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Transportation Research Procedia 72 (2023) 3601–3608

Transportation Research Procedia

www.elsevier.com/locate/procedia

Transport Research Arena (TRA) Conference

Living lab conceptual framework: co-creation and impact assessment of an automated last-mile delivery service

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Abstract

The Future Mobility Solutions Living Lab (LL) at the European Commission's Joint Research Centre was created to bring the Living Lab concept closer to the policy, academic and industrial realms. For higher efficiency and effectiveness of work we have developed a framework, in which projects are distinguished into four categories based on their objectives: business model validation, solutions co-creation, technical validation and impact assessment. This allows to adopt a LL tailored-made approach while allowing a faster identification of the most suitable methods and tools in each specific case. This paper presents results from the application of the LL framework to the co-creation and impact assessment of a last-mile delivery service, outlining ways to refine and validate the LL conceptual framework based on these first experiences.

Keywords: Mobility living labs; Urban mobility; Last-mile delivery; Behaviours and mobility patterns; Co-creation of services and citizen engagement; Automation in urban logistics.

1. Overview and motivation

Mobility Living Labs (LL) aim to support the co-creation of new mobility concepts and promote their public acceptance and subsequently a more sustainable and smarter mobility. In this paper we adopt the ENoLL definition of LLs as real-life test and experimentation environments that foster co-creation and open innovation among the main actors of the Quadruple Helix Model, namely: citizens, government, industry and academia (ENoLL, n.d.).

Living lab is concept already recognised by governing bodies. For instance, the European Commission has adopted the new European urban mobility framework comprising measures to encourage EU countries to develop urban transport systems that are safe, accessible, inclusive, affordable, smart, resilient and emission-free (European Commission, 2021). The new EU urban mobility initiative is highlighting the role of European cities as "living

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10.1016/j.trpro.2023.11.562

laboratories" where new solutions to urban mobility challenges are designed, tested and implemented. In particular, the new EU framework for urban mobility emphasises that city logistics is essential to the functioning of urban economies, even more considering the COVID-19 pandemic which has resulted in greater e-commerce activity and home deliveries. The framework acknowledges that the engagement of public and private stakeholders is central to optimising urban logistics and last-mile delivery in economic, social and environmental terms and aims to support dialogue and collaboration between all parties, networking and exchanges among city planners.

In 2019, the Joint Research Centre (JRC) set up the Future Mobility Solutions Living Lab (FMS-Lab) in Ispra (Italy) in order to engage citizens and relevant public and private players in the co-creation of innovative mobility solutions (European Commission Joint Research Centre, 2019). One of its on-going projects addresses the co-creation of a last-mile automated delivery service based on a droid solution developed by an Italian start-up. Such last-mile delivery droid solution is able to deliver food and goods from point A to point B with a claimed low emission impact on the environment. It consists of a two-wheeled, self-stabilized droid, able to stroll through indoor and outdoor spaces. Co-creating the last-mile automated delivery service with the active involvement of the JRC Ispra staff ensures that the service addresses staff needs and expectations, and thus facilitates the uptake of the solution. Besides, assessing its potential environmental, economic and social impacts is of paramount importance in order to promote zero-emission urban logistics. Moreover, the FMS-Lab activities can guide the development of future regulatory frameworks, especially in case of automated delivery droids, for which regulation does not exist (e.g., regulation on droids testing, regulation on droids certification). This paper applies a tailor-made LL approach (Alonso Raposo et al., 2021) to the co-creation and impact assessment of an automated last-mile delivery service. It describes the main outcomes from this process and outlines possible ways to refine and validate the LL conceptual framework with the experience gained in the FMS-Lab.

2. Literature Review

This section aims to provide a brief review of the methodologies used at the project level of LLs and an analysis of their core elements. In addition, it describes other LL studies and impact assessments that focus on last mile delivery technological innovations. LLs can be seen as an ecosystem, an environment, or an approach/methodology. They can benefit research and innovation projects which address societal challenges by putting citizens at the heart of the innovation development process.

LL projects could be perceived and conducted in a quasi-experimental manner. In this approach, a LL project can be divided into three stage: exploration, experimentation and evaluation (Evans et al., 2017; Schuurman et al., 2013). This innovation development process allows to assess and understand the current state and design possible future states in the exploration stage. Experimentation stage consists of conducting the real-life tests of one or more identified future states. Whereas evaluation stage focuses on the impact assessment of the experiment as compared to the current state and iterate the future state. This 'action-oriented' perspective (i.e., actions taken along the different phases of the innovation process) can be matched with a 'progress-oriented' one, meaning the focus is put on the progress from a concept to a mature innovation. From this perspective, we can highlight the FormIT methodology (Ståhlbröst and Holst, 2013) as an iterative method covering the cycles of concept design, prototype design and innovation design. Each cycle is then divided in four phases: Explore, Create, Implement and Evaluate, which are repeated iteratively. These four phases can be extended to cover two additional steps at the beginning and end of the innovation process, namely: Planning, (Exploration, Co-creation, Implementation, Test and Evaluation) and Adoption. Certainly other LL approaches or methodologies do exist such as the methodology developed for the Belgan iLab.o and Helsinki Living Lab (Almirall et al., 2012). More recently, the Living Lab Integrative Process has been developed by Mastelic, (2019). It is presented as a standardised method in six steps which focuses on open discussion and confrontation of ideas on barriers and drivers to build a common vision of a challenge, drawing on a unique combination of design thinking, social marketing and social practices theory.

As new mobility solutions are being proposed, studies to assess their potential impacts have also started to appear. Exemplary, an Horizon 2020 project called CITYLAB focuses on last mile delivery solutions deployed in several European cities (European Commission Innovation and Networks Executive Agency, 2014). The project aims to improve understanding of the impacts that freight and service trips have on urban areas, through testing and evaluation of innovative urban freight management solutions. The CITYLAB methodology focuses on bringing all concerned stakeholders to evaluate, adapt and improve last-mile delivery in a cyclical way. The projects are evaluated through a series of Multi-Actor Multi-Criteria Analysis workshops. A series of workshops starts off by exploring which ideas could be implemented in each city, afterwards alternatives are evaluated from the combined perspective of all stakeholders involved to assess whether there is overall stakeholder support for one of the alternatives (Gatta et al., 2017). Representatives of each stakeholder group (shipper, transport operator, receiver and society) are present during the workshops. A cyclical approach of re-adjustment is adopted, to meet stakeholder needs, propose a solution that fits the real-life city challenges and finally obtain maximum impact for a long time (Nesterova and Quak, 2016).

For what concerns automated freight innovations, to the best of authors' knowledge, there is still only a limited number of studies that focus on the impact of last-mile delivery innovation. Among the first attempts to study the impact of new mobility solutions, Chiang et al., (2019) have performed a green vehicle routing problem (GVRP) study for drones supported by internal combustion engine delivery vehicles, focusing on costs and sustainability implications. The authors opted for a comparison of greenhouse gas emissions and variable costs of delivery for business as usual, delivery using the drones and combination of vehicles. Moreover, Stolaroff et al., (2018) have estimated the energy consumption and total life cycle emissions of parcel delivery with drones, based on assumed warehouse development according to the current battery ranges of the drones. As for the delivery droids, Jennings and Figliozzi, tried to estimate their impact on freight efficiency (Jennings and Figliozzi, 2019) as well as total energy consumption and emissions (Figliozzi and Jennings, 2020). Moreover, a sustainability assessment performed at the FMS-LAB has recently been conducted (Garus et al., 2022). The results of this analysis are brought in more details in section 4 of this paper. Nevertheless, apart from simulated impact assessments, trials of droids and drones in real setting are still limited. Exemplary, the CITYLAB projects focused solely on improving the used logistic solutions with the readily available infrastructure, without considering the usage of last-mile delivery innovations. This is often caused by the confusing and contradictory national and regional regulation, unsecured safety and numerous struggles with privacy regulations (Martínez Euklidiadas, 2021). Therefore, we have decided to deepen the knowledge field with an FMS-Lab project focused on automated last mile delivery droids.

3. Methodology

To propose the most suitable solution for the last-mile delivery at the JRC site in Ispra, explore the impact that the last-mile delivery droids could have and understand possible policy implications, we apply a conceptual framework developed at the FMS-Lab project level. The framework identifies steps based on the innovation development phases (namely, exploration, experimentation and evaluation) and suggests different suitable stakeholder involvement and co-creation methods for each phase (Figure 1).

The JRC FMS-Lab framework distinguishes four categories of projects based on their respective objectives:

1. **Business model validation** where the solution provider aims to better understand the target group/s of users and validate the solution with target group/s representatives.
2. **Co-creation** of solutions where the solution provider aims to leverage the involvement of citizens to enhance the solution while co-creating with them.
3. **Technical validation** where the solution provider aims to perform technical tests in a semi-controlled setting at the LL.
4. **Impact assessment** where the aim is to assess the potential environmental, economic and social impacts of the innovation.

The categorisation of the project types helps to realise projects in an efficient manner while keeping the tailored made approach of a "living lab as a service" (Ståhlbröst and Holst, 2013). This way the FMS-Lab can play the role of innovation intermediary between entrepreneurs and users.

Similarly to the CITYLAB project, we apply a methodology that allows all stakeholders to evaluate, adapt and improve the tested innovations in a nonlinear and feedback based manner. Firstly, each project, no matter to which category it belongs, starts off with the exploration phase with **an inception activity** between the FMS-Lab research team and the solution provider/entrepreneur to better understand the needs and desired outcomes of the collaboration. The aim of such introductory workshop is to agree on the project objectives and activities to carry out in the project, i.e., identifying which category/ies the LL project will be addressing. Based on the workshop outcomes, the FMS-Lab draws the project timeline and a proposal of the activities and tools to use during the project. Additionally, according to the project type the FMS-Lab could define the research questions that could be addressed during the process.

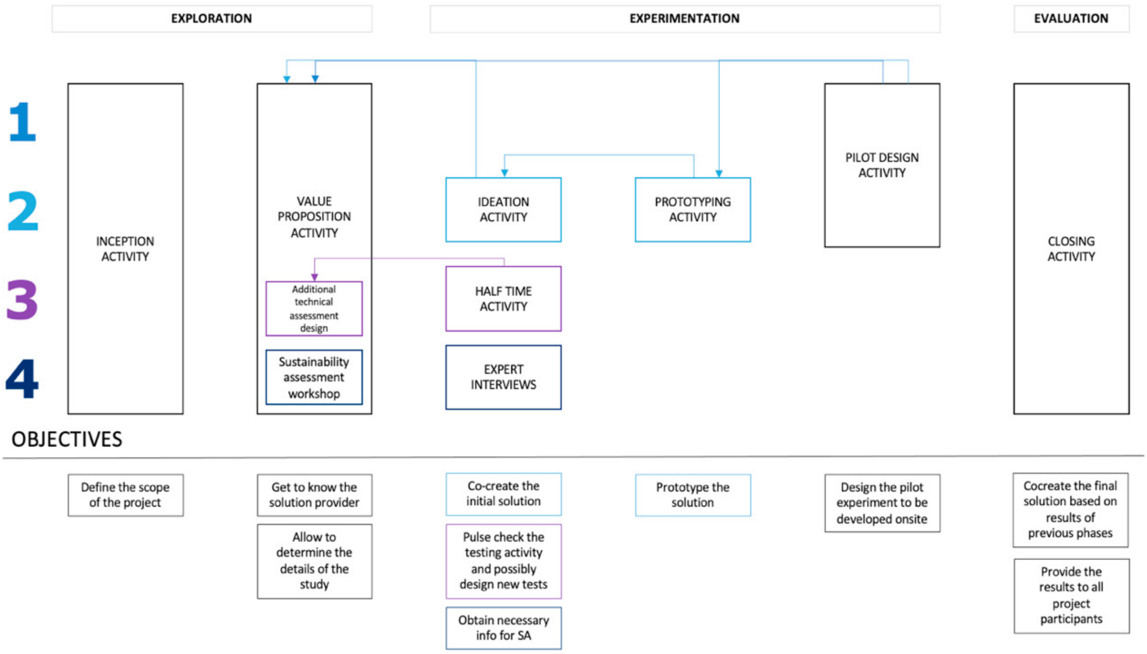

Figure 1 JRC FMS-Lab conceptual framework reflecting the four project categories (colour coding according to the project categories)

Once the project timeline is accepted, a **value proposition activity**, involving all quadruple helix stakeholders is organised. The workshop is designed to understand the problem which the technical provider wants to address and the value proposition it brings. The workshop follows one of the previously established methodologies: Value Proposition canvas (B2B International), Solution canvas (UNLEASH, n.d.) or the Triple Layered Business Model canvas (Joyce et al., 2015). Additional activities, serving specific project objectives such as design of indices useful in an impact assessment or design of the technical feasibility tests, could also be included in this phase of the project (thus being helpful for projects from categories 3 and 4).

The experimentation phase of the project is different for each of the distinct categories. However, there are still certain synergies among them. For the co-creation projects (category 2), an **ideation activity** follows the value proposition one. The ideation activity is designed to develop and enhance the idea, working mostly with identifying and/or improving potential solution, crystallising and developing the value proposition, and identifying the potential customer segments having all stakeholders involved in the process. Following the Quadruple Helix Model of open innovation, the co-design process uses participatory approaches to engage all relevant stakeholders, including citizens, in the generation of ideas. Stakeholders are invited to participate in the co-design process based on an initial stakeholder mapping activity, where relevant actors are identified via interviews, surveys, etc. and classified based on their level of interest and power (i.e. using a power/interest matrix). Thereafter, the co-creation projects go into the **prototyping activity**, during which the co-designed idea is fine-tuned with all involved stakeholders. The next step of the co-creation project – **pilot design activity** is also followed by business model validation projects (category 1). Pilot design activity consists of user identification study (surveys interviews, diary studies etc.), workshop between the FMS-Lab and an interested start-up, during which assumptions and questions (that this stage should answer) are listed (activity diagrams, design specifications), and expo/demo on-site followed by user experience interviews and/or workshops. Implementation of the pilot on the JRC site also includes a collaboration process between the scientific and infrastructure unit. The two teams need to meet to discuss required permissions and the possibility of installing additional infrastructure or technology required to carry out the pilot (such as ICTs).

The experimentation phase for technical validation projects (category 3) consists of installation of Information and Communication Technology (ICT) devices and other required equipment, conducting the technical assessment tests designed during the inception activity and a **half-time activity**, which allows all involved stakeholders to re-evaluate the running tests (choosing new locations, designing new tests), and possibly start a new pathway for a different project category.

For the impact assessment projects (category 4), the experimentation phase consists of **expert interviews/workshops** that allow to fill in any data gaps and clarify the used indices for the assessment. Thereafter the analysis is made according to a chosen methodology using collected data.

The evaluation phase of the project is common to all the identified project categories and pursues the organisation of a **closing activity** to summarise the project outcomes of the study for all stakeholders involved in a project. During the closing workshop, elements of co-creation are also used, and attendees are asked to co-create the desired solution road map and finalise the solution canvas. In addition to the activities that involve stakeholders, the FMS-Lab team along with the solution provider team performs other activities which are selected and fine-tuned based on the desired project outcomes. Those activities could include a market analysis, data collection and modelling for an impact assessment or installation of ICT devices onsite to respond to technical assessment needs. Those activities are planned and especially designed for each of the projects conducted at the FMS-Lab. After the engagement part of the project is finished, the scientific team of the living lab analyses and summarises the results of the singular project and informs the engaged stakeholders of the outcomes. Moreover, a knowledge repository about the acceptance, potential impact and proffered design of the innovative solutions is updated and made available for policymakers.

Moreover, there are numerous complementary tools to enrich and better design the project. A non-exhaustive selection of tools used at the FMS-Lab at various activity levels is described in more details in a FMS-Lab dedicated report (Alonso Raposo et al., 2021). Based on a list of suitable tools at each activity level, the FMS-Lab can identify the most suitable tools to use and propose an adequate project timeline in an effective and comprehensive way.

4. Results and contributions

The last-mile automated delivery project falls within two categories: co-creation (of a last-mile delivery service at the JRC Ispra) and impact assessment. In this section, we document the first activities of the exploration phase carried out in the last-mile automated delivery project and describe the results obtained from a preliminary impact assessment.

4.1. Exploration, experimentation and evaluation phases: Impact assessment activity

A preliminary impact assessment of the last-mile delivery droids focused on a case study of postal deliveries at the JRC Ispra site, where six alternative solutions were analysed and compared: i) the existing service using a manually-driven Euro 4 light commercial vehicle (LCV); ii) the same service using a Euro 6 LCV; iii) the same service using an electric LCV (eLCV); iv) a service composed by an automated delivery droid (robot) coupled with a Euro 4 LCV; v) a service with the delivery droid coupled with a depot station; and vi) a service with the delivery droid coupled with the eLCV. The droid-based service required to be coupled with an alternative solution as its small size does not allow to handle all delivered parcels. Nevertheless, we acknowledge that this is a preliminary impact assessment based on a simulation, therefore further experiments are required. More about the manner in which the indices were obtained and the outcomes of the study can be found in our publication (Garus et al., 2022).

This impact assessment effort could be perceived as a LL experimentation as the postal services on site serve as an adequate representation of a last mile delivery system. Meaning that the Italian post as well as courier services deliver mail and parcels to post office found on site, which is then distributed by the JRC logistic services to the buildings onsite (approx. 600 incoming and 300 outgoing deliveries per week). Additionally, to the external mail services, internal deliveries of goods and letters between buildings on site are handled every day (approx. 75 deliveries per week). Moreover, the site could stand for a micro urban environment with its size (167 ha), population (almost 2700 employees), infrastructure (36 km of roads connecting 230 buildings).

During the exploration phase of the project, an introductory activity in the form of interviews with site management team, which is responsible for the postal deliveries onsite, was organised to better understand the service that the last-mile delivery droids could have and to deepen the objectives of the impact assessment study. Those interviews were used to determine the sustainability framework used for the analysis (Garus et al., 2022). As a second part of the exploration phase, brainstorming sessions between the FMS-Lab and the site management were organised to better define which indices should be accounted for in the sustainability assessment study.

From then on, the impact assessment study entered the experimentation phase, which consisted of further interviews with the delivery droid provider and the site management aimed to fill in the knowledge and data gaps in terms of each used index. Moreover, a desk research activity was performed to understand how other impact assessment studies of last-mile delivery were made and which indices were used. The final list of used indices and the chosen methodological pathway is represented on Figure 2.

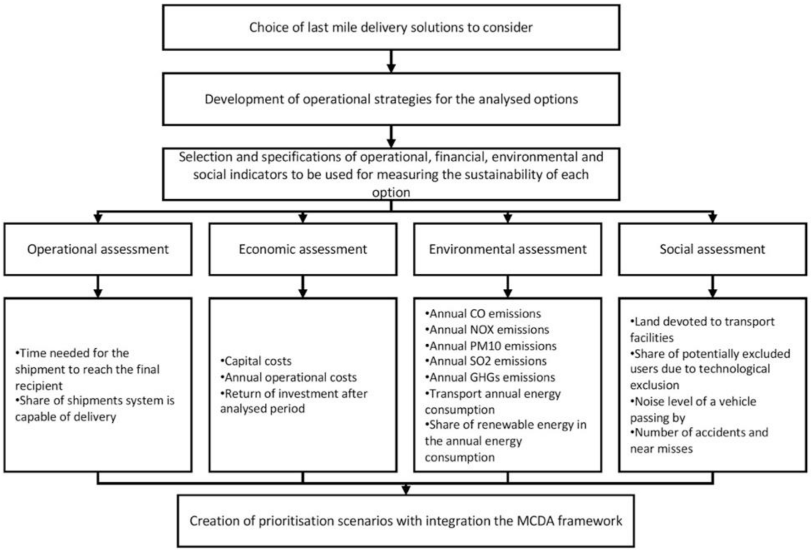

Figure 2 Sustainability assessment framework used for the impact assessment

The experimentation part of the project also included an initial acceptance assessment for the technology with the population of the JRC Ispra site, which was performed through a mobility survey distributed at the JRC in October 2020. A fraction of the questionnaire was dedicated to the future of mobility at the site, and out of the 25% of staff that filled in the survey, 60% of employees declared willingness to use last mile delivery droids for lunch delivery as well as private or work-related postal services.

The evaluation part of the project consisted of a seminar organised for the JRC employees during which the results of the impact assessment study were presented. The results clearly showed that the implementation of the delivery droid system can have a positive impact on the environment, whilst improving the quality of services by shortening the delivery times. Nevertheless, due to compact size of those solutions, they should always be implemented with utmost caution for the type of delivered shipments. Moreover, further viable safety tests of the delivery droid must be performed along with digital education and co-creation with those users unwillingly excluded by technology. The results point out that there is no fit for all solutions, but a string of conflicting needs and criteria, hence trade-offs and compromises are necessary. Therefore, before the droids are actually tested at the JRC Ispra site, we have decided to follow a co-creation project framework as to better understand the needs of potential users. It is also important to note that the evaluation at the JRC Ispra site can be limited in terms of the testing nature of the experiments and the involvement of mostly JRC employees. Therefore, evaluation findings will need to be interpreted with caution and be supported by additional evaluation contexts, such as SWOT analysis, cost benefit analysis or multi-criteria decision analysis, or other impact assessment methods adjusted for representation of the real-world.

4.2. Exploration phase: Co-creation activity

Living lab definitions clearly underline the importance of active user engagement in the innovation process. Nevertheless, in many cases, the term LLs is used to describe testbeds which lack the co-creation element. In testbeds, users assume a passive role, limited to testing and providing feedback on an innovation. On the contrary, LLs involve users in all stages of the innovation process, collaborating towards a new product or service and making sure the opportunities for contribution are equal for all. Georges and Gilbert (2017) compared LLs and testbeds and found the main differences related to: (1) the context which is controlled in testbeds and real-life uncontrolled in LLs; (2) users' contributions which in LLs are valued equally compared to other stakeholders; and (3) the fact that LLs address user needs from ideation until commercialization. The situation is similar with pilots or demonstrations, that usually have short-term goals and focus on the validation of a solution/technology involving end-users and/or technology providers (Ståhlbröst and Holst, 2013). In this paper we would like to present the implementation of our framework to the co-creation of last-mile delivery system that would use the readily available innovation – delivery droids. The co-creation process focuses mostly on the development of a sustainable last-mile delivery service, while the droid developers are also able to obtain feedback and adapt their technological solution.

The exploration phase started with an inception activity consisting in the organisation of an introductory workshop between the JRC FMS-Lab scientific team and the start-up providing the last-mile delivery solution. The aim of such workshop was to better understand the needs and desired outcomes of the collaboration, and based on those, agree on the project objectives and activities to carry out in the project (i.e. project scope, detailed work plan). Both entities agreed on applying a gradual approach to start with simpler delivery scenarios which then increase in complexity over time until a safe and robust multi-service solution can be put in place. In practical terms, this means organising two pilot activities, with specific goals and target users:

1. **First pilot:** Deploy and test an initial (and simpler) delivery service dedicated to stationeries

Activities:

1.1. System setup: mapping, tests on connection quality and autonomous driving

1.2. Recruitment of volunteers and service deployment: Launch of an initial survey (before) – attitudes towards automated last-mile delivery droids

1.3. Testing of the service (during ~1 month)

1.3.1. User experience/acceptance survey (to be filled in after using the service)

2. **Second pilot: Co-create, deploy and test a more comprehensive (and complex) delivery service dedicated to lunch**

Activities:

2.1. Co-creation of the service:

2.1.1. Launch of an initial survey (before) – needs and preferences for a lunch delivery service,

2.1.2. Organisation of a co-creation workshop

2.2. Service deployment

2.3. Testing of the service:

2.3.1. User experience/acceptance survey – longitudinal study (to be filled in at 3 specific moments) (during ~3-6 months)

2.3.2. Focus groups or interviews to collect people's attitudes towards the service and automated last-mile delivery droids

Based on the workshop outcomes, the JRC FMS-Lab Scientific team has drawn the project timeline and a proposal of the activities and tools to use during the project. To approach the first pilot, user surveys are being defined, taking user acceptance and experience literature into consideration.

5. Conclusion and future works

Through the application of the LL project framework to the co-creation of a last-mile delivery service, we have realised how the framework could be refined and validated.

Firstly, we have realised that the sustainability assessment workshop, which focuses on the definition of considered indexes should not be part of the value proposition activity, but rather a dedicated standalone activity during the experimentation phase of the project. Secondly, we have understood that the theoretical approach towards impact assessment could be deepened as compared to the preliminary one during the co-creation project, by using the real consumption and emissions data collected from the experiments. More importantly, there is a need to incorporate a policy dimension into the framework, possibly since the early exploration phase by setting clear policy goals and regulatory needs, and until the evaluation phase, during which an extraction of overall regulatory impact could be performed. Lastly, with agile projects, to which LL projects belong, it is important to always re-evaluate and readjust the framework based on the tested solutions and expected objectives including the needs of the population. Therefore, we expect that the framework will keep evolving with each project of the FMS-Lab. Our mission in creating the JRC FMS-Lab is to bring the LL concept much closer to the policy, academic and industrial realms. In particular, we are using it as a human-centred policy design and regulatory-support tool to test a variety of mobility-related policy and regulatory approaches in a real-life environment. We aim to stimulate scientific debate on the use of LLs to address mobility challenges and accelerate the co-creation of innovative mobility solutions contributing to the smart and green urban transformations.

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