means) and intended processes in living labs, and also about *critical performance factors* (CPF), the last 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; Van Geenhuizen 2018; ENoLL 2019; Santonen 2020; Bergmann et al. 2021). In a similar vein, important do’s and don’ts are addressed in practical handbooks (e.g. Evans et al. 2017; McCormick and Hartmann 2017; Habibipour et al. 2020). In the meantime, more precise definitions and typologies of living labs are forwarded like drawing on type of innovation processes and different stakeholders’ roles (e.g. Leminen and Westerlund 2017; Berberi et al. 2023). In addition several service organisations emerged in the energy sector, like in Switzerland in 2020 aimed at supporting energy initiatives and living labs (Energy Living Lab Association, 2024). Energy solutions that may benefit from living lab approaches include for example, district heating systems, smart energy services, energy efficiency programs, and energy management systems (sensor supported).

Addressing tension and challenges in living labs’ practice started around 2018 (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 (e.g. Bronson et al. 2021; Paskaleva and Cooper 2021; Beaudoin et al. 2022), and this signals a ‘growing up’ of living labs and a potential turning point, where practical application calls for action and adaptation serving a *new generation* of living labs (JPI Europe 2022). This happens however in a situation of fragmentary understanding of practical challenges and of partial assessment of influence of causal factors and statistical generalization using larger samples (Voorberg et al. 2015). Against the above background, the research questions are as follows:

(1)Which are the trends and dynamic contexts that underly living labs' popularity in urban innovation today? And what remaining tensions of living labs have been signalled in recent empirical studies?
(2)Which *implications* can be perceived in knowledge enhancing and learning for changing the situation in an overall purpose to increase policy relevance of urban Living labs?

The paper's contribution to literature is the following. As a scoping review, it is one of the first writings that considers the popularity of living lab methodology in a clarifying context of new societal and policymaking trends since the 1990s, yet also points to limits from a system perspective (section 2.1). Next, and in more detail, the paper presents an overview of practice-oriented tension in application of the methodology in the past 4/5 years following an input-throughput-output/outcome logic (section 2.2). This overview leads into presentation of strategies that are advised to be adopted at the level of individual living lab projects, focussing on basic knowledge extending in ex-ante learning, specifically stakeholder analysis, and on ex-post evaluation of living lab results, e.g. of effectiveness, which are relatively new (section 3).

2. Scoping Review

The paper is partly a *'scoping review'* of literature and takes as a point of departure that new planning/policy tools evolve over time. Accordingly, the review addresses the strong popularity of living labs but also the emergence of unanswered critical questions. In detail, the selected literature focuses on recent tensions in practice, and as an implication, pays attention to effectiveness of the tool. As indicated previously, the review deals with urban sustainability issues, in particular sustainable energy.

The collection of literature for the review started in 2010, both retrospectively and simultaneously, and lasted until early 2024. Further, regarding type of selected literature, a majority is *published literature (journals*). In addition, some 'grey' literature is used that presents novel insights or application, like conference proceedings, reports of policymaking organisations, and of universities and research institutes. Study of the literature for this paper essentially also included a broader perspective on living labs, for example, theory of change, and socio-technical and policy system views.

2.1 Dynamic Contexts of Change and Planning

The time-line of living lab methodology as a tool can be summarized as follows. Living labs are in practice for around 20 years since first experiments at Massachusetts Institute of Technology (2003) and establishment of the European Network of Living Labs in 2006 (ENoLL) (Schuurman and Leminen 2021). After start, use of the concept was broad, e.g. including intermediation and coordination platforms of network partners in innovation (e.g. Katzy et al. 2012) but also single living lab projects, all this at different spatial scale, like entire city (region) areas, university or large firms' campuses, and single site projects. Over time a stronger focus developed on study of localized single projects managing real-life experimentation and design with participation of local end-users. Attention also emerged for *instrument mixes*, including other participative approaches like citizen science and citizen consulting, and other experimentation like in field labs (Capano and Howlett 2020; Veeckman and Temmerman 2021; Pfotenhauer et al. 2022). Experts in the field nowadays talk about a global movement (Leminen and Westerlund 2019; Schuurman and Leminen 2021), though most living labs have been established in Europe (e.g. under the important influence of R&D financed within Horizon 2020).

The popularity of living lab methodology is a response to and matches with several (novel) trends in past policymaking and innovation, and in use of ICT technology (e.g. Nesti 2018). In addition, awareness has increased on certain limitations following from growing uncertainty in transitional change, and in policymaking and planning models concerned (e.g. Funtowicz and Ravetz 1993; Dewulf and Biesbroek 2018; Baudoin et al. 2022). The 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 needs for new qualities 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, underpinning 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, transdisciplinary, and it became subject to multiple accountability (Gibbons et al. 1994; Nowotny et al. 2001). These changes were reinforced recently by a more prominent position of public sector and civic society actors in knowledge production, with citizens as participants in solving societal challenges, including data collection (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 application areas like biking circulation and CO_2 free buildings.
Thirdly, in business innovation studies, users (or customers) have become recognized as an important information source on innovation design, and 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 specific environmental qualities (air, noise, radio-activity, etc.) in a distributed way (e.g. Berti-Suman and Van Geenhuizen 2020), and visualization support in learning sessions (e.g. Wilson and Tewdwr-Jones 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. 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).

An important context for understanding living labs' processes and results is so-called change 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. Such development follows from so-called *regime* factors that are firmly anchored in mainstream social and economic behaviour, and in institutions (e.g. Geels 2002, 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. However, resistance may be decreased by convincing outcomes of experimentation, like in niches as 'protected places' (e.g. Smith and Raven 2012) and in real-life living labs, eventually enabling first steps towards transition (Belcher et al. 2020). Figure 1 shows in a simplified multi-level model of socio-technical transition, the lowest level of niches with processes of experimentation like in living labs. Learning processes and designed solutions may become convincing, and successful upscaling may gain overall legitimacy among important actors, in such a way that their pressure can be coupled with pressure at the landscape level (like from the Paris Agreement) creating opportunities for (radical) change. In fact, a myriad of breakthrough paths is being created, of which only a few are successful and become mainstream.

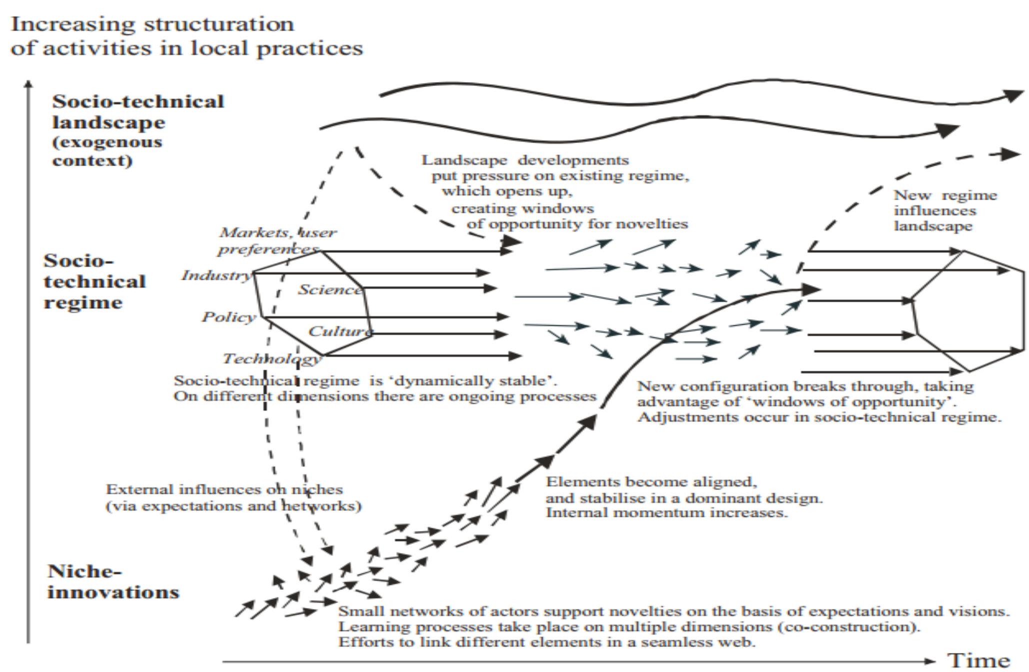

Figure 1 A simplified multi-level model of socio-technical transitions (Geels, 2002)

Furthermore, the character of planning models used in cities may influence living labs' application. This influence holds for differences in openness and flexibility in planning, namely in requiring a set of prior defined steps and outcomes, 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). Different planning models in this sense would also be coupled with difference in evaluation methods, namely, when *intended* results are determined in detail *prior to start* of the living lab, including back-casting to set the necessary processes/steps, like in precede-proceed models (Crosby and Noar 2011; Ahmed et al. 2017). More open models, in contrast, would take a broader perspective in evaluation, work with bandwidths of results and with monitoring of early-warning signals (Walker et al. 2013; Dewulf and Biesbroek 2018).

2.2 Challenges in Recent Application

We present recent case study evidence on tension and problematic situations in application of the tool is ordered according to the logic of *input (interventions) – learning processes (co-creation) - output (outcomes) (direct/indirect results)* (Figure 2). Exogenous influences stand for those factors that exert influence on learning and design processes and outcomes, but remain beyond control for living labs managers and policymakers. Examples are not expected pricing by large energy suppliers, suddenly emerging better solutions, but also emerging economic downturn leading to smaller budgets.

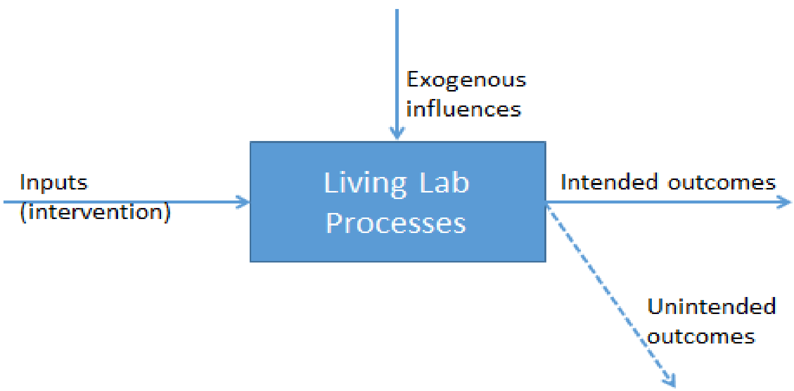

Figure 2 Living labs in a simplified system approach (Van Geenhuizen 2018)

The case studies used in the current analysis include work by Nesti 2018; Dijk et al. 2019; Engels et al. 2019; Von Wirth et al. 2019; Van den Broek et al. 2020; Ersoy and Van Bueren 2020; Habibipour et al. 2020; Rizzo et al. 2021; Companucci et al. 2021; Kalinauskaite et al. 2021; Van Waes et al. 2021; Nguyen and Marques 2022; Molinari et al. 2023. First, recent writings have put emphasis on short in anticipative learning before or during start of the living lab (Table 1, point 1.1 and 1.2) (e.g. Dijk et al., 2019; Van den Broek et al. 2020). Such a situation holds in particular for living labs' contribution to transitional change, different stakeholders' role in the problem and in potential solutions, and living labs' site-specificity and upscaling potentials. Also, shortcomings have been seen in lack of embedding of livings labs in other innovation research in the city. A weak anticipative learning specifically refers to *stakeholder analysis* (point 1.1). In general, it is a difficult task 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. Such circumstances would influence legitimacy and democratic value, and cause smaller (perceived) *policy relevance*.

Importantly, several practical tensions have been signalled in the core learning (co-creation) processes at project level (Table 1, point 2.1) mainly among participants, concerning short in time, in capabilities and motivation, and concerning lack of guidelines and shared understanding of the living lab methodology (Nguyen and Marques 2022). The challenge of living labs is also to keep momentum 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, also in ‘*older'* literature, like diminishing motivation of stakeholders and diminishing trust. Of course, such situations need to be avoided (mitigated) but this requires good understanding of social dynamics and adequate 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 interest of municipalities may differ between cities, some being closely interested and active as managers of a set of living labs, and others remaining more off-side. Table 1 (point 3) indicates that dependent on processes in living labs' practice, results may be different in convincing power and legitimacy. In view of dissemination, it seems preferable that municipalities are active, 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 if well-co-ordinated. We mention living labs on municipal buildings (offices) that are aimed at decarbonization (through solar energy; city heating), improvement of energy efficiency, use of smart energy services. Likewise, municipal road systems could be facilitate experimentation with new ways of charging of electrical vehicles on the road by driving, improved fixed charging stations; and optimizing management of municipal wind-parks. Such municipal experimentation sites could also involve practical application of innovations developed at local universities, eventually through their spin-off firms (Van Geenhuizen and Nejabat 2021; Nejabat and Van Geenhuizen 2023). Acting as a ‘launching customer’ enhancing market introduction, is one of them.

And finally, small attention has been given to external *influences beyond control* of living labs' management (Table 1, point 4) which originate from the broader socio-technical situation where ‘regime factors’ may block change (Geels 2002, 2014). Such cases of limits set at the system level, needs to be recognized and understood, and incorporated in the strategies of 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 human services, e.g. medical services and shopping services.

Table 1. Tension in living labs (LL) practice (*recent* case studies)

	***Tension* in practice/action**
1.1 'Inputs': Preparation	*Weak preparation* and *anticipative learning*. In particular: -Weak reflection on transitional change (socio-technical and policy systems), and design of testing and upscaling of LL results -Small learning on 'factors beyond control'; on stakeholders' positions and the problem *(stakeholder analysis)*; on needs for representativeness in stakeholder and site selection -Lack of embedding in and learning about past or on-going urban research programs -Small preparation of monitoring and dealing with early warning signals
1.2 'Inputs': Real-life environment	-Poor match between small scale or site-specificity of project and expectations on replication -Weak understanding of site-specificity and relevance in upscaling -Short in regulation concerning accidents, privacy etc.
2.1'Learning': Participation in co-creation	-Participants are facing lack of time, short in capabilities and motivation to participate; also, their learning potentials tend to be under-used (short in guidelines and understanding methods) -Participants are facing slow decision-making by management -Specific stakeholders hesitate and are not sufficiently motivated to participate -Trust among participants needs to be preserved *On the way (not-intended turns)* -Citizens/users get demotivated and abandon if intended LL results are not quickly achieved -Open projects turn into closed projects with aversion against disruptive/undermining of established stakeholders' interests -Managers are facing tension and short in resources
2.2'Learning': Wider Participation	-Relevant stakeholders may not be motivated to participate while LL learnings miss broader relevance and appreciation (e.g. indifference of municipality) -Living labs are badly connected to other innovation projects in city/region -Underestimation of constraints from regulation and business (market) environment
3. Outcomes: Policy relevance and dissemination	-Outcomes may be incidental, without structural impact in broader urban policy/planning; these may also lack democratic value and relevance -Existing power structures are reproduced (not challenged), not matching citizens' expectations on improvement - Small testing and upscaling (dissemination), because not-included in project aims; or lack of experience (with site-specificity of LL location) -Small involvement of municipality, eventually small interaction with innovation elsewhere in municipality
4.External influence beyond control	-*External* stakeholders and institutions are diverse and fragmented, and power relations may be strong and firmly established (lock-in) -Local 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 e.g. next LL steps towards upscaling -Unforeseen events (change) elsewhere in cities may influence LL processes and outputs -Disturbance in levels of city services

Upscaling of living lab results tends to be more an exception than a rule. Upscaling - in the sense of application of the results at other (similar) places - requires understanding of site-specificity, both in a social sense (network/tissue, stakeholders) and concerning built environment, which is fragmentary or missing, and this situation remained over time (e.g. Dijk et al. 2019; Engels et al. 2019). Accordingly, a weak understanding of what may hamper the steps of replication and upscaling may cause lack of legitimacy and policy relevance (e.g. Von Wirth et al. 2019; Ersoy and Van Bueren 2020; Bronson et al. 2021; Scholl and De Kraker 2021). On the other hand, upscaling can also be seen as too ambitious for the time being, and not as an aim in itself in the current situation (Pfotenhauer et al. 2022). A more modest and more realistic approach can be provided by 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 be supporting in decreasing several lock-ins (technology, institutional, legal) and better embed results in larger local innovation programs, thereby taking living labs methodology further into daily routines of urban planners and policymakers (Rizzo et al. 2021).

While awareness and understanding of issues of legitimacy and of upscaling of living labs results are important, we prefer to delve deeper into more basic knowledge, namely gained by stakeholder analysis and a comprehensive ex-post evaluation.

3. New Understandings and Needs

3.1 Stakeholder Analysis

In general in policymaking practice, it is important to gain understanding of different intentions of stakeholders involved in the problem 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). By analysing the roles and different strength of involvement of stakeholders, dynamics and temporality can be 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 of 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 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 the project specifically, 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. Q-methodology is a structured, both qualitative and quantitative, method 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.

For illustration purposes, we mention a list of main stakeholders in a living lab approach to social integration (well-being) of wheel-chaired persons; this through improved accessibility of a shopping mall within large scale reconstruction (Alexis Nihon, in Montreal, Canada) (Kehayia et al. 2014; Ahmed et al. 2017). Main stakeholders include regular customers, wheel-chaired customers, real-estate owners (managers), construction companies, shopkeepers, medical faculty (living lab design, practice, management), and wheel-chair constructors and navigation software developers.

3.2 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 causal links with actual living lab results, using representative samples that would enable statistical generalization (e.g. Bronson et al. 2021; Paskaleva and Cooper 2021). The most recent study that signals this challenge is a bibliographic review of evaluation studies so-far (Berberi et al. 2023).

At the same time, in existing evaluations the focus has been 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 often makes use of participant observation, researchers and participant stakeholders act and learn together using a *holistic* view while paying attention to complexity and multi-dimensional character of problems, thereby producing highly valuable evidence. Ex-post evaluation aimed at statistical generalization has remained behind due to several complexity, 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. We mention differences in scale, age (maturity), sector, and living lab aims, inputs and intended processes, etc.
- *Multiple perception on what (matter) to evaluate.* The focus on *effectiveness* can be manyfold, like on implementation of inputs (interventions) and specific learning processes gained on the way, but also on solutions derived from experimentation, or longer term impacts on transitional change (Beaudoin et al. 2022; Von Wirth et al. 2019). An assessment framework is given by Bouwma et al. (2022), built around the core learning functions and contribution of living lab outcomes to transitional change.
- *Open character of living lab processes*. Open and co-creative learning and designing of solutions make evaluation to a certain extent 'fuzzy', with somewhat 'moving' aims and outputs to evaluate. 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 of results is preferably also organized on participation, providing perspectives that are credible in framing key evaluation questions (Rodríguez-Campos

2012; Van Geenhuizen 2018; Beaudoin et al. 2022). Aside from participants, managers, local experts, etc. it is reasonable to also involve a few outsider evaluation experts.

- *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 factors (e.g., Walker et al. 2013).
- *Specific data characteristics.* Part of living lab data on processes and results is vague, imprecise and biased (overall fuzzy). Such characteristics follow from partial/fragmentary perceptions (opinions) among stakeholders, and these are often measured on rank and categorical level, thereby limiting choices in statistical analysis. However, use of AI (self-learning methods; data-mining) provides new opportunities to overcome limitations.

In the remaining part we discuss *four* decisions that need to be taken in design of an evaluation study, i.e. subject matter to be evaluated, evaluation aim (type), living lab type, and specific technique (methodology) of analysis.

Regarding subject matter to be evaluated, this may differ regarding the time dimension, scale and scope. Taking the time-dimension into account, we mention as short term results, the lessons learned about potential solutions and satisfaction of participants. Regarding longer term results, evaluation may focus on how designed solutions are accepted in other situations than the living lab at hand (upscaling). Further, the evaluation aim (type) needs to be selected, i.e. to achieve in-depth theory-based results and/or (statistical) generalization. Exploring theoretical trends can be undertaken with a small selected sample, while a sufficiently large sample size needs to be analysed if the results aim to be statistically representative for a (sub)population of living labs. A special situation holds true for evaluation using a Delphi approach. What matters here are the opinions of specific experts on effectiveness of living labs and to reach consensus in these opinions (e.g. Beaudoin et al., 2022), but the ways used in the Delphi approach may be different.

Next is the decision on *types of living labs* to include in evaluation, this on the basis of sharing sufficient *similarity*, e.g. age and maturity, resources like financial budgets, sector specificities, aims and objectives, and planning context. In any case, the *counter-factuality issue* needs to be solved. This means a research design on performance of the unit involved (e.g. a shopping mall) at one point in time thereby comparing malls with and malls without implementation of a living lab (everything else being equal), or comparing single malls before and after implementation (Khandker et al. 2010).

With regard to *techniques of analysis*, regression and structural equation modelling are important ‘candidates’, but data characteristics 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 to 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 of project performance, in domains like urban revitalisation, university incubation of small firms, and project performance in market introduction (e.g. Nijkamp et al. 2002; Taheri and Van Geenhuizen 2016) (note 2). 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 performance significantly changes. At the same time, using advanced regression analysis in reaching statistical generalization may also overcome above-indicated limitations (STATA ERMs 2023).

Given the complexity involved, it seems reasonable that (large scale) evaluation of living labs is a task for overarching organizations, like EnoLL, universities, and sector specific organizations.

4. Concluding Remarks

It can be concluded that urban living labs have 'grown-up' in the sense of being broadly applied and at the same time having provided critical visions on performance (effectiveness) and frameworks (evaluation) to improve. In this context, the paper addressed often mentioned *tensions* experienced recently. Two important ones have been taken further in this paper, namely, anticipative learning, in particular on stakeholders' roles in defining problems and influencing outcomes and ex-post evaluation of effectiveness, in particular concerning complexity in subject matter and methods. An adequate strategy is a stronger *anticipative learning*, specifically analysis of dynamic stakeholder situations and problem definitions (Dijk et al. 2019). Such knowledge advancing needs to be facilitated before living labs' start, as it takes time and budget. Also, it has been forwarded that critical performance factors' relative importance and effectiveness still have to be assessed ex-post, preferably enabling statistical generalization (Engels et al. 2019; Bronson et al. 2021). In this context, the paper discussed a set of practical decisions on the design of evaluation.

This paper is in part a scoping review. A weakness that is difficult to avoid in such review, is the often merely 'touching upon' some relevant issues, like methods of stakeholder analysis and effectiveness analysis. Another issue that has been addressed but not elaborated, is management of living labs, given sometimes low motivation for participation, and short in resources and capabilities. Future research is needed on good solutions and best methods involved. To conclude, despite the signs of living labs of 'being grown-up' as a policy tool and the continued popularity of the tool, it is still worth to aim at considerable improvement. This improvement would mainly encompass extending knowledge advancing concerning stakeholder analysis and evaluation of living labs' results, this in an overall building of tighter relations with municipalities, derived from stronger legitimacy and policy relevance of living labs' in enhancing innovation. The best context for research concerned in the urban arena, would be smart cities encompassing many living labs on digitalization and data-integration to increase local communities' quality of life.

Notes

1. Expert-meetings in 2023 include CitSciHelvetia'23, 29-30 March 2023 (Solothurn, Switzerland) and Workshop on Living Labs and Real World Experiments, Ecole des Mines, 30 Nov-1 Dec. 2023 (Paris, France).
2. In rough set analysis, the living labs and their scores on different dimensions (causal influences) are arranged in a so-called 'information table' using condition attributes (causal influences as

‘independent variables’) and a decision attribute (living lab result/impact as ‘dependent variable’). After data reduction, so-called ‘decision rules’ are composed of an ‘if … then …’ nature, at different strength (Taheri and Van Geenhuizen 2016).

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