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Dipartimento di Economia Marco Biagi
Fondazione Marco Biagi

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# TESTING AND ACCEPTANCE OF AUTONOMOUS VEHICLES. LIVING LABS AND USERS' ATTITUDE STUDIES

Dottoranda:
Dott.ssa Silvia Della Santa

Supervisore (Tutor):
Prof. Gianluca Marchi

Co-tutor:
Prof. Bernardo Balboni

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# Executive Summary

The diffusion mechanisms of an emerging technology have been the subject of extensive debates within the literature, given the increasing role they may play within society and the consequent interest of policies towards them. Autonomous Vehicles (AVs) are perceived as one of the fundamental disruptors in the upcoming technology revolution, where the evaluative complexity of technological innovations increases exponentially and defines a deep sectoral contamination. The complexity of the issues emerging from these technological innovations implies the need for a broader reflection with respect to the processes of acceptance and future diffusion of AVs. Therefore, the following thesis aims to analyse two different approaches – Living Labs (LLs) and models investigating users' acceptance toward new technologies - that, assuming a complementary perspective, have the ultimate goal to facilitate and investigate the processes of technology acceptance for AVs.

A first research line looks then at LLs as entities that are potentially able to detect the technological and social complexity linked to the AVs. Based on a multi-stakeholder approach, LLs aim to analyse new emerging technologies, by placing them within real-world settings that allow for an integrated study with the surrounding context. However, dealing with a phenomenon that only recently has been institutionalized, where theory has been developing after that practice was already emerged, the first paper proposes a systematic literature review on the studies analysing LLs under the lens of in-depth case study methodology. Three perspectives are detected - namely actor based, methodological and environmental - and some theory/practice gaps are highlighted as future research streams to be addressed. In an attempt to answer to one of this gaps, two experiences of LLs focusing on new forms of mobility are selected and analysed, with the purpose to offer new insights to theory from case study research. With the final aim to find the theoretical foundation for the real-life setting principle of LL, drawing from the concept of Enabler Space (ES), as multidimensional container fostering innovation processes, we investigate how the space influences LLs, looking at the physical, social and organizational spaces dimensions. Results show how the physical, social, and organizational dimensions of ES interrelate and influence the evolution of the LL. Finally, within the third chapter, a focus on the final consumer is proposed. In line with the transformation the sector is having that may eventually discourage car ownership, some studies state that AV technologies fit well into a car sharing business model, leading to a more fleet-oriented market. An online survey has been conducted on an Italian sample of 361 individuals. A validation of variables and items with a panel of experts studying the topic of AVs from different fields preceded the survey distribution, with the additional attempt to capture the cross-sectoral aspects of these technological innovations. Integrating the

Technology Acceptance Model with Innovation Diffusion Theory, the carsharing compatibility is introduced as moderator of the model, to analyse its effect on Perceived Usefulness (PU), Perceived Ease of Use (PEOU) and perceived safety risk. Results suggest that carsharing compatibility influences the relationship between PU, PEOU and intention to use AVs.

Besides enriching the theory on LLs and models of acceptance studies, with the ultimate scope to provide evidences for the analysis of an emerging complex technology, the following thesis offers some practical implications as well. They address a diverse audience, affecting all the actors involved in the process of technological evolution: policy makers, helping them to make decisions at the level of regulation of the ecosystem hosting the new technology; those involved in technology development who can understand from these studies how to fine-tune the vehicle in terms of functional attributes and technical features improving users' needs; and actors dealing with marketing positioning and product communication, as well as strategic decisions related to business models.

# Executive Summary

*(Italian version)*

I meccanismi di diffusione di una tecnologia emergente sono stati oggetto di ampi dibattiti all'interno della letteratura, considerati i profondi cambiamenti che possono comportare all'interno della società e il conseguente interesse delle politiche nei loro confronti. Nel panorama della quarta rivoluzione industriale, dove la complessità valutativa delle innovazioni tecnologiche aumenta esponenzialmente e definisce una profonda contaminazione settoriale, i veicoli a guida autonomi (*Autonoumus Vehicles* - AVs) sono percepiti come uno dei principali protagonisti. La complessità sociale che emerge da queste innovazioni tecnologiche implica la necessità di una riflessione più ampia rispetto ai loro processi di accettazione e di futura diffusione. La seguente tesi si propone quindi di analizzare due diversi approcci - i *Living Lab* (LL) e i modelli che indagano l'atteggiamento degli utenti verso le nuove tecnologie - che, assumendo una prospettiva complementare, hanno l'obiettivo ultimo di facilitare e indagare i processi di accettazione tecnologica degli AV.

Una prima linea di ricerca guarda agli automotive LL come entità potenzialmente in grado di rilevare la complessità tecnologica e sociale legata agli AV. Basandosi su di un approccio multi attoriale, i LL si pongono l'obiettivo di analizzare tecnologie emergenti ponendole all'interno di ambientazioni reali che ne permettano uno studio integrato con il contesto circostante. Tuttavia, trattando un fenomeno che solo di recente è stato istituzionalizzato, dove il cappello teorico di riferimento si è sviluppato a seguito della nascita spontanea e diffusa di esperienze pratiche, il primo articolo propone una revisione sistematica della letteratura che analizza i LL attraverso una metodologia basata sul *deep case study*. Sono quindi individuate tre differenti prospettive ed evidenziate alcuni *gap* teorico/pratici su cui indirizzare le future ricerche sui LL. All'interno del secondo capitolo, nel tentativo di trovare il fondamento teorico per il principio del *real-life setting* dei LL, si analizzano due esperienze di LL incentrate su nuove forme di mobilità. Prendendo in prestito il concetto di *Enabler Space* (ES), ossia un spazio multidimensionale che favorisce i processi di innovazione, si indaga su come lo spazio influenzi i LL, analizzando le dimensioni fisica, sociale e organizzativa. I risultati mostrano come le tre dimensioni dell'ES si influenzino tra di loro e influenzino l'evoluzione dei LL. Infine, nell'ultimo capitolo si propone un'analisi incentrata sull'utente finale. In linea con la trasformazione del settore, alcuni studi evidenziano infatti una sinergia tra le tecnologie AV e un modello di business basato sul *carsharing*. Partendo da questa riflessione, si analizza un modello di ricerca che proponga un'integrazione tra il *Technology Acceptance Model* e l'*Innovation Diffusion Theory*, dove la variabile di *carsharing compatibility* è

introdotta come moderatrice, per analizzarne l'effetto sulle relazioni tra tre delle variabili indipendenti (utilità percepita, facilità di uso ed il rischio percepito legato alla sicurezza) e la variabile dipendente relativa all'intenzione all'utilizzo. I risultati, misurati su di un campione italiano di 361 rispondenti, suggeriscono che la *carsharing compatibility* influenza la relazione tra utilità percepita, facilità di uso e l'intenzione di utilizzare gli AV in futuro.

Oltre ad arricchire la teoria sui LL e sui modelli relativi sull'*acceptance*, con lo scopo ultimo di fornire un contributo per l'analisi di una complessa tecnologia emergente, la seguente tesi offre anche alcune implicazioni pratiche. Esse si rivolgono a un pubblico eterogeneo, interessando tutti gli attori coinvolti nel processo di evoluzione tecnologica: gli attori pubblici, aiutandoli a prendere decisioni a livello di regolamentazione dell'ecosistema che ospita la nuova tecnologia; gli attori coinvolti nello sviluppo tecnologico, offrendo spunti su come mettere a punto il veicolo in termini di attributi funzionali e caratteristiche tecniche che migliorino le esigenze degli utenti; nonché gli attori che si occupano del posizionamento di mercato e della comunicazione del prodotto, nonché delle decisioni strategiche relative ai modelli di business.

# 1. Introduction

The diffusion mechanisms of an emerging technology have been the subject of extensive debates within the literature, given the increasing role they play within society and the consequent interest of policies towards them (Rotolo et al., 2015). This has given rise to a broad characterisation of emerging technologies that has highlighted their "*enhanced economic influence*" (Porter et al., 2002, p. 189) and the uncertainty associated with their emergence processes (Boon and Moors, 2008). On the one hand, the literature converges in defining emerging technologies as those ones having a strong impact on the economy and society (Porter et al., 2002), occurring simultaneously at various levels, including the social and institutional context level, and the knowledge and technological evolution level (Rotolo et al., 2015). On the other hand, the ambiguity due to the variety of potential outcomes that each social group might recognise during the emergence of a technology, ascribing different meanings to that, is pointed out (Mitchel, 2007). This makes the study of the diffusion and acceptance processes of emerging technologies as crucial for analysing the future demand mechanisms and context of use related to them. In particular, the following thesis focuses on the emergence processes related to a specific technology, Autonomous Vehicles (AVs), whose inherent complexity is expressed not just at the technical and engineering levels, but also at a social level, making the AVs be perceived as one of the fundamental disruptors in the upcoming technology revolution (Kaur and Rampersad, 2018) and increasing the attention they are receiving in recent years.

This introductory chapter aims to accompany the reader in understanding three different contributions that, albeit with different points of view and methodologies, aim to offer a framework on the mechanisms that prepare the market and society to accept these technologies. Therefore, this chapter is divided as follows: the first part briefly describes the technical characteristics of the AVs, and some of the issues such complex systems can have on a social level. Subsequently, some literature strands are presented that can be used in the field of Innovation Management for the analysis of the diffusion and acceptance process of an emerging technology, such as AV, which is still far from the

introduction in the market, with few exceptions related to experimentation if the field of public transportation. Finally, the research questions that the thesis attempts to answer are drawn, placing them in the context of an enlarged socio-technical system approach.

## 1.1 Field of application

The automotive sector is among the biggest investors in R&D. In 2019, according to the ACEA (European Automobile Manufacturers Association) report, R&D expenditure for the European automotive industry amounted to around 58 billion of euros (ACEA, 2019), surpassing traditionally high-innovation fields such as pharmaceutical or biomedical (Clements and Kockelman, 2017). Among the strands of innovation characterizing this sector, autonomous vehicles (AVs) are included, fitting in the landscape of the Fourth Industrial Revolution, where the evaluative complexity of technological innovations increases exponentially and defines a deep sectoral contamination (Kaur and Rampersad, 2018).

According to the Society of Automotive Engineers (SAE) there are six different levels of automation for AVs, ranging from a level 0 of no automation to a level 5 of full automation (Table 1). From level 0 to level 2, the driver has to actively drive the car and constantly supervise the vehicle, steering, braking or accelerating when needed to maintain safety. From level 3 to 5 the driver does not drive and the system performs the driving tasks. However, in level 3 the human driver must take over when necessary. Differently, levels 4 and 5 do not require any interference of the human driver, since the vehicle will provide all tasks on its own.

The AV works with a set of ADAS (Advanced Driver Assistance Systems), allowing the vehicle to perform the driving tasks, assisting the vehicle in driving and parking functions, and ultimately improving car and road safety. They are usually classified in four categories: adaptive, which includes all systems changing or adapting depending on input from the surrounding environment; automated, including systems that take control and perform functions that a driver cannot do safely; monitoring, such as sensors, cameras, or other means used to observe the surrounding area or to drive the vehicle

and assess whether a correction is necessary or not; warning, alerting the drivers to potential issues in their own driving or the driving of others that could increase the risk of accident. Table 1 depicts the existing ADAS for each level. ADAS from level 3 to level 5 are not yet incorporated in commercial vehicles.

Table 1.1 – SAE levels: description and ADAS

| **SAE level** | **Name** | **Description** | **ADAS already incorporated in commercial vehicles** |
|---|---|---|---|
| Level 0 | *No automation* | Human driver controls all the dynamic driving tasks. The automatic system produces alerts and may briefly intervene | parking sensors, surround-view, traffic sign recognition, lane departure warning, night vision, blind spot information system, rear-cross traffic alert, and forward-collision warning |
| Level 1 | *Driver Assistance* | The driver assistance system can execute either steering or acceleration or deceleration using information about the driving environment however all the other aspects of the driving task are still performed by the human driver. | adaptive cruise control, emergency brake assist, automatic emergency brake assist, lane-keeping |
| Level 2 | *Partial Automation* | The driver assistance system can execute both steering and acceleration or deceleration using information about the driving environment, while human performing all remaining aspects of the dynamic driving task | highway assist, autonomous obstacle avoidance, and autonomous parking |
| Level 3 | *Conditional Automation* | The system can perform all the aspects of the dynamic driving tasks, while human driver has to respond to a request to intervene | Not yet available |
| Level 4 | *High Automation* | The system can perform all the aspects of the dynamic driving tasks, even if human driver does not to respond appropriately to a request to intervene | Not yet available |
| Level 5 | *Full Automation* | Driving system has a full time control of all the aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver | Not yet available |

Source: Authors' elaboration on SAE website

Current literature is now focusing on demonstrating the large amount of benefits as well as risks deriving from their diffusion. Among others, AVs are expected to improve performance and efficiency over traditional vehicles and to enhance roadway safety (Fagnant and Kockelman, 2015). As a matter of fact, some studies demonstrate that the adoption of AVs is expected to reduce accidents by 80% by the year 2040 (Alessandrini et al., 2015; Paden et al., 2016), deleting the human error, the main responsible for car accidents (Fagnant and Kockelman, 2015). Of importance, environmental

sustainability is another factor that authors see as a potential gain derived from the diffusion of AVs, that should decrease traffic congestion, gas emissions and fuel consumption (Anderson et al., 2014; Fagnant and Kockelman, 2015; Ross, 2014) and enable smart platooning (Haboucha et al., 2017). Albeit all the benefits, some barriers of different nature stand in the way of such innovation by identifying constraints for the future market supply and demand. From a regulatory point of view, for example, legal and responsibility issues arise, questioning who would be responsible for any disfunction in AVs (e.g., Gurney, 2013). Moreover, some privacy issues may occur from the storage and use of a huge amount of personal data involved in the connection of the vehicles with other vehicles and infrastructures (V2X protocol) and from potential problems related to data breach (Miniscalco, 2020; Al-Sabaawi et al., 2020; Fagnant and Kockelman, 2015). Furthermore, some technical barriers are expected: although the improvement within sensors technology, before reaching the level 5 of full automation, there are some challenges to be addressed such as poor weather perception, unfavourable lighting conditions and human perception of sensors (Van Brummelen et al., 2018). Finally, although the enhancement in traffic safety is expected by most of the experts, some studies demonstrate a possible increase in collisions due to the replacement of human error by system failures leading to a lack of agreement in defining the safety of AVs (Othman, 2021).

As a result, issues related to AVs extend also on a social level, where the most difficult barriers in their deployment are identified. Topics of this kind highlight indeed an evolution of technology that travels faster than the evolution of regulatory systems and the understanding of socioeconomic impacts (Fagnant and Kockelman, 2015). This reflection raises the question on how the acceptance of a product not yet in use can be determined. On the one hand, their antecedents, the ADAS, could be analysed. In this sense, AVs could be seen as the final evolution of the existing ADAS technologies, that define their technological complexity. However, highlighting the technological linkage with ADASs is not sufficient to predict the AVs acceptance and future impacts on the market because the complexity of an AV is not linearly connected to and is greater than that observed till

now in association with ADASs. The complexity for AVs increases exponentially with respect of the previous technologies, since more radical societal issues are likely to emerge once it will penetrate the market. On the other hand, AVs acceptance and future impact could be measured through a better framing of the context of use. From the supply side, an efficient strategy may include all the actors involved in the production processes and within an approach of sectoral contamination, gaining a clearer picture of the ecosystem within which the AVs could be used. On the demand side, a strategy focusing on the analysis of potential scenarios whereby AVs may exploit existing usage patterns to fit more gradually within the market. Therefore, the complexity of the issues emerging from AVs requires taking into account dynamics pertaining both to the spheres of demand and supply, as well as the context of use where these emerging technologies will be used, implying the need for a broader reflection with respect to the processes of acceptance and future diffusion of AVs.

### 1.2 Technologies in development: in search of Theoretical Frames

The Innovation Management body of studies has dealt with the management of emerging technologies by looking mainly at the early stages of commercialization of the new products and trying to modelling the set of variables influencing the first adoption and then the diffusion in the market. Scant attention has been reserved in anticipating attitudes and behaviours of market users with regard of emerging technologies that are still in development and far from an actual introduction in the market. Thus, we need theoretical frameworks to support the analysis of how these technologies evolve towards the market, along with how perceptions of future users are progressively shaped as they discover, and interact with, the emerging technologies. That can be leveraged to frame, at a more general level, the specific research questions and theoretical frames that will be used in the following chapters of this thesis work.

One of the theoretical themes is offered by innovation ecosystems, defined in the literature as "*the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor*

*or a population of actors*" (Granstrand and Holgersson, 2020, p. 3). From this angle, innovation ecosystems aim to analyse the relationships established among the actors who are part of the innovation process. The coexistence, usually within a spatial boundedness (Brown and Mason, 2017), of actors of different nature, mutually interdependent, ranging from companies to universities, scientific parks, and public government (Audretsch et al., 2019), defines, through the network of relationships, the evolution of the innovation processes and the diffusion of the emerging technology on the market. A useful tool for the systematization of the collaborations emerging from the variety of actors taking part in innovation ecosystems may be represented by Triple Helix Model (Etzkowitz and Leydesdorff, 2000), that identifies indeed a triadic collaboration between industry, academia and government in three interdependent spheres. The model is founded on the idea of knowledge-based society, where knowledge becomes an increasingly important part of innovation (Etzkowitz and Leydesdorff, 2000), and innovation is defined as an open and non-linear process spreading at different levels within and amongst local institutions (Carayannis and Campbell, 2009). Collaboration and substitution relationships that are inherent in an innovation ecosystem (Granstrand and Holgersson, 2020), occur here among the three institutional spheres, each of which contributes in the innovation process. Based on the consideration that innovations must completely adhere to the social dimension of the environment of which they are a part, leading to the public to become more integrated within the innovation systems, the Quadruple Helix model, as evolution of the Triple Helix model, introduces a fourth sphere, the civil society, placing "*a stronger focus on cooperation in innovation and the dynamically intertwined processes of co-opetition, co-evolution, and co-specialization within and across regional and sectoral innovation ecosystems*" (Carayannis et al., 2019, p.49)

The coexistence, promoted by innovation ecosystems, of different actors taking part to the innovation processes, when applied to AVs, has a twofold consequence. On the one hand, the definition of new forms of collaboration that broaden the boundaries to actors beyond the traditional automakers to include software related firms and high-tech companies (such as Google and Apple), and transport providers (such as Uber) that change the ecosystem and define a contamination between

AVs and emerging business models. On the other hand, in line with a Quadruple Helix model, it enhances the creation of new forms of innovation ecosystems that include policy makers, research institutes and the final users' point of view for "*customer facing solutions*" (Adner, 2006, p. 99). This is the case of Living Labs (LLs), defined "*as user-centred open innovation ecosystems that integrate research and innovation processes in real-life communities and settings*" (ENoLL). In this way, the user and the context of use are included by proposing co-creation processes and exploiting or recreating the actual environment within which the technology might fit once in the marketplace.

The need to include the external context of use in an experimental setting relates also to further literature stream, helpful in the analysis of which variables may influence the processes of social acceptance and diffusion. Socio-technical systems are defined indeed as the structure supporting any societal function, such as mobility in the case of AVs (Geels, 2002). Considering two different orders of variables - the technical and the social regimes – they contribute equally to define a productive system that evolves contextually with the social dynamics within which the technologies will be used (Geels, 2002). Consequently, a continuous dialogue and exchange between the two regimes is necessary, integrating the technological trajectories with the activities that take place within the community and the different social groups of reference. In this view, the processes of diffusion and acceptance of these innovations are not to be thought of as linear dynamics, but as the combined result of the capabilities and policies of the different actors governing the social technical systems (Borras and Edler, 2020). In addition to that, the exchange must take place in an open system, allowing a contamination with the external environment. It is in this transition from the technical to the social regime that some entities belonging to the world of innovation ecosystems, such as LLs, are placed, becoming a boundary interface between the experimentation and the context of use. On the one hand, they become a place for learning technical and innovative solutions; on the other hand, they create the space for building the social networks that will support innovations, such as supply chains, policy regulations, and user-producer relationships. This results in organizational flexibility, which allows the implementation of innovative processes promoting a change in the external context.

Therefore, applying a social technical system point of view to AVs requires to understand how technologies can be integrated within communities and social structure. Specifically, along with engineers and firms, which define technological trajectories, technological regimes of reference, and the body of rules enabling technological improvements, users and institutions play a role, as social groups that promote other set of rules which are essential in the technological innovation (Geels, 2002). In line with this, AVs' technological innovations depend on state actors' regulation, authorisation and transport planning, as well as on consumers' acceptance. However, a mismatch between the emerging technology entering the market and the social structure that should host its diffusion is frequently observed. For instance, the mechanisms for adapting to the context of use of AVs require a change from the regulatory point of view, a modification of the Traffic Laws, of the rules related to liability in case of accidents; they require a structural rethinking of the city and its infrastructure, consisting of a set of deep structural trends, such as spatial arrangements of cities, endowment of sensors and cameras facilitating AVs' circulation. They also require a rethinking of consumer habits, with a radical change in transportation systems and in the meanings associated to the vehicle, which increasingly embraces a concept of service and whose ownership paradigm is being challenged by new business models based on the sharing economy.

When the alignment between the technological improvements and the social system which should accept this technology is weak or absent, as in the case of AVs, whose technological dimension has a faster development than the social one, users' preferences are not fixed, but they are in flux and under definition (Sovacool and Hesse, 2017). From this perspective, we can gain insights from the literature about the diffusion of innovation (Rogers, 1995), that describes customer acceptance of innovative products as a result of interaction between future adopters and their surrounding environment. According to Rogers (1995) the diffusion and adoption of innovations is affected both by the individual's characteristics and the nature of the social system in which the individual is a member. Consequently, for the users the final decision related to the acceptance of an innovation

partly depends on the innovation-decisions of the other members of the system about how, for example, that technology will be introduced (Rogers, 1995). Similarly, other acceptance models that draw directly from the socio technical systems literature (Sovacool and Hess, 2017), may prove to be useful tools for predicting future users' attitudes toward the technological innovation when it is dropped into the context of use, revolving around individual and interpersonal levels (Sovacool and Hess, 2017). For example, through the Technology Acceptance model (Davis, 1989), the importance for the technological dimension to fit with the social one is highlighted, proposing to explore the technical dimensions by examining users' attitudes and beliefs in relation to intentions to adopt or use the technology. Concerning AVs, this means that their ultimate acceptance by society will depend on how they adapt to social norms, pointing out the need to highlight the "*behaviour patterns for the members of a social system*" (Rogers, 1995, p. 27).

### 1.3 Research question and structure of the thesis

Based on these reflections, the following thesis aims to answer to the following research question:

RQ1 - *How can we determine the processes of diffusion and acceptance for emerging technologies not yet in use, such as AVs?*

Given the fact we are dealing with emerging technologies not yet available on the market, the result, in line with a socio – technical system perspective, is an ongoing dialogue between the innovation environments developed around AVs and the changes in the group of stakeholders affected by the introduction of that technology, such as the end-users, whose opinion become a precious benchmark to investigate how AVs could be more gradually included within the society. The following thesis is therefore divided into two macro parts. The first two studies analyse a specific form of innovation ecosystems, Living Labs (LLs), defined as innovation ecosystems which facilitate the diffusion of a specific innovation by recreating a real life setting where to carry out research and innovation processes exploiting a systematic user co-creation approach (ENoLL). They are entities that are potentially able to detect the technological and social complexity linked to the AVs and the

needs coming from the different typology of actors involved in the emergence of a developing technology (manufacturing companies, research laboratories, policy makers etc). The third paper aims to analyse the attitudes of future users toward AVs, integrating the Technology Acceptance Model with the Innovation Diffusion Theory, both of them willing to analyse the degree of acceptance of a new technology from the end-user's perspective.

To test new automotive and infrastructural technologies and better analyse and facilitate acceptance among end-users, there is indeed an urgency to extend the experimentation settings outside laboratories and protected test-areas, moving towards real-world settings and urban areas (Almirall et al., 2012). Among these new experimental forms of collaboration, automotive LLs are drawing a growing attention. In the automotive sector, LLs can be seen as a powerful tool able to better understand and foster the transition towards new forms of mobility where an inter – disciplinary approach becomes essential (Cellina et al., 2020) to prepare the future social technical regime of AV. For instance, in order to understand how to integrate smart mobility within a city centre, it is not sufficient to merely study the technological efficiency of AVs, but it is also necessary to analyse how these are integrated within neighbourhoods, what are the actual barriers to their use from the citizens' point of view, and how the infrastructure can be placed for a more efficient distribution of the service, thereby asking for a set of experts having engineering, managerial and urban policy backgrounds. Thus, a LL-based strategy, under a socio-technical perspective, may capture both the technological and social dimensions and grasp, in this way, the overall trajectory of technology evolution, depicting the interdependencies that exist between physical, social, and regulatory contexts, and assisting in a thorough knowledge of a user-based future environment.

However, literature on LLs still suffers from a lack of systematic organization. Dealing with a phenomenon that only recently has been institutionalized, where theory has been developing after the practice was already emerged (Leminen and Westerlund, 2019), the purpose of the first paper is to identify the gaps between practice and theory, throughout a systematic review of articles analysing the phenomenon of LL via the methodological lens of the in-depth case study. To do that, a total of

65 papers were chosen and analysed, resulting in a classification of three different perspectives: actor-based, methodological and environmental. Among the gaps resulting from the analysis, the need for the definition of a more consistent theoretical substrate for the real-life setting characteristic emerges.

In an attempt to answer to this gap, within the second paper, two experiences of LLs, focusing on new forms of mobility, are selected and analysed, with the purpose to offer new insights to theory from case study research (Eisenhardt, 1989). Borrowing the concept of Enabler Space (ES) as multidimensional container fostering innovation processes (Peschl and Fundneider, 2012), we investigate how the space influences LLs, looking at the physical, social and organizational spaces dimensions. Results show how the dimensions of ES interrelate and influence the evolution of the LL.

Finally, the ease by which consumers ultimately will come to use this new technology will determine the trajectory of AVs (Sovacool and Hess, 2017). Precisely for this reason, the third study aims to contribute to the analysis of the acceptance processes of AVs, highlighting barriers to future adoption and attitudes users currently have toward these technologies. Users' acceptance studies provide an additional reading to technological development analysis by allowing us to know, ahead of the actual user experience phase of a new product on the market, users' attitudes, intentions, and future behaviour. In line with the transformation the sector is having that may eventually discourage car ownership, leading AVs to fit well into a car sharing business model, we define a model that takes the current socio-technological landscape into account for the inclusion of AVs. In order to tackle this gap, an integration of the Technology Acceptance Model (Davis, 1989), with Innovation Diffusion Theory (Rogers, 1995) is proposed, introducing carsharing compatibility as moderator of the model. Results suggest us that carsharing compatibility influences the relationship between Perceived Usefulness, Perceived Ease of Use and Intention to use.

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# 2. From practice to theory. An inductive roadmap for LL literature

Living Labs are defined as collaborative spaces, innovation management tools, as well as open innovation networks developing and validating new products or services through jointly work among different actors within a real-life context. Dealing with a phenomenon that only recently has been institutionalized, where theory of reference has been detected after that practice was already emerged, the purpose of the following study is to propose a systematic literature review of 65 articles looking at Living Lab phenomenon under the in depth case study methodology to define the perspectives under which they have been analysed and the emerging theory/practice gaps. Results suggest a threefold perspective applied to the LLs - namely the actor-base, the methodological and the environmental perspective - and four main gaps to be addressed within future research: the involvement of users, the need for a clearer definition of LL and for an evolutionary approach to their analysis and the lack of a theoretical paradigm for real- life setting.

## 2.1 Introduction

The relatively recent interest to Living Labs (LLs) leads to a fragmented and dispersed literature that has not encountered the stage of maturity yet and that is characterized by a high number of definitions recognizing LLs as different phenomena depending by the point of view from which they are analysed (Leminen and Westerlund, 2016). One of the most widely used definitions of LL, is offered to us by ENoLL, the European Network of LLs, which defines LLs 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*". However, in addition to this definition, there are other characterizations in the literature that see LLs as forms of test and experimentation platforms (Ballon, 2005), as well as experiments or innovation management tools testing, developing and validating new products or services through jointly work among several institutions and with a direct participation of citizens and users (Almirall et al., 2012). Yet, part of the literature sees LLs as open innovation networks (e.g., Leminen et al., 2011; Ståhlbröst and Bergvall-Kåreborn, 2011), where collaboration among different stakeholders is pursued, till involving customers and users as co-developers (Leminen et al., 2015).

In one of the rare analyses of the emergence of LLs, Leminen and Westerlund (2019) recognize three different phases for what authors called "*living lab movement*". They refer to the first phase as "*toward a new paradigm*" (Leminen and Westerlund, 2019, p.10), where LLs started showing up mainly by American scholars, officially with the PlaceLab at MIT (Leminen and Westerlund, 2019). Other studies point out that LL term was used for the first time by Bajgier et al. (1990), for a student experimentation in a Philadelphia neighbourhood called the "*living laboratory*" (Hossain et al., 2019). The concept was later taken up by the architect and professor of MIT, William J. Mitchell, at the early 2000s. Interested in how citizens could be involved more actively in urban planning and city design, he proposed to move research activity from laboratories to *in vivo* setting enabling to monitor user interaction with innovations in reality (Nesti, 2018). During the second phase, the "*learning from*

*experience phase*" (Leminen and Westerlund, 2019, p.10), thanks to the rise of networked organization such as ENoLL (Hossain et al, 2019), the living labs movement began to spread in European companies and universities, especially in the Northern European countries. Albeit both the European and US perspectives share the idea of co-creation and multi-stakeholder concepts as the basis of the living lab design process (Nesti, 2018), scholars agree in referring to them as two different generations of LLs. Whereas the US approach studies LL as a "demo home", with the field trial taking place in special laboratories and technology made available to the user, who can come to try the innovation for a limited period in that place, the European perspective carries on field trials in a real-world context outside the laboratory, making the technology available "within the home" of the users and studying users' everyday habits, switching the attention to the user-activities in real life environments (Leminen and Westerlund, 2019, Schuurman et al., 2011). Finally, in third phase, the "*professional living lab phase*" (Leminen and Westerlund, 2019, p.10), LLs started to assume a set of standardized tools or procedures in their activities (Leminen and Westerlund, 2017). Within this phase, a wide number of LLs emerged and an increasingly number of scholars has been starting to study LLs as units of analysis to understand the innovation processes and outputs from different perspectives and diverse fields (Greve et al, 2020; Leminen and Westerlund, 2019). Initially born to test ICT innovations, LLs use was indeed extended to other areas of product and social innovation, characterizing them as a transdisciplinary topic.

According to this, Leminen and Westerlund (2019) argue that we are dealing with a phenomenon that only recently has been institutionalized, where the theory of reference has been identified after that practice was already emerged (Leminen and Westerlund, 2019). In the LL movement the practical experience is often related to entities that had emerged spontaneously and only later found their theoretical label under the umbrella of LL. This could lead to some inconsistencies due to the fact that the theoretical analysis applied to LLs may not be able to capture the full complexity and articulation of the phenomenological issues that could emerge from the observation of the practice. Hence, a top down direction in the definition of the theory applied by some institutions willing to

spread the LL method worldwide, such as ENoLL, has to deal with a bottom up emergence of practical cases of LLs, "*scattered initiatives*" (Leminen and Westerlund, 2019, p. 5), not always covering all the characteristics recognized by the literature and testing innovation coming from a variety of sectors. Being these forms of theoretical/practical gaps, with the additional attempt to detect the different perspectives that emerge from a systematization of the literature, the following paper proposes a thorough systematic literature review of 65 articles analysing the phenomenon of LL via the lens of in-depth case study. This methodology may be indeed a good proxy to catch the initial inductive nature of the LL phenomenon and to determine the gaps to be addressed in future studies, either identifying those theoretical frameworks related to LLs that do not always adhere to the practical experience or pointing out parts of the LL phenomenon that have not been sufficiently framed in a convincing theoretical perspective.

The paper is structured as follows. First, the research design and methodology are outlined. Then, results are presented, organizing the collection of articles across three different perspectives that emerge from the analysis of the papers, namely actor-based, methodological and environmental. In the third paragraph, the main persisting gaps between theory and practice are discussed. Finally, conclusions and implications are drawn.

## 2.2 Research design

This paper uses a systematic literature review for analysing studies addressing the LL phenomenon through the adoption of the in-depth case study methodology. The aim of systematic review is to offer insights through theoretical synthesis into topics and sub-topics, providing an overview of studies (Tranfield et al., 2003). The search was done using Scopus, one of the most prestigious academic literature databases (Chadegani et al., 2013). Table 2.1 shows the terms used for the search. The entire period available in the database on July 2022 was considered, resulting in 635 occurrences.

Table 2.1 – Search string on Scopus

| Operators | Search string | Content |
|---|---|---|

| | | |
|---|---|---|
| | "Living Lab*" | Title – abstract – keyword |
| AND | "Case study" or "evidences" or "experimentation" | Title – abstract – keyword |

Source: Authors' elaboration

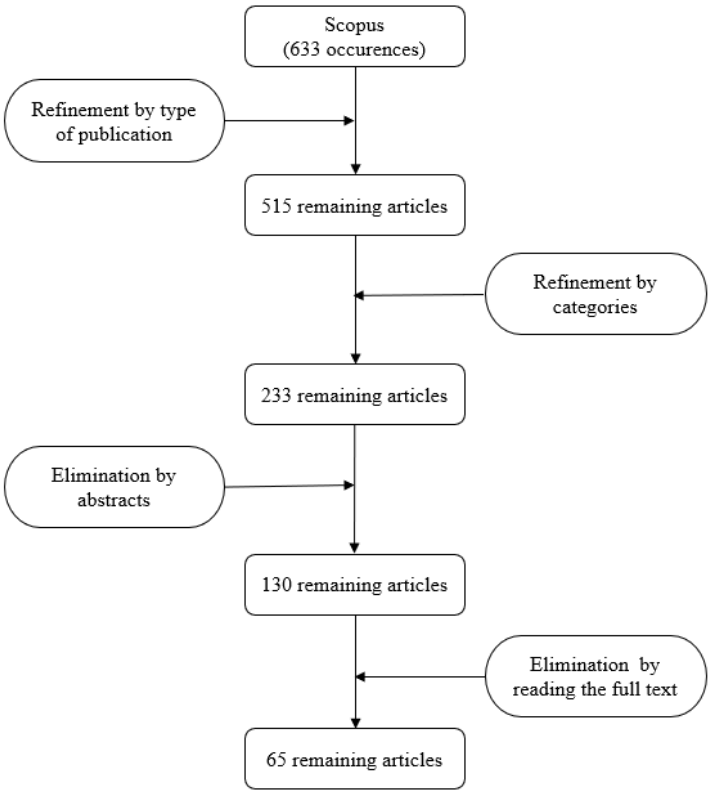
Some filters among Scopus categories have been adopted, limiting the documents to papers and conference papers, and obtaining a total of 515 studies (figure 2.1). Then, we cleaned the keyword selection, eliminating not useful terms, such as "laboratories", and limiting the papers collection to those strictly focusing on "living lab/s" or "living laboratories". Finally, all the papers but those ones in English have been eliminated and the source type was limited to Journal or Conference Proceeding. This, resulted in 233 papers (Figure 2.1), which were classified by author, year, title journal, DOI and abstract. During the reading of abstracts first and of full papers later, we excluded those ones that:

- only had the pre-print version;
- they were not related to social science (for instance, we excluded paper explaining engineering outputs obtained within a LL, but not mentioning anything about the LL structure);
- focused on aggregate case studies without giving specific details about the LLs (such as where the LL is located, the actors taken part in it or the field of interest) and not on a single or multiple in-depth case studies;
- did not contained any case study

Among the 65 selected papers, 46 were journal articles and 19 conference proceedings. We have decided not to exclude the conference proceedings from the data, deeming them potential insights to identify theory-practice gaps. The final papers were organized to have an overview of them in order to proceed with the codification. The first reading phase of the 65 articles was aimed at identifying definitions of LL applied to the case study by each author (see table A1 – definition-based perspective column). The definition-based analysis allowed us to recognize three main perspectives used by the articles. The first one focused on the actors taking part in the LL. According to that, LLs are, for example, defined as "*intermediaries that focus on the mediation between users, public, or private organizations*" (Gasco et al., 2019, p.92). The second perspective analysed LL as a methodology,

defining it, as instance, as "*a participatory approach that enabled communities to shape trial implementation*" (Masunaga et al., 2021, p.3). Finally, the third one viewed LL as an environment, such as "*a space with formal and informal relationships between all those involved in the process*" (Rodrigues et al., 2018, p. 784)

Figure 2.1 – Paper selection process




Source: Authors' elaboration

Through a content analysis, we developed a thematic synthesis, based on the above-mentioned perspectives, highlighting the focus of analysis (actors involved, processes implemented or the LL context) each study used (see table A1 – focus of analysis - based perspective column). In case of discrepancy between the perspective emerged by the definition given to the LL and the one from the focus of analysis, the latter was used to label the perspective where the paper should had been inserted. For instance, a paper which adopts a definition of LL based on a methodological perspective, but then focusing more on the involvement of actors, was assigned to the actor-based perspective, changing the attribution based only on the definition. After mapping the articles, once the attribution of the

papers to three groups was cross-validated, further possible subclassification emerged within the same classification group, thus leading to pattern papers into further subgroups to enable a more accurate analysis. Table 2.2 depicts the process used for the identification of the perspectives and the disposition of the papers under the three perspectives. Results will be outlined over the following section. Table A1 identifies all the definitions and the focus of analysis of each article and the corresponding perspectives.

Table 2.2 – Data analysis process

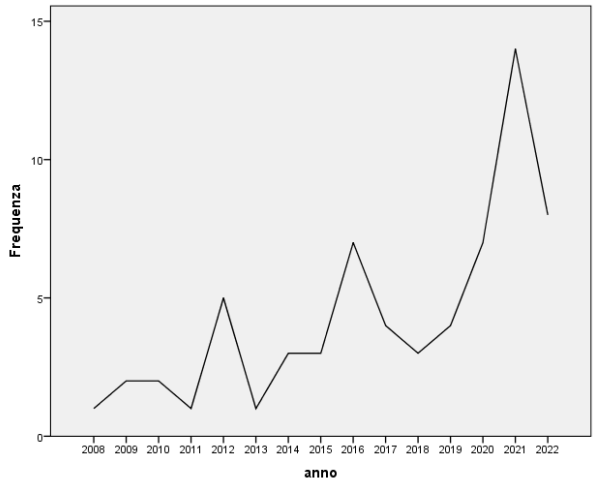
| **Phase** | **Task** | **Outcome** |
|---|---|---|
| LL definition-based analysis | Analysis of definitions of LLs applied to case study by each author | Identification of three main perspectives: actor-based, methodological, environmental |
| Content analysis | Analysis of the focus of analysis for each paper, and classification based on the three perspectives;<br>Comparing focus of analysis and definitions classifications | Reorganization of the paper within the three perspectives by focus of analysis |
| Sub-groups classification | Analysing the lens of analysis applied by authors within each group | Identification of sub groups |

Source: Authors' elaboration

### 2.2.1 Descriptive analysis

The analysis covers a period which spans from 2008 to July 2022. Since 2018, the in depth case studies using LLs have been increasing significantly, suggesting a rise in research interest on this topic (Figure 2.2).

Figure 2.2 – Frequency of papers using in depth case studies over the years (2008- July 2022)




Source: Authors' elaboration

Table 2.3 depicts the countries where the LLs are placed and their typologies, according to the sectors of application. Concerning the country where case studies were situated, more than the half of the LLs is located within Europe, with a higher frequency of Spain and Belgium.

Table 2.3 – Descriptive analysis

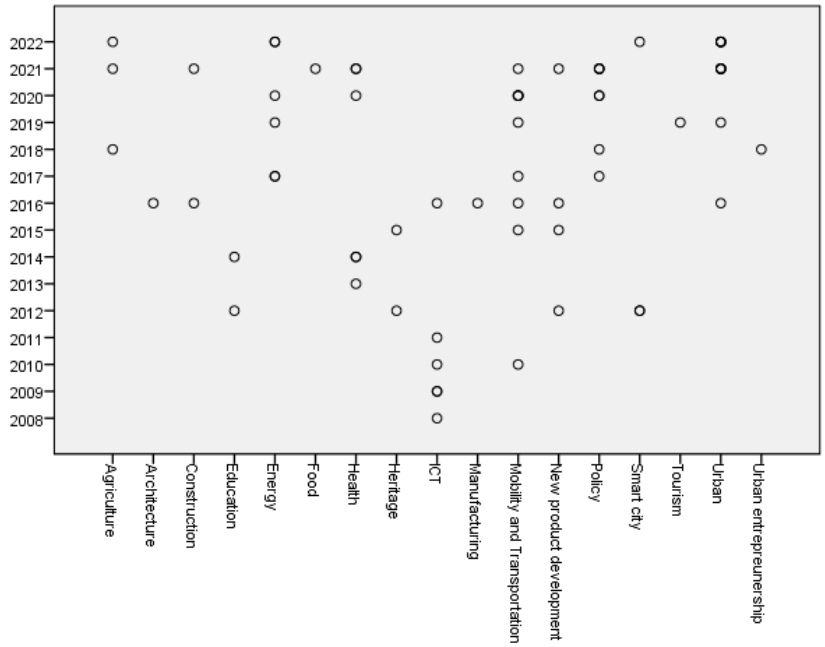
| | Frequency | % |
|---|---|---|
| **Country where the LL was applied** | | |
| Spain | 9 | 13% |
| Belgium | 7 | 10% |
| France | 6 | 9% |
| Italy | 5 | 7.6% |
| Germany | 5 | 7.6% |
| Austria | 4 | 6% |
| Finland | 3 | 4.5% |
| Netherlands | 4 | 6% |
| Others (EU) | 11 | 17% |
| Extra EU | 11 | 16% |
| **Typology of LL** | | |
| Urban | 13 | 20% |
| Energy | 6 | 9% |
| Construction | 3 | 4,5% |
| Mobility and Transportation | 9 | 14% |
| Public Administration and policy | 7 | 11% |
| Food | 1 | 1,5% |
| Health | 7 | 11% |
| New product development | 4 | 6% |
| Tourism | 1 | 1,5% |
| History and Heritage | 2 | 4% |
| Education | 2 | 4% |
| ICT | 6 | 9% |
| Agriculture | 4 | 6% |

Source: Author's elaboration

Most of the papers focused on case studies based on Urban and on Mobility and Transportation LLs. However, case studies contained in the articles are not always related to a unique field of application. In these cases, the decision about the field of application of LL was done by considering the main context of use in the analysis. For instance, a LL studying new technologies based on ICT for the public administration, was labelled as a Public administration and policy LL.

The chart below (Figure 2.3) identifies the typologies of LL (x axis) analysed by year of publication (y axis). While in the early years LLs are mainly used for technologies involving the ICT sector, since 2010, an increasing number of LLs has been starting to be applied to other sectors.

Figure 2.3 – typology of LL per year of publication




Source: Author's elaboration

## 2.3 Three different perspectives to analyse the LL phenomenon

For each paper the most relevant definition that authors give to the LL concept in accordance with their case study was highlighted. The analysis of the definitions defined three different perspective, that have been then used to classify the papers based on the focus of analysis (see table A1 in the appendix). The following session analyses each perspective. The perspectives must not be seen as mutually exclusive, but as different lens to analyse LLs. Distinguishing the studies within different perspectives allows us to grasp the variety of characteristics composing studies as well as detecting the gaps that exist from theory and practice. Table 2.4 divides the papers on the basis of perspectives and identifies the sub-themes that emerge from them.

Table 2.4 – Perspectives

| Perspective | Sub-topics | Authors |
|---|---|---|
| **Actors-based** (Who) | **Actors' dynamics** | Georges et al., 2016; Gasco, 2017; Fitzpatrick and Malmborg, 2018; Svesson, 2014; Nguyen et al., 2022 |
| | **Actors' roles** | Lai et al, 2009; Gasco, 2017; Kuba et al., 2016; Marone et al., 2020; Toffolini et al., 2021; Nguyen et al., 2022; Mukama et al., 2022 |

| | | |
|---|---|---|
| | **Drawbacks of multi-actor collaboration** | Schuurman et al., 2013; Hyysalo and Hakkarainen, 2014; Gasco, 2017; Fitzpatrick and Malmborg, 2018; Waes et al., 2021; Nguyen and Marques, 2022 |
| **Methodology** (How) | **Processes leading to LL setting up** | Baltes and Gard, 2010; Schuurman et al., 2011; Alaoui and Lewkowicz, 2014; Haider et al., 2016; Romero et al., 2016; Amenta et al., 2019; Lasarte et al., 2021; Arnould et al., 2022 |
| | **Bottom up processes to develop solutions** | Monguet et al., 2010; Schuurman et al., 2011; Lupp and Van Greunen, 2013; Veldsman and Van Greunen, 2013; Bertlet, 2020; Cellina et al., 2020; Calzada et al., 2019; Masunaga et al., 2021; Kretschmer and Dehm, 2021; Dietricht et al., 2021 |
| | **Enabler of new technology** | Monguet et al., 2010; Bourgault et al., 2012; Katzy et al., 2012; Heyvaert et al., 2015; Kazi et al., 2016; Haider et al., 2016; Chech and Wagner, 2019; Di Biccari et al., 2020; Gerhold et al., 2020; Gabriel et al., 2020; De Vita and De Vita, 2021 |
| **Environment** (Where) | **Arena for actors' relationships** | Song et al., 2009; Georges et al., 2015; Canzler et al., 2017; Rodrigues and Franco, 2018; Criado et al., 2020; Haug and Mergel, 2021; Hernández-Pérez et al., 2022 |
| | **Community where innovation takes place** | Bergvall - Kåreborn and Larsson, 2008; Song et al., 2009; Edwards-Schachter et al., 2012; Santally et al., 2014; Claude et al., 2017; Cuomo et al., 2020; Temmerman et al., 2021; Turku et al., 2022 |
| | **Place to test new technology** | Cooseman et al., 2010; Labeau et al., 2010; Galache et al., 2012; Joller and Varblane, 2017; Zwierenberg et al., 2017; Lovell et al., 2018; Engels et al., 2019; Lusikka et al., 2020; Dekker et al., 2021; Taylor, 2021; Hristov et al., 2022; Ascione et al., 2022; |

Source: Authors' elaboration

*Actors-based perspective*

Within the actors-based perspective, studies focus on the actors taking part within the LLs, stressing the openness principle and the subsequent multistakeholder aspect proper of them. Within this perspective, emphasis is put on: the actors' dynamics (e.g: Gasco, 2017; Nguyen et al., 2022; Fitzpatrick and Malmborg, 2018); the diversity of the LL's actors and the roles they play (e.g: Marone et al., 2020; Toffolini et al., 2021; Nguyen et al., 2022); and the drawbacks emerging from the multi-actor collaboration (e.g.: Hyysalo and Hakkarainen, 2014; Nguyen and Marques, 2022; Fitzpatrick and Malmborg, 2018).

When focusing on actors' dynamics, LLs connect users and support and facilitate the exchange of ideas and knowledge (Gasco, 2017). The LL is then placed in direct continuity with the Quadruple Helix Model (QH). Expanding on the Triple Helix Model (Etzkowitz, 2012), the QH adds to the collaboration between the three institutional spheres driving innovation processes – namely academia, industry and government and the social sphere, represented, within the LLs, by citizens and end users (Carayannis and Campbell, 2009). According to Nguyen et al. (2022), who analyse a LL in the context of the smart city, power dynamics are the engines moving the spheres of QH which transform the LL into an orchestrator that can define changes in power relations between the citizens and the other stakeholders, especially through the function of LL coordinators who transfer citizens' information and opinions to the other stakeholders of the LL. As LLs bring actors of different natures to interact through co-creation, co-production and knowledge exchange (Gasco, 2017), conflicts between actors, such as a different degree of influence and decision-making power within the LL, lead to different forms of collaborative dynamics (Fitzpatrick and Malmborg, 2018, Nguyen et al., 2022). As instance, Fitzpatrick and Malmborg (2018) analyse collaboration issues among citizens, industrial, public and academic partners in a LL based on co-design project, identifying the areas of tensions among the actors. Authors state that conflicts emerging from different visions, as a higher attention to time to market aspect by commercial actors than by actors belonging to the other spheres of the model, lead to tensions which become productive and contribute to the innovation process, forcing the actors to discuss and find a balance (Fitzpatrick and Malmborg, 2018).

A second group of authors, in accordance with the TH and QH, focuses on different roles recognised to each institutional sphere. Government offers infrastructure and develops policies that encourage the demand of product and services emerging from the LL, academia provides knowledge and funds, managing and co-leading most of activities, while industry contributes usually with physical equipment (Nguyen and Marques, 2022; Marone et al., 2020). Mukama et al., (2022), analysing an energy LL for poor urban environments, classify actors' roles, basing on motivation and

legitimacy. The government sphere is referred as a "*dominant stakeholder"*(Mukama et al., 2022, p.6) gaining in power and legitimacy but lacking the urgency to solve the community requirements, probably given the large number of other tasks and demands of the community itself. Industry is defined as a *"definitive stakeholder"* (Mukama et al., 2022, p.5), due to the effective legitimacy and power and its urgency to implement the innovation. Finally, university is viewed as a "*dependent stakeholders*" (Mukama et al., 2022, p.5), as they have the legitimacy and urgency but lack power "*to impose their developments or innovations on the community*" (Mukama et al., 2022, p.5). A similar role division is proposed by Kuba et al (2016) in the context of an eHealth LL telemonitoring subjects with neurological diseases. Authors recognise the patients and the healthcare workers as the central stakeholders, while companies interesting in Telemedicine application, such as device manufacturers and providers, as supporting parties. Toffolini et al. (2021) use the concept of boundary object (Star and Griesemer, 1989), referring to the LL's ability to converge actors from different social worlds to work together in a new way, exploiting a structure that combines high flexibility with a level of standardization sufficient to be common enough for actors coming from different institutional spheres (Toffolini et al., 2021). To those spheres, the LL ideal model provides that users actively participate in all the innovation process, as they are expected to become co-creators, or co-designers (Marone et al, 2020; Mukama et al., 2022). However, authors argue that these roles' assignment, even if intended, face with the dynamics of working within the existing innovation system (Toffolini et al., 2021). Hyysalo and Hakkarainen (2014), comparing two new health technology projects within a LL, state that extensive collaboration between designers and users is the key for the success of innovation technologies, being this a LL or not. However, a LL offers indeed "*a legitimate rationale to lead parties engaged to go through all the work needed to create the specific and particular relationships by which the relevant information can be made visible and transferred to the other party*" (Hyysalo and Hakkarainen et al., 2014, p 206). Authors thus emphasize how the redistribution of roles in LLs with respect to assigned tasks depends on the multitude and diversity of forms of interaction occurring within the LL (Toffolini et al., 2021) as well as the technological context within which the LL is

embedded (Mukama et al., 2022), given that the users' roles within a LL cannot be considered as chosen by the steering actors, but rather as the result from multiple interaction processes (Hyysalo and Hakkarainen, 2014). Toffolini et al. (2021), analysing the processes through which different roles emerge within an agricultural LL, based on the interpretation concerning the LL innovation model and the territory, recognize four different groups of farmers roles ranging from efficiency factors to "*agricultural citizens*" (Toffolini et al., 2021, p. 161) who promote innovation initiatives and processes. Different degrees of end-user involvement are also identified by Gasco (2017), who, analysing two civic LLs, shows how, in one case, users spontaneously create new services through individual processes, while, in the other case, the creation of new services is the result of a collaborative process, with the organization of activities depending on associations that manage individual projects.

Finally, the third group of authors focus on the drawbacks of actors' collaboration. Beside the degree of user involvement, other issues related to the collaboration among different actors emerge indeed. Despite some of the drawbacks, as different needs, are usually seen by authors as potentially productive tools for the innovations processes (Fitzpatrick and Malmborg, 2018), when different actors work on the same projects, some dilemmas can arise and they have to be recognized and carefully managed. As the variety of ideas and innovations increases, and the group of actors converging in the same LL become more heterogeneous, a degree of lack of effective communication emerges from LLs cases studies (Fitzpatrick and Malmborg, 2018; Gasco, 2017; Waes et al., 2021). This lead, for example, to a different conceptualization of LLs and a consequent ambiguity related to the roles and tasks, leading to some actors to assume multiple roles (Waes et al., 2021; Gasco et al., 2017). In addition, a diversity within the strategies and needs among actors, continuously evolving as the innovation process changes, is recognized as another challenge emerging from the multi-actor collaboration (Fitzpatrick and Malmborg, 2018; Hyysalo and Hakkarainen, 2014) .

*Methodological perspective*

Within the methodological perspective, studies focus on methodological frameworks and processes used, in LL context, to test innovations through collaboration between different actors and the involvement of end users in a realistic context of use. Following this, papers look, for examples, at the processes and methodologies to be developed and validated to assess innovations with users and multiple stakeholders. Here, LLs are seen: as a process, analysing the methodological framework leading to the implementation of the LL (e.g: Arnould et al., 2022; Amenta et al., 2019), as participatory approaches, focusing on the co-creation processes enhancing solutions (e.g.: Masunaga et al., 2021; Kretschmer and Dehm, 2021), or as enablers of new technologies within society (Di Biccari et al., 2020; Heyvaert et al., 2015; De Vita and De Vita, 2021).

Within this perspective, an initial focus is placed on the procedures and processes for the LL setting up. Indeed, part of the innovation of LLs lies in the LL itself and how it is generated (Schuurman et al., 2011; Batles and Gard, 2016). Before the LL is set up, an exploration phase, using both desk analysis and observational ethnographic research, is usually conducted (Schuurman et al., 2011) as well as consultations with the key stakeholders of the process allowing to focus to user's requirements (Lasarte et al., 2021; Haider et al., 2016). As instance, Amenta et al. (2019), analysing the processes leading to the setting up of LLs in some peri urban areas, define a five phases process. The co-exploring phase aims to obtain a common understanding of the territory, developed with the collaboration of all the researchers, stakeholders and experts identified and involved in the project. The co-design phase identifies specific challenges and problems that are then developed in the co-production phase to address the model to answer to the specific issue. Within the fourth phase, the co-decision one, conflicts between different interests and groups of decision-makers involved in the project are solved. This phase is necessary to get to the co – governance phase and the definition of the LL. Arnould et al. (2022), propose a methodological framework based on three methodological stages leading to a forestry LL creation. Within the planification phase the guidelines of the LL are

defined, as well as an analysis of the real environments and the identification and selection of stakeholders and users. The exploration phase allows to define a shared vision of the real environment and to formalize LL, evaluating users' needs and expectations. Finally, in the third phase, the creative co-design one, solutions and ideas are provided thanks to a co-creation activity by collective workshops.

In accordance with the co-creation logic, authors stress the idea by which, within LLs, innovative ideas are not planned and implemented top-down but co-created within an open-ended process of innovation (Kretschmer and Dehm, 2021; Masunaga et al., 2021). Following this, LL is a method to develop and test solutions exploiting a bottom-up, participatory approach, empowering partners and users and exploiting their experience aspect (Cellina et al., 2020; Veldsman and Van Greunen, 2013). To do so, some LLs intertwine co-creation processes with the Participatory Action Research (PAR), "*a collaborative, action-based process between researchers and participants, who work together in making socio-technological changes by promoting the multi-faceted understanding of a complex issue in its real-life context*" (Kretschmer and Dehm, 2021, p.5). LL are then seen as a cycle process (Masunaga et al., 2021; Kretschmer and Dehm, 2021) by which participants identify a problem, collect and analyse data, and "*iteratively take and reflect upon actions*" (Kretschmer and Dehm, 2021, p.5). According to Kretschmer and Dehm (2021), the framework involves three phases – namely action planning, stakeholder engagement, and reflection – which are repeated across two consecutive *feedback cycles*. Masunaga et al. (2021) analysing a LL for health, present a back and forward community participatory approach consisting in different steps. The first one, the ethnographic study, enables the construction of the clinical trial and addresses the requirements of community. Then, the stakeholder analysis follows, engaging key informants and individuals to be involved within the project. Through participatory-discussions, ethnographic results are validated, and researchers and communities evaluate the relevance of the study, share possible solutions and implement strategies in a co-development manner. Some authors compare LL approach with other methodologies aimed

at co-creation with the end user (Dietrict et al., 2021; Bertlet et al., 2020). For example, Dietricht et al (2021) compares a LL with a co-design project. The authors argue that, while the co-design process is easily evaluable and provides a step-by-step approach that is replicable in other technological contexts, the LL promotes a broader approach that, while purposeful to involve the end user since the earliest stages, is more vague and less efficient.

The third stream within this perspective looks at LLs as forms of enablers of new technologies, mixing them with a variety of methodologies such as behavioural models (e.g.: Heyvaert et al., 2015), or scenarios analysis (Gerhold et al., 2020). As instance, Di Biccari et al., (2020), analyse LL as a whole methodology that enables the introduction of new technological solutions within a workplace, in the context of Public Administration. Using quantitative methods such as a pre-use and post-use questionnaire, they underline how, through the use of instruments such as training workshops and focus group, the willingness to change the in use technology by the employees increases. Likewise, Heyvaert et al. (2015), studying a mobility LL, point out the possibility to enhance the efficiency of on road trials of electric vehicles with models measuring consumers' attitudes, questioning test users about their perception after some weeks of testing trial and analysing how their attitude toward the vehicle technologies change. Another example is given by Bourgault et al. (2012) which analyses a LL to train engineers in project management field, where a collaborative platform was set up to allow to teams from different campuses to participate.

*Environmental perspective*

The environmental perspective focuses on the context in which LLs are embedded. LLs are defined as real-life contexts as the interaction between user and technology takes place in a real (e.g.: Temmermam et al., 2021) or semi-real (e.g.: Geroges et al., 2015) environment. The LL, in this perspective, is analysed as: the arena where relationships between actors take place (e.g.: Canzler et al., 2017; Song et al., 2009; Hernández-Pérez et al., 2022;), the context where innovation processes

are implemented (e.g.: Turku et al., 2022; Temmerman et al., 2021; Brigitta et al., 2008), or the place where technology is tested (Lusikka et al., 2020; Engels et al., 2019; Joller and Verblane, 2017).

The LL is therefore the arena where formal and informal exchanges between actors take place, an open space where different actors' interests converge (Rodrigues and Franco, 2018), but also what makes stakeholders part of the innovation process, allowing actors from previously separate organizations to participate in developing the new solutions and forcing those ones with divergent expectations and pursuing different strategies to find a first compromise (Canzler et al., 2017; Criado et al., 2020). Canzler et al. (2017), dealing with a LL in the field of energy and mobility, demonstrate how the proximity leads actors belonging to different organizations to compete for the limited resources and decision power in managing the area. At the same time, LL becomes the "*encountering space*" (Hernández-Pérez et al., 2020, p.6) where actors come together and cooperate to make innovations happen (Hernández-Pérez et al., 2020; Canzler et al., 2017). Transforming the space into a place where multiple stakeholders come together and take part to the innovation process (Hernández-Pérez et al., 2020) LL may affect the entire community. In line with this, Haug and Mergel (2021), analysing a LL in the Public Administration (PA) context, view LL as an environment based on public value creation, providing a place to establish interactions between the PA and its stakeholder.

LLs, as "*physical or virtual user-centric innovation environments aiming to solve societal challenges*" (Temmerman et al., 2021, p.169), embrace a wider vision that is intertwined with the Social Innovation (SI) concept (De Filippi et al., 2017). Within the domain of SI, LLs are labelled as collaborative platforms (Dekker et al., 2021; Temmerman et al., 2021), defined as an "*open environment with clear frameworks, guidelines, resources and supports which invites all actors to collaborate in producing public value as well as value which directly benefits the actors themselves*" (Millard, 2013, p. 79). In line with the SI theory, the way in which this innovation process takes place transforms the social dynamics of the community in terms of social cohesion and community

engagement (Temmerman et al., 2021). For this reason, the context in which innovations are developed, evaluated or tested is an important element. The context can be a community, or the focus can be placed within an organisation (Temmerman et al., 2021; Song et al., 2009). Authors look at the "*social and cultural practices, consumption, everyday life and social learning*" (Turku et al., 2022, p. 9) where the very activities carried out by the community are transformed into community-building innovations (Cuomo et al., 2021). Through the LL, the users of a district can, for example, make changes necessary to regenerate the territory and transform it into a more inclusive place that is less detached from the rest of the city (Temmerman et al., 2021), thus allowing the LL to take on the appearance of a "*full-scale urban laboratory*" (Song et al., 2009, p. 4).

A third group of authors views LLs as platforms for testing new solutions within protected contexts (Ascione et al., 2022, Lusikka et al., 2020). This allows to test hazardous technologies in a controlled environment while investigating how they interface with society, making the LL taking on the traits of a "*miniature society*" (Engels et al., 2019 p. 3). From this, the need to harmonize unique social conditions under which actors operate with developing scalable solutions that could serve as models to follow for other innovations once the test is completed (Engels et al., 2019; Lovell et al., 2018). For example, Hristov et al. (2022) analyse a *digital twin*, a virtual replica of a real city, which gathers data from the infrastructure and services of the city using connected devices and sensors. In this context, the establishment of urban LL, on the one hand, it provides useful data to the digital twin, on the other, it allows to better monitor and understand the urban processes and policies (Hristov et al., 2022). Within this research stream, some authors compare LLs to: test beds, technology tests accepting/refuting scientific hypothesis (e.g.: Lovell et al., 2018; Galache et al., 2012); regulatory sandboxes, where actual regulations are not totally applied to help fostering innovation (Hristov et al., 2022; Engels et., 2019); or fields trial, settings thought for stimulating the end-users - technology interaction in real-life contexts (Georges, 2015; Canzler et al., 2017). However, Joller and Varblane (2017) state that, in case of radical innovations, LL should not to be seen as a mere test bed, which

alone would not be sufficient for investigating on social acceptance and market success, but only the technical functioning of the technology; but it should provide a tool for exploration of new solutions in a controlled environment before their deployment. Following this, Cazler et al., (2017) proposes the Multi – Level – Perspective theory as lens of analysis to study the emergence and change of socio technical arrangements, considering LLs as "*incubation spaces for technological transition*" (Cazler et al., 2021, p. 26). In this way, the necessary changes can be effectively captured not only at a technological level, but also at a societal level (Cazler et al., 2021; Ascione et al., 2022).

## 2.4 Critical points and future research streams

The perspectives through which LLs have been analysed demonstrate the plurality of definitions that have been associated with them over time, as well as the variety of theoretical frameworks and lenses of analysis that have been used by the authors. The table A1 in the appendix summarizes the papers analysed and the definitions each of them associates to their own case study.

Because this phenomenon is recent and cross-sectoral (Leminen and Westerlund, 2019; Følstad, 2008), drawing universal criteria for all sorts of LLs is unavoidably challenging and may produce ambiguities (Fulgencio et al., 2012). As Leminen and Westerlund (2019) argue, the institutionalization of what the authors call LL movement, is a process that started not so many years ago. In this process, collective organizations promoting LLs, such as ENoLL, started to emerge (Leminen and Westerlund, 2019), considering them as suitable models for an increasingly complex society in which the boundaries between different disciplines are increasingly blurred (Guzman et al., 2013). LLs have thus shifted from being considered, at the earliest stages, as a phenomenon based on ongoing and sporadic practical experiences with no overarching theoretical frames to support the conceptualization and the analysis, to become, in the latest studies, in search of a stronger institutionalization, a more top-down defined phenomenon. In addition to this, the extension of the LL model to an increasing number of sectors is to be considered. As instance, if technologies are tested in the healthcare sector, not only the actors and the location are different with respect of a LL

operating – I say – in the tourism sector, but the innovation process itself has different dynamics. As a consequence, the fragmented empirical basis leads to some gaps between practice and theory.

In some cases, we observe an attempt to frame the analysis of the LL practical experiences into theories that sometimes fail to offer an adequate support for model building, analysis and the interpretation of the phenomenon. While the institutionalization of LL movement has allowed to spread the interest on the LL phenomenon, it has also placed some theoretically-driven analytical constraints that do not always take into account the peculiarity of the innovative contexts under consideration and the heterogeneity of the situations we may observe once the LLs are dropped into society, albeit as just an experiment. The User Innovation itself identifies users as direct innovators, participating in all innovation processes within a co-creation process (Von Hippel, 2007). This concept, although central in the literature of LL, does not always find practical resolution within the case studies, where, in some cases, the user or community does not become an active part of the innovation processes defined within the LL. Moreover, what we observe, perhaps also dictated by the plurality of definitions, is the use of the term LL for case studies that are identifiable as forms of joint collaborations, but which, although they contain similarities with LLs, are different from them. This is the case, for instance, of authors who refer the term LL to other forms of collaborative platforms, such as sandboxes, field trials or test beds (e.g.: Hristov et al., 2022). Finally, being an on-going still under development phenomenon and experiencing the first natural transition from a diverse and differentiated practice to a unique theoretical body, some areas of the LL phenomenon are still searching for a theoretical lens through which to be examined. This is the case of the real-life setting, which is expressed within the case studies with a variety of nuances making the empirical baseline even more fragmented.

The systematic review based on selected papers focusing on in-depth case studies allows us to capture some of these inconsistencies between the analytical and methodological tools offered by the theoretical apparatus which is starting to be consolidated in the LLs literature, and the concrete

dynamics that are observed into practice. In the next paragraphs, with the aim to promote a more critical and constructive debate on LLs and to better embrace all the differences and subtleties of the emerging phenomenon, four critical points are highlighted that - we believe - need to be more widely explored in future research streams.

*The application of User Innovation within LL*

User Innovation (UI) is defined as a phenomenon where customers and users develop new products and services, for their own benefit, (Von Hippel, 1976). The innovators are labelled as lead user (Von Hippel, 1986), "*serving as a need forecasting laboratory for marketing research*" (Von Hippel, 1986, p. 791) and "*having real life experience with novel product or process concepts of interest*" (Von Hippel, 1986, p. 796). Following this, Von Hippel identifies certain mechanisms to transfer innovation from the user to the manufacturer and thus enable large-scale diffusion, such as, for example, the use of market-research departments to actively seek innovations developed by lead users, the design interactions done with "*toolkits for user innovation*" (Von Hippel, 1976, p. 37), or the transformation of users themselves into manufacturers. One of the main characteristics of the UI theory, is that the innovation comes from the user, who is an active designer of it, never mentioned as a passive object to be analysed, even if in its interaction with the new product or service. The UI paradigm does not provide a passive observation of the user indeed, even if in a real setting, but always it identifies the user as a subject who brings a direct modification of the innovation or who suggests that modification to the manufacturer, with the aim to answer more effectively to his/her needs.

According to the literature of LL, a key element is Users Involvement (Bergvall-Kåreborn and Stahlbrost, 2009; Leminen et al., 2015; Hossain et al., 2019), drawn directly from the UI theoretical apparatus. Hence, it provides that users are not just observed in their interaction with technologies, but they are also actively involved in the innovation process (Bergvall-Kåreborn and Stahlbrost, 2009; Leminen et al., 2015). In this sense, users are made part of the innovation strategy and their feedback

can be collected in a useful and efficient way to exploit the creative power of user communities (Leminen et al., 2015). However, when intertwined with the practical cases, the adoption of a UI framework shows some inconsistencies. Within the cases analysed, when the theoretical framework is dropped into practice, different interactions with the end user are observed, ranging from a situation where users are mere passive units of analysis to cases where users act as co-creators. What emerges, in particular, is the importance to adopt models that can support the analysis to embrace different degrees and types of involvement of end users in the innovation process, because of the heterogeneity related mainly to the differences in the context of technology use. The role of the user changes greatly depending on the case study. The user can take on the function of an evaluator, as in the case, for example, of a LL created to allow companies to test products and services asking consumers to test them (e.g.: Georges et al., 2016); play an active role, as in the case of citizens taking strategic decisions to change the district in which they live (e.g.: Temmerman et al., 2021); but also become a passive unit of analysis, when a complex technology is shifted into a real, albeit protected, life setting and the human-technology interaction is analysed (e.g.: Engels et al., 2019). Therefore, we argue that the different roles of the end users within the LL should be clarified, and a deeper reflection about the interaction taking place between user and other stakeholders is needed, considering the type of innovation the LL is focused on.

*An ambiguous definition of LL*

Some authors when explaining LLs, in accordance with the classification given by Ballon et al. (2005), define LLs as specific types of Test and Experimentation Platforms (TEPs), in some cases identifying LLs as synonymous of test beds (Engels et al., 2019; Galache et al., 2012) or field trials (Gorges et al., 2015). While it is true that, on the one hand, if we look, for example, at the improvements that can be made on the technological efficiency side, LLs can be described as having characteristics that make them similar to test beds, on the other hand, the contribution to innovation brought by LLs is not merely technical, but it aims to identify the social context in which the use of

technology is embedded. As for field trials, while it is true that the technology is dropped into a real-life setting, within a LL context, the realism is not limited to the appraisal of the interaction between a single technology and a single user, but it is also extended to the ecosystem of actors of the LL: to the users who participate in the innovation process as well as in the arrangement of roles entrusted to the stakeholders that try to foresee problems or opportunities that occur when that innovation is adopted within a real social context.

For these reasons, considering the LL simply as a test bed or field trial seems to apply a reductive lens to the study of innovation process in a LL, since recurring to these conceptualizations does not allow to grasp all the features characterising the whole innovation process typically occurring within a LL. Future stream of research should be focused on identifying the differences between LL and other kinds of TEPs, looking at practical cases that can highlight how the innovation processes take place and the actors who are involved in it.

*An evolutionary lens of analysis of LL*

Within the actor-based perspective, some lens of analysis that are gaining ground, in line with the guidelines proposed by ENoLL, are the Triple Helix (TH) and Quadruple Helix (QH) models (e.g.: Gasco et al., 2017; Kuba et al., 2016; Toffolini et al., 2021). The TH, developed by Etzkowitz and Leydesdorff (2000), identifies a triadic relationship between university, industry and government. TH system works with a set of *components* (the three spheres of interest - Industry, Academia and Government), *relationships* between the components and *functions* (the competencies of the system components) (Ranga and Ezkowitz, 2013). Within the QH, as extension of the TH, a fourth sphere is added, called "*media-based and culture-based public*" (Carayannis and Campbell, 2009), involving societal based innovation user stakeholders. The contribution of these lenses of analysis is twofold. On the one hand, they allow the multi-stakeholder characteristic of a LL to be captured. On the other hand, the helixes metaphor refers to the evolution of the structure, as the balance between the spheres changes and evolves over time (Leydesdorff, 2012). Through processes of substitution, collaboration, technology transfer, or networking among the different spheres, which are the functions identified by

Ranga and Ezkowitz (2013), new equilibria are established, bringing about a change and evolution in the form, and sometimes the purpose, of the phenomenon analysed.

Under the evolutionary perspective, as TH or QH application, a LL could be analysed as a dynamic, and constantly changing process. However, in the case studies analysed is often described as a finite and already determined element, embracing more a static view of the model. The aforementioned ambiguities in the definitions of the LL when compared to the other forms of TEPs could thus be partly overcome through the use of an evolutionary perspective in their analysis. For instance, a LL taking the form of a test bed could be conceived as the result of a specific evolutionary path, where the industrial sphere has assumed greater prominence than the governmental sphere. Analysing LLs by using an evolutionary perspective could thus offering a theoretical framework able to conceptualize in a unitary way phases where its characteristics are more akin to those of a test bed and other phases where instead the conception of LL is fully embraced.

*The lack of a theory for the real-life setting*

Since LL is still an under-construction phenomenon, some theoretical gaps exist also in relation to the place and spatial dimension of the concept. Within the environmental perspective, further light is to be shed on the real-life setting as central element of LLs (Bergvall-Kåreborn et al., 2015). Offering a theoretical foundation for the real-life setting dimension can lead to a more specific conceptualization of the space where the innovation process takes place, helping to better define the open context and the participatory and co-creating method by which innovations within LLs are implemented. On the one hand, substituting the experimental and controlled approach of a traditional lab with an open lab concept based on real setting, it incentivizes and facilitates the collaboration among different stakeholders. On the other hand, it allows to analyse users in their everyday life, while helping to define a co-creation process (Bergvall-Kåreborn and Ståhlbröst, 2009). The real-life characteristic allows then to observe the innovation within the surrounding environment, analysing

the interaction with the context in which it is embedded. However, the real-life setting, albeit its centrality, up to now has been failing to find a clear theoretical paradigm of reference.

This implies that the spatial definition of a LL, although central at a theoretical level, takes on very different characteristics at a practical level, thus increasing the entropy to the LL characterization and identifying substantial differences between them. Analysing LLs from their real-life setting, two different generations of LLs can be recognised. A first generation takes place in special laboratories resembling some facets of real-life experience (sometimes referred to as the American Living Lab approach), while a second generation is set in a real-world use context, in relatively uncontrolled settings outside of the laboratory (Geroges et al., 2015). In particular, within our case studies, real-life setting spans a variety of contexts, from relatively small-scale and geographically limited LLs, such as buildings designed to be nearly zero energy (Ascione et al., 2022) or the *house of presents* analysed by Zwierenberg et al. (2017), to large-scale Living Labs covering entire geographic region, such as the agriculture LL analysed by Toffolini et al. (2021). Hence, future stream of research should focus on such spatial differences, to further explore the characteristics of LL and to define a theoretical base on which to define a clearer characterization of the real-life setting.

## 2.5 Conclusions

This paper aimed to identify the gaps between practice and theory in a still relatively young domain, that of LLs. The different theoretical frameworks used in the extant literature on LLs offer a plurality of definitions and show some indeterminacies which do not allow a full comprehension of the transversal nature of a concept which cuts across different perspectives and disciplinary fields. The following study contributes to the evolving discussion of LLs through a systematic review of papers that analyse the concept of LL through the methodology of in-depth case study. This study took a step forward in conceptualising LLs and discussing their underlying assumptions, identifying three research perspectives through which the authors look at the same phenomenon – actor based, methodological and environmental perspectives - and nine subtopics that allow for a quite complete

classification of the literature on LLs. Within the actor-based perspective, the focus is given to the actors' dynamics, their roles, and drawbacks of multi-actor collaboration. The methodological perspective looks at the processes leading to the implementation of LL, processes to develop solutions, and LL as enabler of new technologies. Finally, the environmental perspective analyses LL as the arena for actors' relationships, the community where innovation takes place and the setting where new technologies are tested. Literature review highlights then four aspects that call for further research on LLs and their common assumptions. First of all, we argue that users' roles cannot be disentangled by the type of innovation which is tested within LL. Secondly, a definitory ambiguity emerges when confronting LLs to other forms of TEPs, highlighting the importance of promoting an evolutionary approach to LLs, looking at it not as a static element, but as a dynamic and continuously changing topic. Finally, the need to define a more consistent theoretical substrate for the real-life setting is pointed out.

However, each study has its own limitations. In our case, only Scopus has been used for the systematic review, meaning that probably more papers could be added to our database. Also, since these are qualitative papers, the systematization of the literature within different perspectives may lead to simplify some concepts and not cover all the conceptual nuances. Moreover, since existing LL publications are scattered, also conference papers were included in the analysis, thus leading to the risk to analyse papers still not mature and with some incomplete features. Finally, this study did not attempt to quantify the reliability of identified research streams based on the number of references and we did not investigate the kind of journal, neither the theme of a special issue of a journal or a conference.

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## Appendix A

Table A1 – Definition and focus-based perspectives

| Reference | Definition of LL | Definition - based perspective | Focus of analysis | Focus of analysis - based perspective |
|---|---|---|---|---|
| Bergvall-Kåreborn and Larsson, 2008 | *"a human-centric research and development approach whereby ICT innovations are cocreated, tested, and evaluated in open, collaborative, multi-contextual real-world settings. Not only focuses on involving users in the development processes, but it also strives to facilitate the interaction among other relevant stakeholders*" (Bergvall-Kåreborn and Larsson, 2008, p. 113) | Methodological | Involving users of an IT-product focusing on the realism principle as the main characteristic distinguishing a LL from other methods | Environmental |
| Lai et al., 2009 | A Public-private partnership approach, as "*a cooperation relationship between government and private sector* […] *to provide for public requirements*" (Lai et al., 2009, p. 1264). | Methodological | Investigating the actors' roles to conduct an empirical case study for the exploitation of business model and market trends of tourist system which building up upon convenient stores in Taipei. | Actor-based |
| Song et al, 2009 | "*It is a typical mode of innovation 2.0 which involves user. It is in sharp contrast to the traditional mode* […]. *Living Labs are full scale urban laboratories for such service development and innovation, are about experimentation and co-creation with real users in real life environments, where users together with researchers, firms and public institutions look together for new solutions, new products, new services or new business models*" (Song et al., 2009, p. 4) | Methodological | Comparing three in depth LL cases study based on extended technology organization-environment framework. | Environmental |
| Baltes and Gard, 2010 | "*As actors and facilitators of open innovation,* [LLs] *conduct knowledge transfer for* […] *science-industry relation.* […] *Intermediaries conducting science-industry transfer* | Actor-based | Developing a methodology for Living Lab implementation, subdividing into Microlevel and Macrolevel Living Labs, each providing distinct approaches to fostering the commercialization process. Paper focuses on an | Methodological |

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| | *address environments where speed of innovation determines the success of a company. Intermediaries such as TTOs, BIs and SPs foster the commercialization of Intellectual Property (IP).* [characterized by] *lead user integration* […], *technology interaction* […], *Latency free stakeholder access* […]*."* (Baltes and Gard, 2010, p. 2) | | eArchitecture Living Lab implementation on early stage entrepreneurial support | |
| Monguet et al., 2010 | "*User-centric research methodology where users experiment and co-design together with researchers, enterprises and public institutions for new products, new services or new business models*" (Monguet et al., 2010, p. 117) | Methodological | Analysing LL as tools and strategies that help organizations to improve their innovation management during collaboration with others, focusing on a LL which co-design prototypes of new eHealth services. | Methodological |
| Schuurman et al., 2011 | "*Methodologies incorporating the described advances in user research and innovation management theory*" for "*problems of understanding and cross-disciplinary communication*" (Schuurman et al., 2011, p. 271) | Methodological | Presenting a concrete application of LL research into the possibilities of mobile TV. Focusing on the description of different research steps and the most notable results they yielded, and the analysis of the strengths, weaknesses, opportunities, and threats of LL. | Methodological |
| Bourgault, 2012 | A tool "*for developing professional competencies in a specific field (project management/product development) and in a specific educational setting (university)*" (Bourgault, 2012, p. 77) | Methodological | Using a LL method within a teaching environment for developing professional competencies | Methodological |
| Coosemans et al., 2012 | "*An experimentation environment in which technologies are given shape in real life contexts and in which users are considered coproducers are called living labs*" (Coosemans et al., 2012, p. 1003) | Environmental | Within a on Electric Vehicles (EVs), platforms related serving as an environment in which members as well as other partners can carry out experimental research related to the roll-out of electric vehicles (EVs) are described. | Environmental |
| Edwards - Schacter et al., 2012 | "*functional places" in real-life contexts and enablers of public–private partnerships among individuals* […] *enterprises, public entities, universities, institutes* […]. *These real-life contexts may be cities, neighbourhoods, towns, or rural areas that constitute "social* | Environmental | Analysing citizens' participatory processes within a LL focusing on the gap between elderly people's needs and the business opportunities for collaborative placed-based innovation | Environmental |

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| | *spaces for innovation," which support social action and are part of the innovation system. LLs, as in our case study example, are mechanisms enabling "scaffolding" endeavours and intermediation for structuring and providing governance to people participating in the innovation process*" (Edwards - Schacter et al., 2012, p. 682-683) | | | |
| Galache et al., 2012 | "[…] *the meeting point to align the creation of large scale experimentation facility* […] *and the user involvement in ICT-based innovation targeted by the Living Labs community*" (Galache et al., 2012, p. 180) | Environmental | Describing smart city experimental facility, Wireless Sensor Networks (WSN) and Machine to Machine (M2M) communications, using a twofold approach: experimentation support experimentation and service provision. | Environmental |
| Katzy et al., 2012 | Innovation intermediaries coordinating concurrent processes of product development, user-involvement, and entrepreneurship activities impacting an innovation success | Actor-based | Analysing mechanism for involving users in development of an internet-based physician exchange platform to reduce risk | Methodological |
| Lupp and Van Greunen, 2013 | "[…] *systematic approach and a framework for stakeholder engagement to provide guidance through different phases of the [technological] co-creation processes*". (Lupp and Van Greunen, 2013, p. 3) | Methodological | Giving preliminary insights into the stakeholder perspective of the ongoing collaborative planning and design processes in a LL testing nature-based solutions to hydro-meteorological risks | Methodological |
| Schuurman et al., 2013 | "[…] a *practice able to structure user involvement by keeping the users continuously involved in making better products and services while their expectations are continuously monitored and reflected upon in a systematic process*" (Schuurman et al., 2013, p. 51) | Methodological | Strengths and weaknesses of crowdsourcing for idea generation and selection within a smart city context | Actor-based |
| Veldsman and Van Greunen, 2013 | "*Systemic initiatives which focus on creating multi-stakeholder collaboration in different stage of R&D processes*" (Veldsman and Greunen, 2013, p. 2) | Methodological | Description of an eHealth case study of Motherwell community using an approach of participatory design | Methodological |

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| Alaoui and Lewkowicz, 2014 | "[…] *an approach combining lab and field studies and integrate the user in the design projects to ensure active participation*" (Alaoui and Lewkowicz, 2014, p. 4) | Methodological | Designing communication services for elderly people at home using LL approach | Methodological |
| Hyysalo and Hakkarainen, 2014 | "*An open ended, sustained and complex coproduction arrangement that brings together technology providers, users, researchers and other social actors such as cities*" (Hyysalo and Hakkarainen, 2014, p.192) | Actor-based | Comparing two different LLs projects within health technology to understand challenging and benefits of LL collaboration | Actor -based |
| Santally et al., 2014 | "*An environment for user-centered innovation, based on the observation of every-day user practice and experience for solving problems, but also based on their active participation, with an approach that facilitates their influence in the open and distributed innovation process (participatory design)".* (Santally et al., 2014, p. 1) | Environmental | theoretical foundations and operational framework of LL analysing a LL focusing on the classroom education of the future | Environmental |
| Svesson, 2014 | "A *framework for cooperation between experts and citizens for innovative practices*" (Svesson, 2014, p. 11) | Methodological | Analysing the participation of citizens in archaeological excavations, to investigate issues related to attractiveness, and participation to the heritage activities | Actor – based |
| Georges et al., 2015 | "*An interesting approach to discover and understand how technologies are being used and adopted in real-life setting, with all the socio-technological parameters present. The goal of field trials is to explore the users' understanding, practices, and eventual uses of the system*" (Georges et al., 2015, p.27) | Environmental | Analysing the impacts of the user's participation within a LL evaluating go to market products | Environmental |
| Georges et al., 2016 | "[…] *a way to involve end-users in the development of an innovation over a longer period of time using a combination of different research methods, following an iterative process*" (Geroges et al., 2015, p. 2) | Actor – based | Defining a user engagement model investigating more specific on the needs and wants of end-users concerning green apps | Actor – based |

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| Heyvaert et al., 2015 | "*User-centric research methodology for sensing, prototyping, validating and refining complex solutions in multiple and evolving real-life contexts*" (Heyvaert et al., 2015, p. 85) | Methodological | Investigating consumer barriers for the diffusion of electric vehicles | Methodological |
| Haider et al., 2016 | "*real-life test and experimentation environment where users and producers co-create innovations, often operating in a territorial context (e.g., city, region) […].*<br>*The purpose of such a laboratory is to enable different stakeholders to experiment, test their mental models (assumptions, values, understandings) and to anticipate the consequences of their actions, policies and strategies*" (Haider et al., 2016, p. 102) | Environmental | Defining a suitable path towards the design and implementation of a LL for developing, testing and demonstrating innovations in sustainable transport operations. | Methodological |
| Kazi et al., 2016 | "[…] *tools and applications built around model servers to support the design, engineering, and management of products and services* [with on demand customization]" (Kazy et al., 2016, p.2) | Methodological | Findings from a living lab case study of a textile machinery manufacturing using the concept of model-based collaborative virtual engineering | Methodological |
| Kuba et al., 2016 | "*Environment for testing development of* [a certain technology], […] *based on an Action Research approach*". (Kuba et al., 2016, p.2)<br>"*A communication channel between the patients [the user] and the developing teams* [other stakeholder], *to create a context for the acquired information*" (Kuba et al., 2016, p. 4) | Environmental, Methodological | Analysing the management of information flow between LL users and other stakeholder in a e Health LL telemonitoring system, to monitor subjects with no or with stable neurological disease, where medical or the industrial stakeholders may often need contextual information that can be provided only by human supervisors | Actor-based |
| Romero et al., 2016 | "*user-centric environments and collaborative innovation networks supported by state-of-the-art construction collaboration technologies*" (Romero et al., 2016, p.2) | Environmental | Overview of a collaborative research project for sustainable innovation in construction industry | Methodological |
| Canzler et al., 2017 | "*A sociotechnical niche. An urban site of innovation designed to foster and* | Environmental | Observing the cross – field innovation activities taking place at a particular local site | Environmental |

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| | *pro-mote the convergence between formerly separate industries*" (Canzler et al., 2017, p. 26) | | | |
| Claude et al., 2017 | " […] *a transdisciplinary research approach* […] *to respond to sets of problems with a high level of complexity*" (Claude et al., 2017, p. 122) | Methodological | Analysing a LL to renewal the source of energy for a vacancy village | Environmental |
| Gasco, 2017 | "*Living labs are intermediaries that focus on the mediation between users, public, or private organizations, capturing and codifying users' insights in real-life environments*" (Gasco, 2017, p. 92) | Actor-based | Understanding the actors' dynamics and challenges of living labs as intermediaries of public open innovation. | Actor -based |
| Joller and Varblane, 2017 | "*A pilot programme […] to analyse different socio-economic and technical aspects of using a specific technology*" (Joller and Varblane, 2017, p.59) | Methodological | Providing insights into the setting up of a LL on the electromobility technology | Environmental |
| Zwierenberg et al., 2017 | "*A home that display and demonstrate assistive technology meant to support among others older people with a chronic illness. The models are meant to inform all kinds of stakeholders. Hence they help to diffuse technology and promote its use on a wider scale*" (Zwierenberg et al., 2017, p. 242) | Environmental | Analysing Smart Home and assistive technologies of a Health LLs basing on the attitude of visitors. | Environmental |
| Fitzpatrick and Malmborg, 2018 | LLs as "co-design approach" managing a diverse group of co-design project partners in a Quadruple Helix model | Methodological | Analysing the tensions among actors within Participatory Design projects organized in a Quadruple Helix model for innovation | Actor-based |
| Lovell et al., 2018 | "A *policy and technology experiment, seeking to explore and better understand ways of managing and governing* [a sector], *as well as investigating the technical possibilities for, and constraints on* [a technology]" (Lovell et al., 2018, p. 147) | Methodological | LL methodology to enhance significant energy innovation, as new decentralized smart grids comprising household level, in rural locations in developed countries. | Methodological |
| Rodrigues et al., 2018 | "*A space with formal and informal relationships between all those involved in the process,* | Environmental, Methodological | Analysing how LLs contribute to promoting urban entrepreneurship | Environmental |

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| | *where functioning as an open network is crucial and requires the participation of all, citizens, and firms*" (Rodrigues et al., 2018, p. 784)<br><br>"*a form of organising innovation and opportunities*" (Rodrigues et al., 2018, p. 784)<br><br>"*a strategic instrument that intends to activate models clearly oriented towards the real needs of users and consumers, and in this way promote the creation of needs through the appearance of products so innovative that they can act directly on the market*" (Rodrigues et al., 2018, p. 784) | | | |
| Amenta et al., 2019 | "*Case-specific approaches for developing innovations, combining planning and design* […] *with a versatile methodology that is flexible and adaptive to the different local contexts*" (Amenta et al., 2019, p. 7) | Methodological | Outlining an approach to address Circular Economy challenges in peri-urban areas, using a co-creation process among researchers, experts and stakeholders within LLs process | Methodological |
| Calzada, 2019 | "*A participatory itinerary through a multistakeholder scheme following the Penta Helix multistakeholders framework, by encompassing local authorities, the private sector, academia, research centres, civic society, (social) entrepreneurs, and activists*". (Calzada, 2019, p. 456) | Methodological | Exploiting a Tourism Living Lab as an innovative methodology based on Penta Helix framework to response to a globalized trend of increasing visitors within post-violence/ peripheral village. | Methodological |
| Chech and Wagner, 2019 | Action research situated within real world labs engaging local communities<br><br>"*Action research is most often implemented as a cooperative, participatory effort between researchers partnering up with experts from different fields […]. This is* | Methodological | Evaluating a LL approach in term of its transformative potential over the users engaging the local community in cooperation with an eMobility LL to co-design a digital interactive tool visualizing the participants' personal CO2-footprint | Methodological |

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| | *possible only through the use of everyday language in the discourse between the different partners, which can be both challenging and rewarding and provides a great source of discussion and reflection*." (Chech and Wagner, p. 3) | | | |
| Engels et al., 2019 | "[...]*spatially confined, purposeful experimental settings aimed at testing and demonstrating the viability and scalability of new sociotechnical orders and associated forms of governance based on particular visions of desirable futures*" (Engels et al., 2019, p. 3). | Environmental | Analysing the challenges within a rural and an urban renewable energy lab | Environmental |
| Bertlet et al., 2020 | "*A methodology to guide the testing of emerging technologies in real environments*" (Bertlet et al., 2020, p. 3) | Methodological | Investigating how LL methodology used in the public sector within the smart cities context leads to better collaboration and innovation. | Methodological |
| Cellina et al., 2020 | "*processes aimed at co-creating and validating innovation within collaborative, real-world environments, through the involvement of a broad range of stakeholders (public-private-people partnership) and in a long-term perspective. They allow to […] "participatory mindsets", where users are seen as active "partners" of the value creation process*." (Cellina et al., 2020, p. 2) | Methodological | Aanalysing a smart city where a LL experiment was set for the co-creation of a behaviour change app targeting a reduction in car-based traffic | Methodological |
| Cuomo et al., 2020 | "*Innovative policy instrument open to integrate people into the entire development process as users and co-creators to explore, examine, experiment, test and evaluate new ideas and creative solutions in complex and everyday contexts*" (Cuomo et al., 2020, p.4) | Methodological | Presenting a case study on sharing and circular economy to point out possible future scenarios of urban sustainable policies | Environmental |
| Criado et al., 2020 | [Public Innovation lab as] "*arenas for experimentation in public sector* | Environmental | Analysing two innovation LLs to define emerging trends | Environmental |

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| | *agencies organizations*" (Criado et al., 2020, p.2). | | | |
| Di Biccari et al., 2020 | Whitin the public administration sector, "a*s an enabler of importing the open innovation paradigm from the private sector to the public one, as it eases the generation of technological solutions customized for the specific territorial context of the public administration involved* " (Di Biccari, 2020) | Methodological | Investigating whether methodology can facilitate the introduction of new technologies within a Public Administration (PA). | Methodological |
| Lusikka et al., 2020 | *"Open innovation platform allow[*ing*] businesses to develop new, better and more personalized services to citizens".* (Lusikka et al., 2020, p.1) | Actor-based | Describing value creation of a LL investigating on Intelligent Transport Systems (ITS) | Environmental |
| Gabriel et al., 2020 | "*Design research methodology* […] *aimed at cocreating innovation through the involvement of aware users in a real-life setting*" (Gabriel et al., 2020) | Methodological | Using LL methodology to analyse the introduction of a new technology within the PA | Methodological |
| Gerhold et al., 2020 | "*In the context of the Future Security Lab (FSL), a LL is understood as an open space for feedback on technological innovations in security contexts. Because of their potentially high impact on society, it is necessary to discuss such innovations openly. The living lab* […] *aims at creating a space to experience new technologies and enable a broad array of stakeholders to reflect on innovations from the field of security*" (Gerhold et al., 2020, p. 569) | Environmental | Testing evolving technologies by using scenarios to stakeholders from civil protection and policy making by telling a future story about the potential usage of emerging technologies. The scenario is ran within living lab, equipped with demonstrators to understand and use technologies that may become relevant within the next five to ten years | Methodological |
| Marone et al., 2020 | "*A facilitator for multi-stakeholder collaboration and knowledge sharing* […] *allow*[ing] *the integration of both internal and external knowledge dealing with the open innovation paradigm, and it is strategic for the implementation of public, private and people* | Actor - based | Identifying stakeholders' needs in building a LL in healthcare | Actor-based perspective |

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| | *partnerships (PPPPs) to develop and deliver technological innovation*" (Marone et al., 2020, p.14) | | | |
| De Vita and De Vita, 2021 | "*A real-life context in which authentic use situations are created and studied* [and] *various stakeholders can contribute to the innovation processes*" (De Vita and De Vita, 2021, p. 11) | Environmental | Understanding objectives and product outcomes of organizations using a LL case study | Methodological |
| Dekker et al., 2021 | "*Generative experimentation in public policymaking* [using] *design methods to analyse problems from different angles and develop, test and improve prototypes to work in a particular context*" (Dekker et al., 2021, p. 349) | Methodological | Evaluation of a public policymaking experiment addressing the improvement of asylum seeker reception as a wicked policy problems | Environmental |
| Dietricht et al., 2021 | From Dell'Era et al. (2014, p.139) "*a design research methodology aimed at co-creating innovation through the involvement of aware users in a real-life setting"* | Methodological | Exploring and showing processes and procedures of how two co-creation methodologies - co-design and Living Lab - co-created virtual reality interventions in an alcohol prevention context. | Methodological |
| Haug and Mergel, 2021 | "A*n environment for public value creation* […] *closely connected to their parent organization and are strategically used by public managers to facilitate innovation processes*" (Haung and Mergel, 2021, p. 5) | Environmental | Investigating the relationship between the living lab and the public sector organization it is embedded in, trying to define organizational factors influencing the process of value co-creation within living labs | Environmental |
| Kretschmer and Dehm, 2021 | "*Participatory action research approach* […] *mixing qualitative and quantitative methods* […] *for piloting transition pathways*" (Kretschmer and Dehm, 2021, p. 30) | Methodological | Developing of a methodological approach to involve key stakeholders in a transformation process toward local organic meal planning and green procurement in a higher education institute | Methodological |
| Lasarte et al., 2021 | "*a methodology* […] *for considering the relationship between stakeholders.* […] *Living Labs seek to contribute to innovative processes where the users become active actors and not just passive recipients*" (Lasarte et al., 2021, p.2) | Methodological | Analysing critical barriers of renovation and the potential for digitalisation to overcome them using a methodology that based on Living Labs, focusing on real needs and fitted to the user's requirements | Methodological |
| Masunaga et al., 2021 | "*A participatory approach that enabled communities to shape trial* | Methodological | Analysing how to involve the right actors for a community – based clinical trial | Methodological |

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| | *implementation*" (Masunaga et al., 2021, p. 3) | | | |
| Taylor, 2021 | "[…] *a space carved out from the public rules and norms of the city to provide the lab's users with the opportunity to test out new systems or products on the public, who may or may not be aware of that testing*". (Taylor, 2021, p. 1906) | Environmental | Analysing research ethics and governance experimentation in an urban LL willing to investigate on people's interactions with local authorities and with each other, including research focusing on the interaction between ethnic groups in the neighbourhood. | Environmental |
| Temmerman et al., 2021 | "*physical or virtual user-centric innovation environments aiming to solve societal challenges by bringing together various stakeholders for collaboration and collective ideation*" (Temmerman et al., 2021, p. 169) | Environmental | Depicting the experience of a collaborative platform for SI to improve the quality of life in two neighbourhoods | Environmental |
| Toffolini et al., 2021 | "*A boundary object under dynamic construction between the various actors*" (Toffolini et al., 2021, p. 159)<br><br>Boundary object as "*what makes possible for diverse actors (administrators, managers, researchers, amateurs, politicians, citizens) to work together*" (Toffolini et al., 2021, p. 159) | Actor based | Studying actors' roles construction within an agricultural LL | Actor based |
| Waes et al., 2021 | "*Strategic urban experiments […] established in a transdisciplinary manner*" within a city (Waes et al., 2021, p. 4) | Environmental | Challenges and dilemmas arising from different actors within LL testing cycling innovation within the context of sustainable mobility | Actor-based |
| Arnould et al., 2022 | "*Living Lab approach allows a new mode of governance through a PPPP by placing the user at the centre of the ecosystem*" (Arnould et al., 2022, p. 13) | Methodological | Providing a methodology to pilot a forestry LL | Methodological |
| Ascione et al., 2022 | "*a research laboratory, suitable for testing and measuring energy, and indoor and outdoor conditions, but also a dwelling in which a comfortable life is allowed*" (Ascione et al., 2022, p. 2) | Environmental | Evaluating net zero energy buildings | Environmental |
| Hernández-Pérez et al., 2022 | "*A specific type of sociotechnical infrastructure open to citizenship that* | Environmental | Analysing within two library living labs how digital technologies can be drivers of social | Environmental |

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| | *has been incorporated over the past few years into innovation ecosystems around the world*" (Hernández-Pérez et al., 2022, p. 3) | | transformation when citizen engagement is placed at the centre of innovation processes. | |
| Hristov et al., 2022 | "*The term encompasses facilities and infrastructure open to various collaborators wishing to develop and test their solutions for smarter urban areas*" (Hristov et al., 2022, p. 152) | Environmental | Analysing a digital twin replica to explore new solutions in a controlled environment | Environmental |
| Nguyen et al., 2022 | "*LLs can be considered orchestrators that may facilitate a shift in power relations between citizens and other participants in collaborative ecosystems involving Quadruple Helix actors*" (Nguyen et al., 2022, p. 3) | Actor based perspective | Analysing the power imbalances between citizens and other organisational participants within a smart city case | Actor based |
| Nguyen and Marques, 2022 | An implementation of the Quadruple helix model connecting Academia, Civil Society, government, industry | Methodological | Exploring the implementation of the Quadruple Helix for innovation from a stakeholder perspective. | Actor based |
| Mukama et al., 2022 | "R*esearch and innovation concept for experimental and experiential learning in real-life environment, involving users and multiple private and public stakeholders, and aimed at: 1] co-designing, prototyping, testing, and observing new solutions and novel organisational structures in an iterative fashion; and 2] stimulating changes in the socio-technical regime to create the most favourable conditions for scaling-up of innovations*" (Mukama et al., 2022, p. 4) | Methodological | Understanding actors' role in a LL exploring a gendered energy technology innovation in poor urban environments | Actor-based |
| Turku et al., 2022 | "*public space or places where a local government engages citizens in developing sustainability activities and solutions in conjunction with other actors, such as businesses and research institutes*" (Turku et al., 2022, p. 2) | Environmental | Analysing sustainability pathways in multi-actors' collaborations in an urban LL | Environmental |

Source: Authors' elaboration

# 3. How does space influence Living Labs? Evidence from two automotive experiences*

Living Labs (LLs) are defined as innovation ecosystems that integrate research and innovation processes in a real-life setting, in a logic of open–user innovation. Alongside the openness and user involvement, the real-life setting is seen as the third key element in which LLs are rooted and it defines the space where the innovation process takes place. However, so far little attention has been given to whether and how space influences LLs. Hence, borrowing the concept of Enabler Spaces as multidimensional containers fostering innovation processes, the aim of this paper is to improve the theoretical conceptualization of the real-life setting dimension of LLs. To do this, the paper will investigate how the physical, social and organizational spatial dimensions interrelate with and influence the other two elements characterizing LLs, ultimately shaping their governance. In doing so, two case studies of LLs focusing on new forms of mobility grounded in two different (open and closed) physical spaces will be analysed. Results offer arguments for further investigation into the relationships between the real-life setting of LLs based on physical spaces and the social and organizational dimension of the innovation space.

**The following paper is the result of a jointly work with Giulia Tagliazucchi, research fellow at University of Modena and Reggio Emilia, Marco Biagi Department and Gianluca Marchi, full Professor at University of Modena and Reggio Emilia, Marco Biagi Department. The paper has been published on the special issue of the R&D management journal "Places and Spaces of Collaborative R&D and Innovation: Physical, Virtual and Cognitive contexts". This chapter is the final document preceding the Online Version of Record before the inclusion in the issue.*

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## 3.1 Introduction

Having arisen at the end of the twentieth century, Living Labs (LLs) represent a recent phenomenon that has enjoyed growing interest on the part of academics and policymakers alike (Hossain et al., 2019; Greve et al., 2020). LLs are "*user-centred open innovation ecosystems based on a systematic user co-creation approach, integrating research and innovation processes in real-life communities and settings*" (European Network of Living Labs, 2021). Thus far, scholars have focused mainly on the definitions and categorizations of LLs (e.g., Greve et al., 2020; Leminen et al., 2021), the roles and degrees of involvement of end users (e.g., Almirall et al., 2012; Leminen et al., 2014; Leminen et al., 2015a), the networks operating within LLs (e.g., Leminen et al., 2012, 2015a; Nyström et. al., 2014), and how the co-creation approach directly involves users and other stakeholders in any step of the innovation process (Guzman et al., 2013). Among constitutive concepts of LLs, the emphasis has mainly been on openness and user engagement, while little attention has been paid to their real-life setting element and how it influences openness and user involvement (Hossain et al, 2019). Analysis of the real-life setting and, hence, the space where LLs are embedded, can certainly be worthwhile if we are to gain a deeper insight into the relationships between actors, user involvement and the governance models deriving therefrom.

In an attempt to bridge this gap, this paper borrows from the literature on Enabling Space (ES), defined as a space supporting and facilitating innovation processes (Peschl and Fundneider, 2012). ES is designed as multidimensional and is formed by spatial sub-dimensions functional to foster innovation processes. Specifically, this paper investigates whether and how spatial sub-dimensions interrelate and influence each other, shaping the configuration of LLs in terms of openness, user involvement and the governance models ultimately arising from the relationships between participants. It further focuses on a specific kind of LL where testing of innovation technologies related to new forms of mobility. With the additional purpose of offering more evidence on a still understudied topic (Paskaleva and Cooper, 2021), the paper compares two different automotive LLs:

the Modena Automotive Smart Area (MASA) and the Joint Research Centre Living Lab (JRC-LL), both located in Italy and both experimenting Autonomous and Connected Vehicle (ACV) technologies. ACVs are one of the fundamental upcoming disruptors in the mobility sector (Kaur and Rampersad, 2018) and involve a complex multifaceted set of technological and social aspects to be tested on physical roads, such as the interaction with people and obstacles entrenched in the surrounding urban environment. LLs can thus be beneficial tools. On the one hand, they can test ACVs, enabling a contextual and multidisciplinary analysis of technologies within a real space, foreseeing possible consequences and long-term effects and structural changes deriving from such a complex technology. On the other, they can analyse the interaction with end users and assess future technological diffusion. For the purpose of this paper, the focus shall be on three spatial dimensions - physical, social and organizational (Peschl and Fundneider, 2012) - of ESs emerging as crucial for the analysis of the real-life setting of LLs when testing automotive innovation technologies.

The paper proceeds as follows. Section 2 presents the theoretical framework, while methodology is outlined in section 3. The results and discussion thereof are presented in sections 4 and 5 and, finally, conclusions are drawn, along with implications and limitations, in section 6.

### 3.2 Living Labs as Enabler Spaces

Openness, user involvement, and real-life setting are the key elements defining LLs (European Network of Living Labs, 2021). The openness element has been related to the Open Innovation (OI) theory (Bergvall-Kåreborn et al., 2009; Enkel et al., 2020). Scholars emphasize the open nature of the networks established by different actors working together in the formation of LLs and in innovation processes in a real-setting environment (Leminen et. al, 2012; Nyström et al, 2014; Schuurman et al., 2016; Leminen et al., 2015b). However, in LLs the openness element goes beyond the pure OI paradigm (Bergvall-Kåreborn et al., 2009; Leminen et al., 2015b), as it also reflects the multidisciplinary nature of the LL itself. This is on the condition that – within a collaborative framework – actors from various backgrounds holding different viewpoints need to be involved in

the innovation processes. The user involvement element of LLs has been conceptualized within the User Innovation (UI) framework (Von Hippel, 1976, 2007), to comprehend how and why users might become co-creators and be actively involved in the technological innovation process (Eriksson et al., 2005; Edvardsson et al., 2012; Edwards-Schachter et al., 2012; De Silva and Wright, 2019). Unlike other UI approaches, such as Lead Users (Von Hippel, 2007) and Crowdsourcing (Howe, 2008), LLs allow end users to participate in all stages of the innovation process (Bergvall-Kåreborn et al., 2009) as creative consumers (Leminen et al., 2014) who act as innovators even without the direct participation of an innovating company or other entity investing intentionally in a co-creation process (Leminen et al., 2015a; Greve et. al, 2020).

Hitherto, the LL as a realistic, natural, real-life setting has been relatively undertheorized, despite the complementarity relationship of the three constitutive elements (openness, user involvement and real-life setting) (Bergvall-Kåreborn et al., 2009) and the increasing relevance that naturalness and realism of the innovation processes may have in a LL targeted at a specific technological field. Indeed, the creation of a real-life environment is affected by and in turn influences an LL's ability to involve users and be open to a variety of stakeholders who can offer different perspectives and contributions to the innovation process. Although, little attention has been devoted to investigating the spatial dimensions within which LLs are established; an exception is the contribution of Bergvall-Kåreborn et al. (2009), who argue that the constitutive elements of LLs – referred to by the authors as openness, influence, and realism – transform places into spaces. Here, the former is associated with a sense of similarity and objectivity, while the latter are concomitant with a sense of uniqueness and subjectivity due to stakeholder involvement, the methods chosen and the facilitation of activities.

However, this paper does not emphasize the differences between spaces and places. Rather, it focuses on the spatial dimension as the constitutive element of real-life setting and on how it influences and relates to the openness and user involvement elements. The spatial dimension of LLs is undeniably of pivotal importance. Since LLs aim to substitute the experimental and controlled

approach of a traditional lab with a real-life setting, their spatial conditions are likely to foster or hinder collaboration among the stakeholders involved (Bergvall-Kåreborn et al., 2009). Additionally, since LLs aim to test technological innovations within a natural user environment (Ballon et al., 2005), spatial conditions play a key role in recreating the setting for realistic user involvement (Bergvall-Kåreborn and Ståhlbröst, 2009). Consequently, examining the space of the LL would facilitate more in-depth analysis of its openness and user involvement and ultimately deduce its governance model. Indeed, as open innovation networks (Leminen, 2012, 2020), LLs are based on a number of relationships between the actors involved, one that can be organized into different models of network governance (Provan and Kenis, 2007). On the one hand, there is the *shared participant governed network*, characterized by the involvement and commitment of all participants (or a significant subset thereof) in the network, the symmetrical distribution of decision-making power, and the lack of a distinct and formal administrative entity. On the other hand, there is the *lead organization governed network*, where all major decisions are coordinated through and by a single participating member acting as leader and providing administration for the network and/or facilitating the activities of other members.

In order to improve the theoretical conceptualization of the real-life setting dimension of LLs, it is possible to borrow from the concept of ESs, defined as spaces "*supporting, enabling and facilitating processes of innovation and knowledge creation"* (Peschl and Fundneider, 2012, p.48). Specifically, Peschl and Fundneider (2012) define ESs as multifaceted and composed of a set of sub-dimensions, allowing for the emergence of innovation processes and favouring the spread of radically new innovation. Rooted in the concept of *ba* (Nonaka and Konno, 1998), and defined as a space where participants share their perceptions of reality and create new meanings through interactions, ESs are therefore multidimensional by definition, as exhibited in Table 3.1 (Peschl and Fundneider, 2012; 2014).

*Table 3.1: Enabling Spaces - Dimensions*

| ESs - Dimensions | Description |
|---|---|
| **Physical** | The physical space in which the innovation and knowledge processes take place. It is a physical environment intentionally designed and built that surrounds the users with its concrete physical structure(s). Examples include offices, spaces for creative and knowledge gathering work, houses, urban places or urban settlements. |
| **Social** | The social interaction occurring within the space for innovation and knowledge creation. The authors highlight how trust and openness are key enablers for the social dimension and need to be established before any kind of innovation work can start. That is why it is essential to spend considerable energy in selecting the "right" members of an "innovation team" and to attain a socially as well as functionally well-balanced group. |
| **Cognitive** | The individual cognitive processes that foster innovation through observation, listening, and reflection on one's presumptions. |
| **Emotional** | Pointing out that cognition is always embedded in emotional states, the authors stress how this dimension offers features that trigger such states, supporting processes of innovation and knowledge creation. |
| **Epistemological** | The epistemological space refers to the creation of an enabling environment in which knowledge dynamics can develop, thrive and flow. |
| **Organizational/cultural** | Innovation is always embedded in the culture and organizational structures of an organization. The structures (such as hierarchy, departmental make-up, interaction patterns, communication culture) are often transformed by innovation processes, implying a more or less radical change in the organizational culture. |
| **Technological** | The technological space refers from low- to high-tech tools such as computers, the internet and social media, in which innovation processes are at all times embedded. |
| **Virtual** | Innovation does not necessarily always have to take place in a face-to-face setting, since much of the work can be done in the virtual dimension. Hence, virtual tools enabling these processes may support observation, prototyping, simulating, and so forth. |

Source: Authors' summation based on Peschl and Fundneider (2012; 2014)

Because they appropriately encompass the characteristic elements of LLs, physical, social, and organizational spaces have been chosen to analyse the real-life element in LLs with the aim of testing technological development and its interaction with users within a complex network of actors and in an urban or urban-like environment. The physical space represents the concrete and real environment that surrounds users when they are engaged in the innovation process, and is of crucial importance in characterizing the real-life setting of a LL. For example, if a new technology encompassed in a product is to be observed in its interaction with, or when being experimented by, users, the physical space is called upon to reproduce as best as possible the real environment that usually surrounds the action of users when they operate that kind of technology. Based on the characteristics of its physical space, LL should be designed in order to provide an open setting that allows all the relevant actors to work together and users to be effectively involved (Dowling and McGuirk, 2020). Thus, physical

structures shaping the real-life setting of LLs (Veeckman et al., 2013), such as neighbourhoods, public buildings, urban roads or open-sky labs, also influence the characterization of LLs in terms of openness and user involvement. Along with the physical space, the LL literature has recently highlighted the growing prominence of virtual and technological spaces in creating a setting that could be perceived to be as real as the physical one (Bergvall-Kåreborn et al., 2009). Spaces based on virtual and technological tools, for instance simulators and virtual prototyping, can integrate the physical space in the creation of real-life settings for LLs (Bergvall-Kåreborn et al., 2009, Leminen, 2012), or even replace it based on the technology tested (Bergvall-Kåreborn et al., 2009) and the complexity of the environment in which the technology is used. However, in the case of technologies usually adopted in urban-like settings, such as automotive technologies, and in a complex environment of use, for example public roads, where regulatory and ethical issues are involved, the physical dimension is central in the definition of the space for the real-life setting of the LL (Dowling and McGuirk, 2020), while by complementing the open-air testing activity virtual and technological spaces can be considered as underpinnings of the physical dimension.

The social space is related to the dimension and the composition of the networks and to the quality of the relationships established between the actors involved in innovation processes. Social space is not neutral with respect to the ability of LLs to operate in a real-life setting. Favourable social space conditions (for example, an adequate scope and a purposeful composition of the network and collaborative relationships between actors) should be established before commencing any kind of innovation process. Openness and trust are key enablers of the social space (Peschl and Fundneider, 2012), as they facilitate the creation of a real-life setting that assembles different actors and in which users – identified as trustworthy subjects – are concertedly involved. Openness and trust are intertwined with cognitive and emotional spaces, which, due to the more general purpose of this study, are not disentangled from the related social dimension. Similarly, the epistemological

dimension of ESs is not considered, since an in-depth analysis of knowledge creation and transfer is beyond the aim of this paper, despite the relevance of the knowledge-innovation nexus in LLs.

Finally, organizational space encompasses all the tools that need to be deployed to foster innovation processes in a real-life setting. It is engrained in the need to coordinate the actions and interactions of the actors involved, who are asked to take relevant decisions about the LL and the testing of technologies. The organizational space of the LL is affected by the degree of openness towards new partners invited to participate in the LL (Veeckman et al., 2013), and the level of decision-making power that potential users and involved actors hold (Bergvall-Kåreborn et al., 2009). Openness to new participants and the distribution of decision-making powers interrelate with the social (within which the network of actors involved is entrenched) and physical dimension of the LL.

## 3.3 Research design

In line with its theory-enlarging purpose (Patton, 2002), this study adopts a qualitative research design and abductive approach (Dubois and Gadde, 2002). Two different automotive LLs were selected as case studies (Yin, 2003), purposefully chosen for their technological similarity and for their both being located in Italy, so as to neutralize any contextual elements related to national regulatory frameworks (Table 3.2).

Table 3.2: Overview of Case Studies

| Name | Length | Technological field | Purpose | Network | Location |
|---|---|---|---|---|---|
| JRC LL | 2019 – on going | New forms of mobility | Testing a variety of mobility-related policy and regulatory approaches in a real-life environment | European Commission, Joint Research Centre, start-ups, university spin offs, consultant firms | North Italy – JRC site in the municipality of Ispra, in the province of Varese |
| MASA | 2017 – on going | Autonomous and Connected Vehicles | Testing autonomous and connected driving technologies and their interaction with other elements of the urban space | University of Modena and Reggio Emilia, Municipality of Modena, automotive and Information and communication technologies (ICT) sector firms | North Italy –In a neighbourhood of Modena |

Source: Authors' elaboration

Both LLs pursue projects related to ACV technologies, which are considered one of the most impacting disruptors in the automotive industry (Kaur and Rampersad, 2018) and on everyday future mobility. Despite all the acknowledged benefits associated with ACVs, such as the enhancement of road safety and the decrease in traffic congestion (Fagnant and Kockelman, 2015; Paden et al., 2016), some factors still hinder not only their adoption (Zhang et al., 2019), but even their testing. For instance, security and regulatory issues are limiting experimentation of ACVs in real-life settings (Scagliarini, 2019). And yet, testing ACV technologies in a real (yet safe) setting, open to the potential users, within a LL properly designed in its physical, social and organizational spatial dimensions, could be of paramount importance (Dowling and McGuirk, 2020).

Data were collected from multiple sources to ensure validity and reliability (Yin, 2003; Aguinis and Solarino, 2019). Primary data were collected through semi-structured interviews with key informants of the LLs. In order to triangulate the information, interviews were requested from more than one key informant per LL. Questions aimed to understand the actors involved within the LL and to deduce the main characteristics of the physical, social and organizational spatial dimensions thereof (see Appendix Table B1). Each interview was attended by two authors and lasted on average between 60 and 90 minutes. Each interview was followed by a discussion between the authors to add fruitful and informative observational data to the evidence collected. All interviews were recorded and transcribed verbatim. Secondary data were collected through internal materials conveyed by the key informants, institutional websites and web-based press reviews.

As regards both the JRC-LL and the MASA, the data collected consist of primary and secondary data (Table 3.3). The collection of interviews and materials was driven by the saturation criterion and ended when concepts and descriptive elements of the spatial dimensions of the LL began to repeat themselves. In addition, two of the authors participate in MASA research activities and brought their own direct experience and direct observational data. For this reason, fewer interviews with key informants were required to reach concept saturation level.

Table 3.3: Data Sources

| Kind of sources | JRC-LL | Masa LL |
|---|---|---|
| **Primary sources** (Interviewees=I) | • I1a. Governance actor, scientific activities coordination<br>• I2a. Governance actor, scientific activities support<br>• I3a. Governance actor, policy coordination<br>• I4a. Governance actor, project management<br>• I5a. Actor from a start-up collaborating with the LL<br>• I6a Governance actor, scientific activities | • I1b. Governance key actor from University<br>• I2b. Governance key actor from a company involved in the LL<br>• 13b. Governance key actor from the municipality<br>• Participant's observation of the authors |
| **Secondary sources** | • Call for expression of interest (available online)<br>• EC Website - JRC<br>• Policy report 2018, 2019, 2020, 2021 (available online)<br>• Informative articles and scientific output by JRC research group (internal presentation, scientific papers, conference proceedings)<br>• EnoLL workshop, 2021 | • 6 memoranda of understanding<br>• 25 Letters of interest<br>• MASA Website<br>• Informative articles and scientific output by MASA research group (scientific papers, conference proceedings)<br>• Online available conferences and public engagement events |

Source: Authors' elaboration

All the materials collected were triangulated and merged within a unique corpus of text, with the aim, firstly, of describing in depth each case in relation to the dimensions of ESs and, secondly, to compare the two cases by examining similarities and differences. The authors independently analysed and codified the texts by comparing iteratively emerging elements from the cases to the theoretical framework (Dubois and Gadde, 2002). The authors then discussed the patterns and results that emerged until they arrived at an agreed interpretation.

## 3.4 Results

Results are presented in line with the theoretical framework, describing the identified spatial dimension for each LL, with the aim of highlighting the real-setting environment through its physical characteristics (physical space), the relationships between actors (social space) and how LLs are managed (organizational space). Table 3.4 compares the elements emerging from the two cases.

### 3.4.1 The JRC-LL case

*The physical space*

The JRC-LL is located in the municipality of Ispra within the Joint Research Centre (JRC), the science and knowledge service of the European Commission (EC) which tests new mobility solutions to support and improve European policies (JRC, 2021) empirically. As the interviewees explained, the intention to create a LL arose in 2019 when top management launched a new strategy to make JRC sites more open, efficient, sustainable and smarter (JRC strategy 2030), while accomplishing Green Deal priorities and Sustainable Development Goals. Indeed, for future mobility solutions, the JRC-LL represents the transport structure of the site in which it is located. It comprises "*36 km of internal roads, more than 2000 people working in the Ispra site, and it is considered like a small town. Also, because it is closed from the outside and we take care of the entire management of the site*" (I1a). JRC-LL was then created alongside the already present LL for Testing Digital Energy Solutions (DES-Lab) on new forms of mobility, and its physical space consists of a closed area of 213,000 $m^2$ and more than 80 buildings in the Ispra site, managed by the JRC itself (Figure 3.1).

Figure 3.1 – The physical space of JRC LL




Source: JRC Internal document

The area already had a wide variety of infrastructural elements such as straight road segments and curves, roundabouts, various types of zebra crossings and different parking area layouts. Moreover, to allow safe and effective testing of new mobility solutions, an urban test-track, composed of a 600 m long closed circuit with three intersections and a roundabout, was added. The infrastructure has been modified over the years to include two signalized pedestrian crossing points, as well as other technological infrastructures such as a variable message sign to alert users as to the arrival of other vehicles (Table 3.4).

*The social space*

From the very outset, the physical space involved all the actors for the functioning LL. Firstly, the JRC was responsible for providing the necessary infrastructures, disseminating results and for aligning activities with the national regulations for ACV road testing. As one of the interviewees pointed out, "*on account of its being closed from the outside* […] *we take care of the entire management of the site which means that* […] *we also undertake the role of the municipality. This is because we are in charge of applying the law, meaning Italian law, within the site* […] *and there are 2000 people who then need to move throughout the day for various reasons, so there is a significant flow*" (I1a).

Secondly, companies brought know-how and technological innovations and made it possible to take full advantage of all the facilities and infrastructures. In addition, the JRC-LL opened up a public call to "*attract the interest of different start-ups and SMEs*" (I2a) and to collect expressions of interest by industrial partners engaged in testing new mobility solutions. These activities promoted the openness of the LLs by incentivizing the participation of different industrial actors. Once industrial partners were selected, collaboration agreements were issued to define the activities of interest within the remit of both parties. Indeed, from the very beginning, the companies that joined the LL were SMEs, start-ups or spin-offs with an engineering background. The industrial partners then used the JRC-LL mainly as a protected site to carry out on-road tests, while scanter attention was paid to the

interactions of the technology with the end users. Indeed, as one interviewee stated, "i*n some cases, I would say that these companies did not have a LL in mind, but merely wished to validate their technologies. They did not see the real LL added value in the projects*" (I2a), but rather used the site more as a platform to test the technologies than as a proper LL.

Finally, users were represented by the employees and the approximately 200 visitors per day of the JRC in order to gain insights into how they interact with technologies. Over time, some mechanisms have been adopted to aid the engagement of users, such as the exploitation of the Makerspace, a collaborative space designed to promote active participation and smoother cooperation with JRC employees and external visitors through impromptu experimentations and focus groups. Moreover, the initial involvement of an external advisor, with experience in service design and user research methods, was useful in the adoption of the six-step methodological approach from Mastelic (2019). Based on Design Thinking, this multi-method approach incorporates a wide range of strategies (see Table 3.4) to engage users in open discussion and an exchange of ideas. In addition, email broadcasts have been used to invite all employees to participate directly in co-design activities. Alongside this, several displays have been carried out with the aim, on the one hand of displaying to the public at large the results from technological experimentations and, on the other, of revealing to the companies the importance of user feedback. Consequently, as one interviewee put it, "*they* [users and industrial partners] *started somehow realizing what a LL is, they started to trust more in the innovation*" (I2a).

*The organizational space*

Within the organizational space of the JRC-LL, "*at the operational level,* [the governance] *was imposed from the top to understand who was responsible for what. From the bottom we* [the JRC] *have created a co-group of implementers in which there are two people for each scientific unit* [...] *choosing activities that seem more interesting and reporting what has been developed to the directors who then have the last word* [...]" (I5a). There is therefore a two-level hierarchical configuration of

the organizational space. At the top, a group deals with the general activities and objectives of the LL, having representatives from different directorates: the scientific directorate supervises technical activities, carrying out collaborations with companies that test their technologies; conversely, the JRC support services deals with logistics, equipment and infrastructure, in compliance with the rules of the site and national regulations. At the bottom, the organizational space resembles the spontaneous development of the social dimension of the LL, and only recently have roles been defined in the implementation of daily operations. "*The current set is the output of a very spontaneous development of this project.* […] *For example, I wanted to stay on the project and then this connection appeared rather spontaneously* […]. *But the governance is in a flux*" (I3a). The JRC operational core team manages the applications of new partners interested in LL activities and the relationships with policy Directorates General (DGs) of the EC and across JRC units. The JRC Research Ethics Board (REB) ensures that JRC research complies with ethical standards and principles of the EU framework programmes. In addition, the JRC-LL Management and Evaluation board sets the goals of LL projects and brings them into line with the aim of providing evidence of interest to policymakers. Given the LL's reliance on policies enacted from Brussels, the direct inclusion of other DGs in governance has been proposed, with the goal of achieving results that are more in line with the objectives of policymakers.

What emerges, therefore, is an organizational space where the key decisions on the development of the LL are related to its institutional nature and objectives, and in which the top management actor coordinates the activities of the operating group, which in turn manages relations with industrial actors and users.

### 3.4.2 The MASA case

*The physical space*

Located in a neighbourhood in the northern part of the city of Modena, MASA aims to develop and validate experimentally innovative solutions for an intelligent urban mobility, focusing on ACVs,

Advanced Driver-Assistance Systems (ADAS) and protocols of interaction among vehicles and the surrounding urban environment (V2V and V2X). The LL is located at the heart of the Italian Motor Valley, where a strong presence of well-known car manufacturers and highly specialized SMEs are grouped in the local automotive industrial district. Within this context, the idea of a space to test ACVs was proposed in 2017 by an important car manufacturer. The LL was established in an urban area agreed upon with the municipality of Modena, taking advantage of a tender for suburban redevelopment to finance part of the necessary infrastructure. The area of approximately 3 $km^2$ has several civil and residential buildings, which increase the environmental complexity in performing the technological testing. As stated during a conference, "*since we had to redevelop the area, why not try to build an urban lab?* […] *We have therefore tried to concentrate possible use cases of interest for ACVs technologies: a library with a parking lot, a school, a healthcare centre and a train station with other parking areas and significant traffic flows, and a traffic light crossing simulating visibility problems from one direction to another*" (C3). Once identified, the area was gradually equipped with the necessary infrastructure technologies to allow for on-road testing (Table 3.4) as well as a computing infrastructure, known as the Data Centre (Figure 3.2).

Figure 3.2 – The physical space of MASA




Source: Masa Internal document

In addition to the open urban area that is the core of the LL, a private area within the Autodrome of Modena has been added to pre-test the technologies in a closed environment. Early-stage technologies are developed and tested on the track with the support of simulators at university research centres. The physical dimension of MASA is therefore configured as an open space, which recalls the essential elements of the urban neighbourhood, for pre-testing and technological development that complement the city circuit for V2V and V2X interaction (Table 3.4).

*The social space*

MASA social space was built with the indispensable participation of the local municipality, the local university and industry players. As evidenced by the analysis of memoranda of understanding, these three important industrial partners joined the project and replaced the initial promoter, bringing infrastructure and technical skills to MASA. Along with these main associates, other potential industrial companies from the automotive, ICT or related sectors signed letters of interest (LOI) expressing their willingness to participate in MASA's specific activities, albeit with no involvement in the LL's governance. Through spontaneous social interaction, each partner takes on a specific role for the efficient functioning of the LL: the municipality by making the urban area available and facilitating road testing, and providing the necessary permits and the closure of roads to traffic; the university with skills in basic and applied research into technologies, but also into legal and economic issues; and the main industrial players with their technical and industrial research skills, and by making devices available.

At first, enlarged working groups were envisaged to foster a collaborative climate conducive to the creation of a social space where MASA's main objectives could be shared, and the project's first steps could be made. Once these enabling conditions were achieved, working groups were restricted with the remit to attempt to accelerate decisions within a more operational social space. In particular, the three main industrial partners were the most directly involved in the running of MASA activities, with the support of the municipality and the university. As stated by one of the interviewees, "*We*

*have always tried to keep the groups very open to allow those who attended to understand what was happening.* […] *Then it was obvious that those from that group of relationships that managed to consolidate went ahead, so the need for enlarged groups expired because the relationships were proceeding without them*" (I1b). It was within these restricted working groups that the idea emerged to involve users in MASA activities by exploiting the natural testing opportunity represented by the opening of the LL's social space to the inhabitants of the neighbourhood. Being a physically open space, it was not strictly necessary to adopt active mechanisms to involve users. Rather, interaction with them was obtained by means of the physical dimension of the LL's space. A further interaction with residents is favoured by the establishment of a Data Centre within the urban testing area. Data collected in the area can be returned to inhabitants as instant information on road conditions (potholes or the weather), traffic flows and accidents. In addition, events and public initiatives were organized within the urban area, as well as seminars to disseminate knowledge among residents about the innovation activities taking place in the LL.

*The organizational space*

By quite spontaneously assuming specific roles within the social space, each actor, according to its nature, skills and degree of involvement, had an influence in the formation of the organizational space. The first formalization thereof dates to the signing of agreements and memoranda of understanding, which established the roles, tasks and areas of intervention of the various actors. The complementarity of the roles they played in the formation of social space placed all the actors at the same horizontal level when taking decisions, leading to a diffused and balanced decision-making power between the participants which, it is worth repeating, were the municipality, the main industry players and the university. If, on the one hand, the emergence of a horizontal logic in decision-making allows the pursuit of different and complementary interests and objectives, on the other this requires more time and coordination to align languages and working methods. Similar to what emerged spontaneously in the social space, the organizational space of MASA came into being around a

restricted working group with the aim of guiding the broader developments of the LL, while eight research groups had already started pursuing the development of technologies from a multidisciplinary perspective and coping with the emerging issue related to the circulation of ACV technologies on open public roads. Indeed, when the ACVs started to interact with city life, legal and administrative issues materialized that were of pivotal importance. As testified by one of the interviewees: "*we are now stuck in how to manage security, and this is perhaps the most difficult challenge. It is much easier to have a car that drives alone on the street without any* [technical] *risk than to understand how to make it to drive alone on the street without any legal risk*" (I2b). Overcoming these obstacles would allow for greater and easier involvement of users in the innovation process. In addition, and as expressed by one of the interviewees, "*it is a question of inventing an organizational mechanism that can support the economic activities related to the LL*" (I2b), leading to further progression of its organizational space.

The organizational space of MASA is therefore transformed into a location for dialogue and for the advancement of proposals for overcoming barriers and implementing national legislation for road experimentation (the so-called Smart Road Decree - see Scagliarini, 2019).

Table 3.4: JRC-LL and MASA spaces

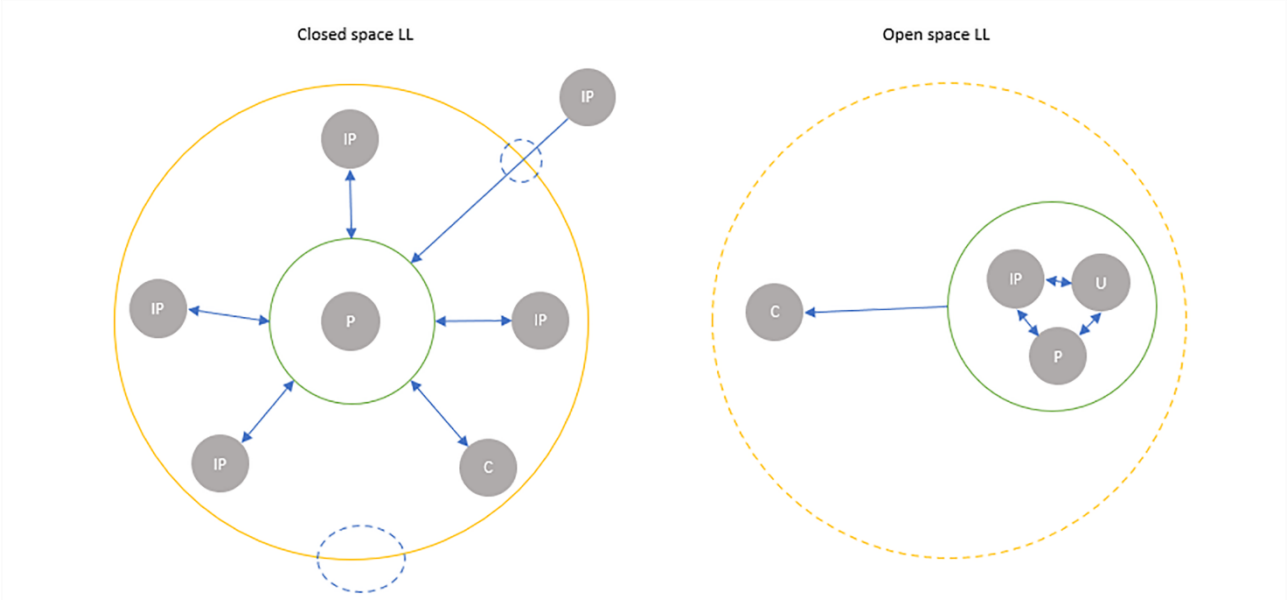
| | | JRC-LL | MASA |
|---|---|---|---|
| **Physical** | Area | Closed area within JRC Ispra site | Open area within a neighbourhood of Modena |
| | Urban-like Infrastructures | More than 80 buildings with staff, straight road segments and curves, roundabouts, various types of zebra crossings and different layouts of parking areas<br><br>Urban test-track, 600 m long closed circuit for testing new mobility solutions at the embryonic stage | Civil and residential buildings, a school, a healthcare centre and a library, road crossings, roundabouts, an overpass and a parking area<br><br>Autodrome of Modena – 2 km of racetrack for testing new mobility solutions at the embryonic stage |
| | Technological Infrastructures | Cooperative Intelligent Transport Systems (C-ITS) via traffic lights, commercial 4G Long-Term Evolution (LTE). Communication, simulators. | 5G, 4G, LORA network, traffic and pollution sensors, traditional and smart cameras, Data Centre, virtual simulators. |
| **Social** | Type of Industrial Actors | SMEs and start-ups from the mobility field | Firms from the automotive and ICT sectors. |
| | Role | Developing and providing solutions to be tested | Providing devices and technical skills to MASA |
| | Mechanism of involvement | Call for expression of interest, collaboration agreements | Memorandum of understanding, Letter of Interest |
| | Type of Users | Site employees and visitors | Inhabitants of the neighbourhood |
| | Role | Co-designing and testing innovative solutions and interacting with technologies | Interacting with technologies |
| | Mechanism of involvement | Makerspace, co-creation workshops, world cafes, interviews, focus groups, surveys, field tests, observations, virtual and laboratory testing, email broadcasts, seminars, and conferences | Public initiatives and seminars, inhabitants' perceptions, sharing of information on traffic status |
| | Type of Research Actors | European Research Centre | University |
| | Role | Research, disseminating results and providing evidence from policies | Research, disseminating results and providing technical and research skills |
| | Mechanism of involvement | Owner of the area | Memorandum of understanding |
| | Type of Policy Actors | European Research Centre | Local Municipality |
| | Role | Managing the area and relationship with other actors, assuring compliance with Smart Road Decree | Managing the area, supporting on-road testing, involvement of residents |
| | Mechanism of involvement | Owner of the area | Memorandum of understanding |
| **Organizational** | Actors of the governance | DGs, JRC LL Management and Evaluation board, JRC Research Ethics Board | Companies participating in LL activities, University, Local Municipality |
| | Governance model | Central/Vertical | Shared/Horizontal |

Source: Authors' elaboration

## 4. Discussion

Results show how the peculiarities in the dimensions of ESs influence the characterization of JRC-LL and MASA as LLs. The first and main element of difference is embedded in their physical space, as an expression of the real-life setting (Veeckam et al., 2013). By exploiting the already existing structure of the JRC, the JRC-LL's physical space looks like a small city closed by in from the outside. The space in which the JRC-LL grows is owned by the EC itself and is therefore protected. Conversely, MASA, located in a real-life neighbourhood, is an open space which leads to a more natural collaboration between different actors. To embrace an OI vision, the JRC-LL activates several mechanisms aimed at making its physical boundaries more porous. For example, the open call for expression of interest and the Makerspace allows the closed space to become a space open to collaboration and creation. Contrariwise, being placed in an open physical space, MASA is a natural setting where OI can transpire. It is arguably the case, therefore, that from these differences in physical space, variances in social and organizational spaces follow logically, leading to distinct configurations of the two LLs and their governance models (Figure 3.3).

Figure 3.3 - Spatial dimensions of the two LLs




Authors' elaboration. The yellow line represents the physical space that leads to diverse mechanisms (dashed blue line) to activate the social space. The social space is defined by the arrows between the actors. Finally, the organization space is identified by the green circle. Actors: IP= Industrial partner, C=Citizens/ end-users, P=Public institution, U=University.

In comparing the cases, it emerges how differences in the physical space may, first of all, determine a diverse evolution of social space. On the one hand, a real-life setting based on a closed physical space requires formal actions to open borders and establish relations with the outside actors. Relationships between actors interrelating in the LL, such as industrial partners and JRC staff, must be built and regulated. The entity in charge of the management of space, which is the JRC, makes strategic decisions that have a direct impact on the social dimension of the space, and thus on the openness of the innovation practices. For example, decisions about which rules to adopt to regulate the access to the area have a direct influence on the number and type of actors to involve and the selection that takes place. The formalization of *a priori* roles can therefore impact on the nature of the relationships. Furthermore, the institutional nature of the entity responsible for administering the physical space may have an effect on the social dimension of the ES for the LL. Since the aim of the JRC is to define guidelines for European policies in the field of mobility, and as the independence of the public entity is critical to ensuring the neutrality of the policy advice, the social space enabling LL testing activity is shaped by the primary goals pursued by the hosting institution. Conversely, the open nature of MASA's physical space leads to the evolution of the social space towards less structured relationships and mutable access rules, so that the degree of openness and the kind of private and public actors involved change flexibly, depending on the goals pursued. The development of the social space in MASA is therefore completely different with respect to the JRC. While the latter needs to adopt mechanisms to lower the hindering effect that closed physical boundaries and strictly regulated access may have on the LL's openness, MASA, being located in an open space, requires mechanisms to draw these boundaries more clearly, in order to enable more purposeful and targeted interactions for innovation in the social space. For example, the narrowing of working groups in the social space of MASA is due to the necessity of involving only those qualified partners capable of contributing to the definition of rules for testing technologies on urban roads, including procedures for obtaining permits from regulatory bodies to test innovation projects. Furthermore, if, in the case

of the JRC-LL, trust is based on formalized rules of access and compliance with them, in MASA trust has to be consolidated and confirmed over time by the actors through a continuous alignment of their own actions to the achievement of the common objectives (Peschl and Fundneider; 2012).

Secondly, the involvement of users under a UI logic also takes a different form, based on the connotation of the physical space. In the JRC-LL, the end users are the employees themselves (even those not directly involved in LL activities) or visitors to the site. Although they do not represent a truly realistic sample of the population, they do take part in the innovation project more effortlessly and actively. The co-creation with the end users, which occurs in the Makerspace through focus groups and a Design Thinking based approach, is also guaranteed by the fact that the majority is unsurprisingly interested in participating. Indeed, the LL is located within a closed community involved and interested in innovation processes and mobility issues. Conversely, involvement of end users is more difficult in MASA. In fact, the end users of MASA are the very people living in the neighbourhood where the LL is located. By making the most of its open space, MASA has the opportunity to analyse and observe in a more vivid way the interaction of ACVs in a real-life setting. However, it is more difficult to involve and establish co-creation processes actively with those who are not innately interested in the experiments carried out within the LL.

With the definition of their social space, LLs transform into multi-stakeholder platforms (Leminen et al., 2012), where actors of different natures are funnelled into the same space. The social interaction of the actors requires the definition of an organizational space within which they can operate, and hence entails demarcation of the governance of the LLs (Bergvall-Kåreborn et al., 2009). In both LLs, the governance model is the output of a spontaneous process reflecting the evolution of physical and social spaces. For example, a diverse collaboration with the industrial partners takes place. In the case of the JRC-LL, the characteristics of the closed physical space has led to a more vertical management of relationships: companies apply through the call of interest and are directed to establish an individual relationship with the JRC-LL. In this sense, the governance network takes the form of a

lead organization (Provan and Kenis, 2007): major decisions are taken by the entity identified as the owner of the space, who also manages each relationship with industrial partners. In conjunction with JRC staff, the latter define the time and aim of their single projects, without having a complete overview of the entire action of the LL. Contrarily, in MASA a horizontal involvement of the players is pursued, leading to a form of governance in line with that of a shared participant governed network (Provan and Kenis, 2007). The main industrial partners, the university and the municipality participate in all activities and make conjointly strategic decisions for the LL, in a logic of multi-stakeholder collaboration. Indeed, for each project the open space requires the intervention of the public authority as a regulatory body to guarantee permits for on-road testing. For their part, the industrial partners contribute to technological experimentation and innovation in collaboration with the university, which, as orchestrating actor (Tagliazucchi et al., 2021), ensures a neutral collaboration space for potentially competing interests.

Finally, both LLs depict an organizational space that evolves over time to face challenges related to the management of interdependencies with the other spatial dimensions. The challenges faced by the JRC are primarily inward. The JRC-LL organization is steered towards a configuration that could better reconcile the need to manage projects from external players in a flexible manner in relation to the demands of the centralized structure imposed by the JRC institutional framework. For this reason, the JRC-LL has also proposed to include higher-ups in its governance team to streamline the communication flows between the top management of the overall JRC structure and the LL, and to find mechanisms that could simplify the bureaucratic processes that are currently slowing down the LL's activities. MASA, on the other hand, being located within a public and open area, is seeking an organizational arrangement which could accelerate the testing activity by university researchers and external actors by smoothing out the hindering effects of national legal and regulatory issues. For example, although compliance with national regulations is required, in the JRC-LL the problem of road safety related to the testing of ACVs does not require direct engagement with decisions taken

by local and/or national regulatory authorities, as the regulatory body for the area, the JRC, is also the owner of the site. In MASA, since road safety issues can be dealt with only by obtaining permits from national and local regulatory bodies for each test project, the organizational space should move towards a configuration which could offer an inclusive set-up where regulatory bodies are required to be flexibly involved in each decision-making process.

## 5. Conclusions

Considering LL as a space for fostering innovation, this paper has proposed an analysis of two LLs involved in the same technological field and has addressed the call for a better understanding of the influence the space has on LL by leveraging the concept of ESs (Peschl and Fundneider, 2012, 2014). In an attempt to define a theoretical framework for the real-life setting, the paper has offered several contributions to the debate. First, by analysing LLs from an ES theoretical perspective, the findings show how the physical, social, and organizational dimensions of ES interrelate and how they influence the evolution of the LL. The presence of a closed and protected physical space is related to the emergence of social and organizational spaces in which the decision-making power of the actor managing the area is central. Conversely, an open physical space makes possible the creation of a social and governance space less centred on a single leading actor, thereby granting different institutional entities, public authorities included, the decision-making powers required to manage the LL. Secondly, the findings of this paper suggest that openness, user involvement and a real-life setting, as constitutive concepts of LL, are intertwined and bolster each other in shaping effective LL activities. This paper has therefore argued that a real-life setting based on a close physical space is likely to favour the involvement of end users with a high level of motivation to participate in the innovation process, whereas OI logic is more difficult to implement. On the other hand, when the real-life setting is an open physical space, OI approaches are easier to implement, while users (albeit potentially much more numerous and spontaneously engageable) are likely to be less involved in the co-creation process. Thirdly, some implications have been drawn for the LL governance model, since

this paper has observed that the management of a physically closed real-life setting has been associated with the formation of a lead organization governance, while a shared participant governance naturally follows the establishment of an LL in an open space. Finally, by offering more evidence on how LLs are performed in practice (Paskaleva and Cooper, 2021; Greve et al., 2020), this paper has contributed to the advancement of the debate by focusing on an as yet understudied type of LL, namely the automotive industry, discussing how the type of technology involved, its complexity and the characteristics of the usage environment influence the configuration of the real-life setting and the ES dimensions considered. This paper has also offered practical implications in supporting managers and practitioners in performing innovative activities, projects or management tools. It has pointed out how the construction of an LL could not commence without careful reflection on the physical space and how this can influence mechanisms supporting the relationship with the other actors and the very governance of the LL.

However, awareness is required of the greater complexity implied in the analysis of spatial conditions affecting LLs as ESs. Several limitations arise, leaving room for the following areas of research. Firstly, although an initial contribution has been made to a relatively new and promising stream of research on LLs, the generalization of the results is low. Secondly, a deeper discussion about micro-level practices is also needed, looking in depth at single projects driven within the LL and how they have been managed. Prospective research could involve more case studies, cross-country samples, or LLs based on different types of innovation. Furthermore, future studies could consider a wider time span to address a deeper analysis of relationships and evaluate the role of trust within collaborations. Future empirical studies should also consider the epistemological spatial dimension, given the strong nexus between knowledge creation knowledge transfer and community-based innovation practices.

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## Appendix B

Table B1 - Interviews Protocol

| | |
|---|---|
| Background and context | Roles and responsibilities<br>Vision and mission of LL |
| Physical dimension | Physical structure<br>Management of activities within the area (infrastructures and places)<br>Technologies implemented within the area |
| Social dimension | Participants and roles of different actors<br>Difficulties and main barriers in co-managed projects<br>Changes in the network over the years<br>End-user relationship<br>Future perspective for the network of actors collaborating within LL |
| Organizational dimension | Foundation and organization of the LL – main difficulties<br>Governance and actors taking part<br>Changes within the governance<br>Management of the differences in the objectives of single actors<br>Organization of activities (on an administrative level) |
| Conclusions | Main issues to be resolved for the development of the LL<br>Expectations VS actual results<br>Medium long-term goals |

Authors' elaboration

# 4. Intention to use Autonomous Vehicles. The role of carsharing compatibility and perceived risk in investigating user acceptance

Users' acceptance is perceived as one of the main barriers standing in the way for the mass diffusion of Autonomous Vehicles (AVs). For this reason, an increasing number of researchers has been focusing the attention on individual characteristics, such as demographic and personality traits, and personal perceptions influencing the acceptance toward AVs, yielding to some preliminary attempts of empirical investigations. The extension of the Technology Acceptance Model to other technologies, such as AVs, has allowed to enrich the model with specific context variables, helping to identify more precisely the phenomenon. However, results are still fragmented and the need for a better integration of the model with context specific variables emerge. Drawing from the Technology Acceptance Model and Innovation Diffusion Theory, the proposed research model analyses the effects of Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Subjective Norm and perceived safety risk on the intention to use AV, while the variable carsharing compatibility is added as moderator, considering carsharing as a business model potentially facilitating AVs diffusion. Results, measured over a sample of 361 Italian respondents, suggest that a high carsharing compatibility decreases the importance of the PEOU variable for the intention to use AVs, while leading to a deeper consideration of the PU variable over intention.

## 4.1 Introduction

Analysing users' acceptance turns out to be crucial in understanding the factors still impacting the barriers related to the use of AVs. As a matter of fact, among the issues standing in the way for the mass diffusion of these vehicles and limiting them to experiments or protected labs, literature argues that, more than the technical barriers, a deep expected barrier to their dissemination is the users' acceptance (Xiao and Goulias, 2022). For this reason, an increasing number of researchers have been focusing the attention on individual characteristics, such as demographic and personality traits, and personal perception influencing the acceptance toward AVs and yielding to some preliminary attempts of empirical investigations. For instance, some studies analysing the effects of demographic characteristics, such as age, income, and education, discovered that young people with a higher willingness to purchase are usually more likely to accept AVs (Abrams et al., 2021; Koul and Eydgahi et al., 2018). Similarly, Xiao and Goulias (2022), using the data from the California Vehicle Survey, recognize young, well-educated, and male people, as the population segment with the highest disposition to use AVs. More recently, literature has started to investigate on how the personality traits, such as desire to exert control or external locus of control, can influence the intention to use AVs (Nastjuk et al., 2020; Choi and Ji, 2015). Authors argue that people with an external locus of control rely more easily on an automated driving system, since they believe less in their own driving skills than individuals with internal locus of control do (Choi and Ji, 2015). At the same time, Hamburger et al. (2022) demonstrate that the personalization of AVs based on people's preferences regarding some important components of AVs enhances their acceptance.

As concern the personal perception of AVs, literature refers to those theories and models developed to understand how a technology use is diffused (Hamburger et al., 2022). In order to understand intention to adopt new technologies, one of the most widely used models in the literature is the Technology Acceptance Model (TAM). First theorized by Davis in 1989, it was originally created for information systems. Its use was later extended to other technological fields to examine

the individual technology acceptance behaviour. According to it, when dealing with new technologies, users are influenced by whether or not they perceive that technology to be useful and the degree to which they think using it will be free of effort. The wide use of TAM has been leading authors to add variables to the model, including those ones related to the social influence processes (TAM 2), and integrating further determinants positively influencing the perceived ease of use (TAM 3). However, although the increasing number of available studies using the TAM (Davis, 1989, 2000; Venkatesh and Bala, 2008) to test their hypotheses and understand the users' acceptance of AVs, they still lead to different results suggesting, for instance, a different impact of the Perceived Usefulness (PU) and Perceived Ease Of Use (PEOU) variables on the intention to use (Koul and Eydgahi, 2018; Man et al., 2020). Hence, the first aim of this research is to enrich the current debate about the TAM theory, contributing with additional data to the analysis of factors influencing intention to use AVs. In order to do that, variables from TAM 1 (PU, PEOU, intention to use), and TAM 2 (subjective norm) are introduced in our model.

The extension of the TAM to other technologies, such as AVs, has allowed to enrich the model with specific context variables, helping to identify more precisely the phenomenon. For instance, some studies integrate the TAM with the trust theory, pointing out initial trust as the most critical factor in promoting a positive attitude towards intention to use AVs (Zhang et al., 2019; Nastjuk, et al., 2020). Other studies have consistently reported perceived risk as one of the most frequently mentioned reasons for not accepting AVs (Man et al., 2020; Choi and Ji, 2015; Lee et al., 2019). However, perceived risk is a wide concept that can be analysed under different perspectives. Some authors refer to the privacy concerns related to hacking treats, considering the huge amount of data collected by connected vehicles (e.g.: Bansal et al., 2016; Nastjuk et al., 2020), and legal issues due to insurance related problems (Manfreda et al., 2021). As Fagnant and Kockelman (2015) point out, the driving task is strictly related to a safety perception, stating it as one of the most important crucial points in determining AVs user acceptance. While using the AVs, people have to entrust their safety

to the automated system, raising the bar for automated driving safety above that of traditional driving (Fagnant and Kockelman, 2015; Xu et al., 2018). In addition to this, there is still a lack of agreements among experts about the perceived safety of AVs: for instance, some studies demonstrate that the human error could be replaced by a variety of system failures that lead to the AV to be much more likely involved in accidents than human drivers (Othman, 2021) and reveal that most of the people do not believe in the safety of AVs performance (Razaei and Caulfield, 2020). However, although its declared importance, few studies have focused the attention on the perceived safety risk related to AVs (Man et al., 2020), analysing perceived safety risk as a predictor of trust or PU rather than to the intention of use (e.g.: Man et al., 2020; Zhang et al., 2019). In order to tackle this gap, the context specific variable perceived safety risk, as the extent to which a person believes the safety of AV could meet the expectations, is added to the model to analyse its effect on the intention to use AVs.

Finally, we try to reach the additional attempt to improve the debate around models of acceptance, by offering an integration of TAM with Innovation Diffusion Theory (IDT) (Roger et al., 1995). The complementarity between TAM and IDT in explaining intention to use has already been analysed in the literature applied to different technological contexts (Zhang et al., 2008; Giovanis et al., 2012). In a precursor work, Moore and Benbasat (1991) find that TAM and IDT tend to lead to similar findings, pointing out also that the compatibility variable from IDT is the only important innovation characteristic that is not considered by TAM. According to the IDT, compatibility represents the extent to which an innovation fits with the needs, values, and experiences of the consumer (Rogers, 1995). However, albeit compatibility has been analysed as precursor of PU (Moore and Benbasat, 1991), no studies, to our knowledge, have investigated the compatibility variable as a moderator in a TAM. Nevertheless, it is difficult to determine compatibility for technologies that are either not widely used or not yet commercially accessible, such as level 4 and 5 AVs. Otherwise, compatibility is related to an external condition in the adoption environment (Zhang et al., 2008) and may indicate the fit with phenomena that are related to, but different from, the technology under consideration and

that have already experienced some degree of diffusion. Then, considering that compatibility plays a crucial role in examining how users' previous experience with antecedent technologies can affect PU and PEOU of new technologies (Min et al., 2019), for the specific purpose of this article, we use the variable carsharing compatibility as moderator of the relationships between intention to use AVs and a group of selected independent variables from TAM approaches.

We believe, in fact, that the joint study of the relationship with carsharing can offer a fruitful enlarging perspective in investigating intention to use AVs. For instance, some researches have already found that AV technologies fit well into a car sharing business model, leading to what some authors call a more "fleet-oriented market" (Wachenfeld et al., 2016; Teece, 2018), where the ownership of the vehicle is growingly separated from its use and the diffusion of AVs technologies is likely to be favoured by the aggregated purchase decisions of relatively few large operators in the market. AV on-demand scenarios are hypothesized, where the AV is made available at any requested location and passengers use the travel time for other activities that are independent from performing the driving task (Wachenfeld et al., 2016). Despite this promising perspective, up to now there is a lack of analysis and modelling on the effects that carsharing services may have in relation to the acceptance of AVs from a consumer perspective. The relationship between carsharing and AVs is, therefore, a still understudied topic from a consumer perspective. In order to tackle this gap, also considering the supposed positive relationship existing between user innovativeness and use of carsharing services (Kim et al., 2017), we assume, by analogy, that people whose mobility style fits well with carsharing services may perceive less risks and a lower required effort associated with the use of AVs, and they could see in the characteristics of the technology a mean to overcome some problems related to carsharing services. To do that, an online survey has been conducted on an Italian sample of 361 individuals. A preliminary study with a multidisciplinary panel of experts complemented the literature analysis, leading the authors to a deeper understanding of the cross-

sectoral dimensions of AV technological innovation and of the variables considered by the literature for the study of the intention to use AVs.

The chapter is structured as follows. In the first part the theoretical framework is discussed, followed by the development of hypotheses and the research model. Then, methodology is presented, such as the analysis of data and the assessment of validity of the defined constructs. Finally, results are discussed and directions for future research outlined.

## 4.2 Acceptance models and AVs: An overview of the literature

In order to carry on a comprehensive literature review, papers on AVs acceptance have been selected through Scopus, matching the keywords "AVs", "Autonomous Vehicles", "Driverless Cars", "ADAS", "Advanced Driver Assistant Systems" with "Acceptance", "TAM", "UTAUT", "Attitude", "Intention to use". A total of 36 papers starting from 2011 has been selected and the variables and the models used have been analysed. Among the selected papers, 21 papers investigate the acceptance toward AVs, without underlining the specific automation level, 8 papers focus on one or more specific Advanced Driver Assistant Systems (ADAS), while 7 paper determine the level of automation they want to analyse. Table 4.1 summarizes the studies addressing AVs and ADAS acceptance, organized according to: the theoretical model used, the main constructs, the research design, the technology of reference (single ADAS or AV), and the main results obtained.

Most of the studies have used TAM and UTAUT models to predict driver acceptance of AVs or ADAS. Since 2017 some contributions have adopted the TAM2 e UTAUT2 models, while only in the latest few years some authors have opted for an integration with IDT variables. One of the main advantages of the TAM is its flexibility and the ability to add or change variables according to the context, considering its reliability in measuring relationships between external users' perceptual variables influencing attitudes and intentions (Ghazizadeh et al., 2012a). For this reason, many researchers in the past have used the TAM framework as the base model, to which adding new

constructs and relationships to offer a better explanation of technology acceptance (e.g.: Taylor and Todd, 1995; Venkatesh and Davis, 2000; Venkatesh et al. 2003).

This section is divided in six different parts. The first and the second paragraphs analyse the two most popular acceptance models (Rahaman et al., 2017). Specifically, Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT) are discussed, along with their development and how they were applied to emerging technological environments, such as AVs. Within the third paragraph the motivation under our decision to focus on TAM variables instead of the UTAUT are outlined. The fourth and fifth parts investigate the integration of the context specific variable perceived safety risk within the acceptance models when applied to AVs and the adaptation of Innovation Diffusion Theory (IDT) toward AVs. Finally, the specific technologies studied, within the field of AVs, ADAS, and other related technologies, are analysed, as well as the analytical techniques employed in the literature to deal with emerging and future technologies.

Table 4.1 – studies on ADAS and AVs acceptance

| Model used | Main constructs | Research design | Technology studied | Main results | Reference |
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| TAM3 | ATT, BI, PEOU, perceived enjoyment, PU<br>*Moderator*: personal innovativeness | Cross-sectional questionnaire survey on 251 drivers from Southern Taiwan | In-vehicle Global Positioning Systems | PEOU has a significant positive effect on PU. PU, perceived enjoyment, PEOU, all have significant positive effects on attitude. Attitude has a positive significant effect on Intention. personal innovativeness moderates the relationship between attitude and BI. | Chen and Chen, 2011 |
| TAM | BI, PEOU, PU, unobtrusiveness | System familiarization via driving simulator experiment and post-questionnaire survey on 36 drivers from Wisconsin, USA | Distraction mitigation system | Both PU and PEOU having a positive effect on BI, with the latter as the major determinant. Unobtrusiveness positively influences PEOU and PU. | Roberts et al., 2012 |
| TAM | BI, PEOU, PU, trust | Cross-sectional questionnaire survey on 34 drivers from a truck company in Washington, USA | On-board monitoring systems | PU is the most important determinant of BI, while trust positively influences BI. | Ghazizadeh et al., 2012b |
| CTAM | ANX, ATT, BI, EE, FC, PE, PS, SE, SI, trust | Longitudinal study (7-months duration); online questionnaire survey on 11 drivers who had the system in their cars recruited via multiple car dealers in Salzburg, Austria | Parking assistance systems | such PE, EE, attitude and SI effects change over time the drivers' experiences in terms of trust and acceptance, depending on how certain characteristics of the system (e.g., the auditive signals) are perceived by the driver. | Trösterer et al., 2014 |
| TAM | ATT, BI, PEOU, perceived locational accuracy, perceived system reliability, PU, satisfaction, service & display quality | Cross-sectional online questionnaire survey on 1045 drivers selected from automobile and car navigation systems sites in Korea | Car navigation systems | Service & display quality components of the systems are the most significant determinants of attitude and BI. Attitude and PU also influence BI. Both satisfaction and service & display quality are affected by perceived system reliability, while PU is affected by perceived locational accuracy and satisfaction. | Park et al., 2015 |

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| | | | | Satisfaction also positively influences PEOU. | |
| TAM | BI, PU, PEOU, Trust, system transparency, technical competence, station management, perceived risk, external locus of control, sensation seeking | Cross-sectional online questionnaire survey to 552 drivers | AVs | PU and trust are the major determinants of BI, with system transparency, technical competence, and situation management having a positive effect on trust. Locus of control has also a significant effect on BI. No significant effect was found between perceived risk and BI and sensation seeking and BI. | Choi and Ji, 2015 |
| TAM, CTAM | ATT, BI, fun, PBC, PEOU, trust, gender, age, UA, UX | Cross-sectional online questionnaire survey on 336 students and staffs from University of Salzburg, Austria | AVs and ADAS | UA and UX are higher in levels of autonomy deployed in modern cars; PBC and fun decrease with higher autonomy; pre-experience with ADAS and demographics have an influence on UA and UX. | Rödel et al., 2014 |
| TAM3, UTAUT, CTAM | PE, EE, SI, SE, perceived safety, ANX, trust, satisfaction, BI | Four stages of automation of AVs scenarios using driving simulator. Total 68 men and women were involved in the experiment. | ADAS | PE, SI, ANX, trust, satisfaction have significant effects on BI. Different scores are rated according to the level of automation. | Cho et al., 2017 |
| TAM, | Intention to use, acceptance, technology interest, environmental concern, enjoyment, public transit attitude | Cross-sectional survey on 721 individuals living across Israel and North America. Respondents are presented with various scenarios and asked to choose the car they would use for their commute. | Shared and private AVs, | Early adopters are young, students, more educated, spending more time in vehicles are the ones with higher intention to use AVs. The study also found various that Israelis are overall more likely to shift to AVs than North Americans | Haboucha et al., 2017 |
| UTAUT2 | Trust, performance risk, finance risk, perceived risk, socio psychological risk, intention to prefer an AV over a conventional car, | Cross-sectional online survey was conducted in the US and in Germany on 313 individuals. | AVs | Innovativeness, desirability of control, hedonic motivation, EE, SI and trust influence BI which has a significant effect on intention to prefer an AV over a conventional car. | Benleulmi, Blecker, 2017 |

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| | innovativeness, convenience, BI, hedonic motivation, EE, PE, SI, desirability of control | | | Trust is influenced by performance risk, perceived risk, socio psychological risk but not financial risk. No significant effect of PE over BI is found. | |
| UTAUT | BI, PE, EE, SI, FC, hedonic motivation<br>*Moderator*: age, gender, experience | A questionnaire survey was administered to 315 users of a CityMobil2 ARTS demonstration in the city of Trikala, Greece. | Automated road transport system | Hedonic motivation, PE, SI, FC have significant effects on BI, while no significant effect of EE was found on BI. No significant moderating effect was found. | Madigan et al., 2017 |
| TAM, TPB, UTAUT | BI, ATT, PU, PEOU, SN, PBC, PE, EE, SI, FC. | Data collection was done using two approaches: a driving simulator approach on 43 participants and an online survey approach on 387 individuals. | ADAS (adaptive cruise control, lane-keeping system, fatigue monitoring system) | All the models (TAM, TPB, and UTAUT) explain 71% or more of the variability in BI, with TAM performing the best in modelling driver acceptance. | Rahman et al., 2017 |
| TPB, TAM3 | ATT, SN, PBC, PU, PEOU, trust, and workload, Intention to use | 74 participants were involved a driving simulation task (practice drive and experimental drive) followed by a survey | AVs | ATT, SN, PBC, PEOU and trust significantly influence intentions to use AV, while no significant effect is found between PU e intention. | Buckley et al., 2018 |
| TAM | Intention to use, PU, PEOU, years of driving experience, age | A survey was distributed among 377 employees working at a truck accessory manufacturer were the participants of this study. | AVs | Results suggest a significant positive relationships between PU, PEOU and intention to use AVs. A negative relationship between years of driving experience, age and intention to use driverless cars is found. | Koul and Eydgahi, 2018 |
| UTAUT | Purchase intention, SI, EE, PE<br>*Moderator*: innovativeness | An online survey was distributed among 241french respondents | AVs | PE, EE, SI positively influence purchase intentions. Innovativeness moderates the relationships between the constructs | Leicht et al., 2018 |
| - | Acceptance, willingness to pay, BI, social trust, | An online survey was distributed among 452 Tianjin residents, | Fully AVs | Perceived benefits positively influences willingness to pay, perceived benefits and BI; perceived | Liu et al., 2018 |

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| | perceived risk, perceived benefits | | | risk negatively influences general acceptance and willingness to pay, while no significant effect was found on BI. All variables are influenced by social trust. | |
| TAM | PU. PEOU, Perceived trust, SI | Cross-sectional online questionnaire survey to 480 respondents | AVs | PU, PEOU, trust, are all significant predictors of BI, with PU having the strongest impact | Panagiotopoulos and Dimitrakopoulos, 2018 |
| AVAM | BI, intention to use, FC, PE, EE, ATT, SI, SE, ANX, perceived safety | A survey conducted to evaluate 6 autonomy scenarios in a pilot survey (n = 54) and follow-up survey (n = 187). | AVs | Acceptance and intention decrease for higher level of autonomy, but ratings for higher level autonomy are still positive. | Hewitt et al., 2019 |
| - | Risk perception, experience, innovation | Focus groups with 17 participants to identify relevant risk factors for AVs followed by a questionnaire answered by 516 German participants. | AVs | Risk perceptions is significantly smaller for conventional driving compared to AVs. With increasing experience, risk perception decreases for novel driving technologies | Brell et al., 2019 |
| TAM | Intention to use, perceived risk, PEOU, PU, SE, relative advantage, psychological ownership | A questionnaire was provided to 313 Korean respondents recruited from an online survey company with the largest panel in Korea. | AVs | SE positively affects PEOU and intention to use, Relative advantage positively affects PU. Psychological ownership affects the intention to use but not PU. | Lee et al., 2019 |
| TAM | BI, PU, PEOU, ATT, trust, privacy risk, safety | face-to-face questionnaire survey was conducted in public parking lots to 216 drivers completed the survey | AVs (level 3) | BI is positively influenced by attitude and PU. Attitude is positively influenced by PEOU and initial trust, but not PU. Initial trust is influenced by safety and PU, but not by privacy risk and PEOU. Finally, PU positively influences PEOU. | Zhang et al., 2019 |
| TAM 3 | PU, PEOU, trust, personal innovativeness, driving enjoyment, intention to adopt of AV | A cross-sectional online survey to 369 participants | AVs | Trust, PU and innovativeness positively influence intention to adopt, while driving enjoyment has a negative effect on intention. No | Hegner et al., 2019 |

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| | | | | significant effect was found for PEOU on intention. | |
| UTAUT 2 | PE, EE, Hedonic motivation, SI, FC, trust, BI | A cross-sectional online survey to 441 South Africans citizens | AVs | EE, PE, FC, SI, hedonic motivation and trust, all positively influence BI. | Morrison and Van Belle, 2019 |
| TPB, IDT | Public acceptance, compatibility, complexity, trialability, observability, relative advantage, trust, perceived value of AVs. | Cross-sectional online questionnaire survey to 526 respondents | AVs | The positive influence of public acceptance over perceived value is mediated by trust. Relative advantage, compatibility, trial-ability and observability positively influence perceived value, while complexity negatively influences it. | Yuen et al., 2020 |
| TAM, IDT | Intention to use, ATT, trust, PEOU, PU, system quality, perceived safety risk, compatibility | A structured questionnaire survey was used to collect quantitative data from 237 drivers in Hong Kong. | AVs | Intention is positively influenced by ATT, which is influenced by trust and PU, but not PEOU. System quality, compatibility positively influence trust, while perceived safety risk negatively influences it. PEOU is positively influenced by system quality and compatibility. Finally, PU is influenced by compatibility but not system quality, perceived safety and privacy risk. | Man et al., 2020 |
| TAM2 | SN, system characteristics, individual differences, PU, PEOU, attitude, BI, actual system use, ecological awareness, desire to exert control, compatibility, enjoyment, price evaluation, trust | Qualitative research design to identify the elements attributed to individual acceptance of autonomous driving; online survey of 316 participants. | AVs | SN positively influences PU, while trust positively influences intention and ATT. Personal innovativeness positively influences PU and PEOU. PU and PEOU, along with relative advantage and compatibility positively influences attitude. Enjoyment and price evaluation positively influence usage intention. No significance was found for desire to exert control, privacy concern and ecological awareness. | Nastjuk et al., 2020 |

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| Media-based Perception and Adoption Model (MPAM) | Intention to use public AVS, PU, risk, self-efficacy, SN, mass media, social media | Cross-sectional questionnaire survey to 355 participants from two universities in Beijing, China. | Fully public AVs | Mass media enhances potential users' self-efficacy, while social media strengthens SN. Both PU and risks of AVs are influenced by mass media, whereas risk is negatively influenced by social media. PU, SN, self-efficacy and risk, all influence intention to use public AVs | Zhu et al., 2020 |
| UTAUT | PE, EE, intention to use, environmental friendliness, perceived safety | A questionnaire was developed, which was completed in a field survey by a total of 942 participants before or after their journey with the minibus. | Autonomous minibus | All the variables significantly influence intention, with PE as the most important predictor. | Bernhard et al., 2020 |
| TAM | Safety, PU, PEOU, trust, compatibility, BI | A total of 30 potential users participated in focus groups to discuss their perception of full driving automation acceptance. Based on the findings from focus group two tested the models for personally owned and shared-use concepts. with 310 and 250 participants, respectively, online. | Fully AVs | The results of focus groups indicate users' concerns as centred around safety, PU, compatibility, trust, and PEOU. Only the impact of PEOU on BI was found to be insignificant. The indirect impact of PEOU was less significant in the personally owned than in the shared-use model, whereas PU, trust, and compatibility effect more the personally owned than the shared ones. | Motamedi et al., 2020 |
| - | Trust, comfort, social norm, dispositional trust, situational trust, learned trust, expectations | A within-subjects experimental design was adopted, whilst the experimental conditions were delivered through travel in an actual AV operating under Level 4 automation under controlled conditions | Shared Autonomous Vehicles (SAVs) | Statistically significant relationships are found between trust and all the other variables. | Paddeu et al., 2020 |
| - | Mobility behaviour, public perception of AVs, perceived challenges of integrating AV into existing traffic systems, attitude towards AVs, perceived safety of passengers who have experienced an AV ride. | A qualitative study based on a content analysis of 19 interviews with participants aged between 20 and 75 years carried put after the trial of a level 3 shuttle. | SAV level 3 | People experienced a general positive feelings toward AVs, perceiving them as an alternative more than as a substitute over traditional vehicles. | Hilgarter and Granig, 2020 |

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| IDT, TAM | Relative advantage, Image, compatibility, result demonstrability, visibility, trialability, PU, PEOU, BI | Cross-sectional online questionnaire survey to 274 respondents | AVs | PU, PEOU positively influence BI and are influenced by relative advantage, compatibility, image, result demonstrability, visibility, and trialability. | Yuen et al., 2021 |
| - | Technological minded individuals, personal and social benefits, security, mobility related efficiency, safety, AVs adoption, technological and legal concerns | Web-based survey was conducted among 380 millennials | AVs | All variables except for security and efficiency have a significant effect over acceptance. | Manfreda et al., 2021 |
| TAM | PU, social demographic characteristics, mobility indicators, built environment attributes, AV ownership, AV shared services, AV pooled services, AV owing vs AV sharing | Using data from the 2019 California Vehicle Survey, the first datasets of public agency surveys (population= 4248) | AVs, SAVs | PU influences BI and it is perceived higher by young, well-educated, and male householders. Households having higher annual income and EVs express a stronger interest in buying an AV but not in ridesharing. Young, educated households with more TNC riders show a greater propensity to AV sharing services but not for owning AVs. | Xiao and Goulias, 2022 |
| UTAUT, IDT | PE, EE, SI, Trialability, Observability, Perceived risk | Cross-sectional online survey to 641 Tehran residents | AVs | PR negatively influences intention; Among UTAUT variables, SI was the most influential factors over BI, while Trialability, and Observability had the lowest effects on AV Acceptance. | Farzin et al., 2022 |
| Cognitive Appraisal Theory (CAT), AVAM | SI, Hedonic motivation, Trust, PE, Perceived risk, Emotion, Intention to use, Objection of the use | Cross-sectional online survey to 361 respondents | AVs level 4/5 | Trust is the most powerful determinant of PE and negatively effects risk perceptions. PE and hedonic motivation positively effects travelers' emotions. The latter determines the acceptance of AVs. | Ribeiro et al., 2022 |

Source: Authors' elaboration.

Legend: AT= Attitude; ANX= Anxiety; BI= behavioural intention; EE=effort expectancy; FC=Facilitating Conditions; PBC= perceived behavioural control; PE=performance expectancy; PEOU= Perceived ease of use; PS=perceived safety; PU=perceived usefulness; SE=self-efficacy; SI=social influence; SN= Subjective norm; UA= User Acceptance; UX= User experience.

*Technology Acceptance Models*

When people deal with new technologies, attitude is a crucial point in the acceptance process (Davis, 1989). Among the models that have been theorized to predict individual's inclination toward a certain type of technology, Technology Acceptance Model (TAM) is one of the most used. Based on the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975), according to which performance or non-performance of a given behaviour is primarily determined by the strength of a person's intention to perform (or to not perform) that behaviour (Fishbein and Ajzen, 1975), Davis (1989) recognizes the Perceived Usefulness (PU) and the Perceived Ease of Use (PEOU) as the drivers for the attitude toward a certain technology. The attitude predicts the intention to use (or behavioural intention - BI) that kind of technology, defined as a person's subjective probability for performing some behaviours, which is the main predictor for the actual system use. While PU is based on the degree to which a person believes that using a particular system would enhance his or her job performance, PEOU refers to "*the degree to which a person believes that using a particular system would be free of effort*" (Davis, 1989, p.320).

Initially thought for studying the acceptance of the information systems, the TAM has extended its use to analyse the acceptance of many other technologies, such as mobile commerce (e.g.: Chi, 2018), mobile banking (e.g.: Alkhaldi, 2017), and healthcare technologies (e.g.: Calisto et al. 2022), until to reach AVs and ADAS. Exploring TAM applied to the AVs (e.g.: Ghazizadeh et al., 2012a; Park et al., 2015; Koul and Eydgahi, 2018), our review reveals that the relationships between PU, PEOU, attitude, and intention to use driverless cars have been growingly investigated in the latest years. Most researches have revealed that a high level of PEOU and PU influences favourably the intention to use AVs (Koul and Eydgahi, 2018; Panagiotopoulos and Dimitrakopouluos, 2018; Rahman et al., 2017), in line with what found for previous technologies. However, results are still not completely homogeneous. Some authors have found that PU does not have a favourable influence on BI, but just on attitude (Man et al., 2020), whereas PEOU has no significant effect on attitude and BI

(Man et al., 2020; Lee et al., 2019; Hegner et al., 2019). This is probably due to the fact that users may believe that most driving behaviours are going to become autonomous, and Ease of Use is not perceived as a so critical variable, since personal ability to operate AVs is not strictly necessary for their actual use.

Among the variations of TAM, Taylor and Todd (1995) added some constructs from the Theory of Planned Behaviour (TPB) (Ajzen, 1985), such as the Subjective Norm (SN), representing the degree to which an individual recognises that people most important to him/her thinks he/she should perform a certain behaviour while adopting a method or a system (Taylor and Todd, 1995). Following Taylor and Todd (1995), Venkatesh and Davis (2000) proposed TAM2, which includes SN and adds two more variables related to the social influence processes, namely Image, meaning aspiration of a person to maintain a favourable position among others, and Voluntariness, as the extent to which an individual decides freely to use a specific technology. This latter variable has demonstrated to have high relevance when studying the acceptance of new technologies within a workplace context. For instance, if a new tool is introduced, the level to which this tool is mandatory for the employers can affect the intention to adopt it (Venkatesh and Davis, 2000). Alongside the PEOU, some other variables are introduced (Venkatesh and Davis, 2000), related to cognitive instrumental processes, such as: Job Relevance, meaning the suitability of a technology to the task that needs to be performed; Output Quality, indicating the extent to which the mandatory task is carried out adequately by the technology; and Result Demonstrability, as the degree to which production of tangible outcome can be demonstrated (Venkatesh and Davis, 2000). Among the new variables introduced with TAM 2, SN is the one that has been used the most to study technologies applied to contexts other than workplace. In particular, within the AV context, the SN, as the extent to which a person perceives that others (e.g.: family, friends, colleagues) believe he/she should use AVs, is considered to have a positive impact on the intention to use them (Zhu et al., 2020; Panagiotopoulos and Dimitrakopoulos, 2018; Rahamn et al., 2017).

Finally, TAM 3 (Venkatesh and Bala, 2008) integrates further determinants positively influencing PEOU such as: self-efficacy, perception of external control, computer anxiety, computer playfulness, perceived enjoyment and objective usability. Self – efficacy refers to individuals' control beliefs regarding his/her personal ability to use a system (Venkatesh and Bala, 2008). Studies on AVs show a positive influence of self-efficacy on the intention to use (Buckley et al., 2018; Choi and Ji, 2015, Lee et al., 2019). In particular, Lee et al. (2019) found that only self-efficacy, and not PEOU, has a significant effect on intention to use when applied to the AVs. On a psychological level, the relevance of self-efficacy could be explained by the persistence of beliefs, among individuals, about the fact that their driving ability remains critical also in case of AVs (even though they are not) (Lee et al., 2019). Perception of external control is the degree to which an individual believes that organizational and technical resources exist to support the use of the system (Venkatesh et al., 2003). Computer playfulness and perceived enjoyment are related, namely, to the enjoyment an individual gets from using a new technology, and to the degree to which a person thinks using a technology could be enjoyable, while computer anxiety measures the extent to which an individual is comfortable in using a new system. In the context of AVs, perceived enjoyment and computer anxiety have both been examined (Hegner et al., 2019; Rödel et al., 2014). Hegner et al. (2019) demonstrate that enjoyment has an important negative impact on the adoption of AV, since the pleasurable experience associated to the driving is even higher in cars than other transportation systems.

The Car Technology Acceptance Model (CTAM) specifically included the anxiety variable, defined as a key driver of acceptance in the context of cars (Osswald, 2012) and the perceived safety as the extent to which an individual feels comfortable while using the vehicle. By adapting the items and variables to the technological parameters under research, the model has been used by numerous authors in the ADAS and AVs domain (Cho et al., 2017; Trösterer et al., 2014; Rödel et al., 2014; Hewitt et al., 2019, Ribeiro et al., 2022). For instance, Cho et al. (2017) modified the variables expressed by the CTAM to ADAS technology, identifying the anxiety as individuals' perception when feeling unsafe while using ADAS, and the perceived safety as the benefits the using of the ADAS

have on individual's health, stating that the influence of both of the factors over BI is expected to increase as the autonomous driving levels advance. Same result is yielded by Hewitt et al. (2019) in adapting the CTAM to the AVs, in the so-called by authors AVAM (Autonomous Vehicle Acceptance Model), where results suggest that acceptance and BI decrease for higher level of autonomy, even if maintaining a positive rating, showing participants were not completely averse to high-level autonomy. Ribeiro et al. (2022) integrates the AVAM with the Cognitive Appraisal Theory (CAT), suggesting that travellers' decisions on AVs depend on their emotions and a complex evaluation process. Finally, objective usability determine a "*comparison of systems based on the actual level (rather than perceptions) of effort required to completing specific tasks*" (Venkatesh and Davis, 2000, pp. 350–351). However, it requires a level of judgment related to the AV performance that is not possible to apply in a phase where the technology has not been diffused yet.

*Unified Theory of Acceptance and Use of Technology*

A comprehensive synthesis of technology acceptance research is contained within Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, 2003). According to the model, three determinants directly influence BI: Performance Expectancy, Effort Expectancy and Social Influence. Performance Expectancy, similarly to PU, refers to the degree an individual believes that using a technology will help him/her to attain gains in performing the required task; Effort Expectancy, similarly to PEOU, relates to user expectation toward ease: when users feel the technology is easy to use and does not require much effort, they would have high chances to adopt that technology. Social Influence means the extent of social pressure exerted on individual to adopt new technology. Finally, the UTAUT model includes BI and Facilitating Conditions, meaning the environmental factors that make a decision easier, both of them representing direct determinants of use behaviour (Venkatesh, 2003). In addition, some moderators related to individual difference variables have been added, including Gender, Age, Experience, and Voluntariness of use (Venkatesh, 2003). As the TAM, the UTAUT has found over the years some applications in the AVs field. Studies demonstrate a positive

association between Performance Expectancy, Social Influence and Facilitating Conditions with BI (Madigan et al., 2017; Leicht et al., 2018; Morrison and Van Belle, 2020), meaning that high system performance, others' opinions, and the provision of the resources supporting the effective use of the AV, have all a strong impact on the intention to use AVs. Differently, controversial results were found for the Effort Expectancy. Similarly, to what found in some studies for the related concept of PEOU (e.g. Lee et al., 2019), Effort Expectancy sometimes fails to reach significance in explaining the intention to use AVs, probably due the fact that AVs do not require continuous input/effort from the user to run effectively (Madigan et al., 2017; Adell, 2010). In line with the UTAUT model, the impact of the moderators suggested by Venkatesh (2003) has been adopted to study the acceptance of the AVs technologies. Gender was found to have a statistically high significant moderating effect on Facilitating Conditions and Effort Expectancy (Morrison and Van Belle, 2020), with women being more hostile than men, as well as Age, where the young students well educated resulted as the greatest potential AV early adopters (Abraham et al., 2017; Haboucha et al., 2017)

Borrowing from the motivation theory (Vallerand, 1997), the UTAUT2 model (Venkatesh, 2012) adds the Hedonic Motivation construct (Venkatesh, 2012) to the previous model. In fact, these authors stated that the first version of UTAUT had emphasized only the importance of the utilitarian (extrinsic) value, through the Performance Expectancy construct, without analysing the intrinsic elements (Vallerand, 1997). Arguing about its important role in determining technology acceptance and use (Brown and Venkatesh 2005), Hedonic Motivation is hence defined as the enjoyment derived from using a technology. Within the studies related to AVs, the Hedonic Motivation has been discovered to have a strong positive impact on BI (Madigan et al., 2017; Morrison and Van Belle, 2020), indicating that those who perceive AVs as fun and enjoyable are expected to be more likely to use AVs when they will become available. With the additional attempt to extend the concept to consumer use, the UTAUT2 model has been enriched with the Price Value variable, defined as consumers' cognitive trade-off between the perceived benefits of the applications and the monetary

cost for using them (Dodds et al., 1991). Finally, Habit, directly influencing both BI and use behaviour, has been added, as the extent to which people tend to perform behaviours automatically because of learning (Limayem et al., 2007). Both of these variables have not yet been explored in the context of self-driving vehicles, due to the fact that the AVs are still at a too embryonic stage to be associated to a monetary value or a routinized usage behaviour.

*Integration of Perceived risk within acceptance models*

Among variables that are considered as integration of acceptance models, Perceived Risk appears to be of relevant importance for AVs. Most of the studies integrate the Perceived Risk with TAM model (Zhang et al., 2019; Lee et al., 2019; Man et al., 2020). Lee et al. (2019) enriches the TAM theory with the perceived risk variable, looking at its influence on the Intention to use of AVs and analysing Self-Efficacy and PEOU as antecedents of Perceived Risk. Similarly to other study (e.g.: Ward et al., 2017) results demonstrate that Performance Risk negatively influences the Intention to use, while it is not influenced by any variable. This is explained by the fact that any accidental situations occurring while driving AVs is perceived as related to external factors, being users involved in few tasks while using the vehicle (Lee et al., 2019). Consistently with these findings, Ward et al. (2017) demonstrate that the information reduces the negative Perceived Risk effect over Intention to use, as participants' risk perceptions decreased after viewing an informational video. Man et al. (2020) consider two types of risks when it comes to AVs: Safety and Provacy risk, both of them failing in having any effect on PU. Concerning safety-critical activities, when using an AV people must entrust their safety to the automated system. Also, privacy risk does emerge, which may result from the possibility that behavioural data or travel data may be obtained by third parties without the consent of users (Man et al., 2020). The same types of risks are analysed by Zhang et al. (2019) as antecedents of the Initial Trust, pointing out that while Safety Risk has a negative significant effect over initial trust, no significant influence can be attributed to perceived Privacy Risk. Similar results are outlined by Benleulmi and Blecker (2017), integrating the Perceived Risk within a research model

based on UTAUT2. Authors focus on different risks consumers using AVs could have. In particular, authors recognize five different types of risks directly influencing the trust variable. The Privacy Risk, due to possible loss of privacy as a result of the risks associated in sharing with the vehicle a huge amount of data; the Performance Risk related to the possibility of AVs malfunctioning; the Safety Risk as the risk of the user's safety to be endangered while using the AV; the Financial Risk linked to the potential monetary loss associated with the initial purchase price and maintenance cost of AV; and the Socio-Psychological risk defined as "*the loss of status in one's social group as a result of using AV, looking foolish or untrendy and risking to lower the consumer's self-image*" (Bleneumi and Blecker, 2019, p. 103). Results demonstrate that Safety and Performance risk are the ones perceived to be more significant, while no significance is related to Financial and Privacy risk.

*Innovation Diffusion Theory and its adaptation to AVs*

Some authors (e.g., Yuen et al, 2020, 2021) integrate acceptance models on AVs by using variables related to Rogers's (1995) Innovation Diffusion Theory (IDT). At the core of this theory there are five main constructs influencing adoption: relative advantage, compatibility, complexity, trialability and observability. Relative advantage reflects the extent to which an innovation is perceived to be better than another product adopted for the same use. For instance, within the AV context, the construct reflects the advantages of AVs compared to other traditional vehicles (Lee et al., 2019) and it has been analysed both in relation with the other IDT variables (Yuen et al., 2020, 2021) and as single variable affecting PU (Lee et al., 2019), showing a positive influence on it (Yuen et al., 2020, 2021; Lee et al., 2019). As defined by Rogers (1995), compatibility is the amount of compatibility of the innovation with the needs, values, experiences of the consumer. Complexity shows the degree of difficulty in understanding and using the innovation. Trialability defines the degree to which an innovation can be tested before the actual adoption. Lastly, Observability shows the tangibility of results obtained by using the new product. In an attempt to integrate the TAM with the IDT model, Yuen et al (2020, 2021) analyse the IDT variables as antecedents of PU and PEOU, arguing that TAM

and IDT are complementary model and that they can be used in an integrated way to explain the AVs BI. Integrating IDT with UTAUT, Farzin et al. (2022) analyse two variables of the IDT model, namely trialability and observability, as external factors influencing attitude toward AVs. Results suggest that both of them have a significant positive effect, albeit lower than UTAUT variables integrated in the model, over intention to use.

*Methods and technology studied*

When acceptance models analyse technologies that are not yet widespread and with high social and technological impact (Fagnant and Kockelman, 2015), like AVs, respondents are likely to have difficulties in understanding what an experience incorporating the use of the technology implies or which are the possible effects in everyday life (Rahaman et al., 2017; Rödel et al., 2014). The same imaginative difficulty is probably one of the reasons for the fragmentation of results in the literature. Indeed, to date, one of the main obstacles encountered by authors in the AVs acceptance debate is the fact that these are technologies that respondents have never directly tested. Therefore, their judgements can be distorted by a lack of experience. To address bias due to respondents' lack of experience with AVs, some specific methodologies have been used, based on scenario techniques or previous experiences with ADAS.

According to Table 4.1, other methodologies have been recently added in the research design to the traditional single questionnaire. Examples include the use of simulators or experiments of AVs, both in protected areas and urban centres (Roberts et al., 2012; Rahman et al., 2017; Buckley et al., 2018; Madigan et al., 2017; Bernhard et al., 2020; Paddeu et al., 2020; Hilgarter and Granig, 2020) as well as the use of quali-quantitative techniques (Nastjuk et al., 2020) that exploit driving scenarios descriptions (Haboucha et al., 2017; Hewitt, 2019) or focus groups (Brell et al., 2019; Motamedi et al., 2020) to help respondents to perceive themselves in real-world situations and to gain a more contextualized and complete understanding of the phenomenon. In case of ADAS, experiments are also used to compare different kinds of technologies, and which one is preferred by the drivers

(Roberts et al., 2012). Roberts et al. (2012), investigating on the drivers' distraction, analyse the acceptance toward mitigation systems, letting users to experience them to see how the intention to use and trust are affected. In particular, authors provide two kinds of mitigation systems: a real-one based prototype, exploiting alarms and visual warnings, and a post drive mitigation system, defining the performance of the drivers compared to the one of the peers. Thanks to the experiment, authors could argue that the real one was considered too intrusive by the users, who usually preferred to receive an evaluation after the driving experience was concluded. In case of AVs, automation is more complex to imagine and experiencing it, either in a real-world or in a simulated or virtual environment, helps to comprehend and process all the possible impacts related to its use (Paddeu et al., 2020). Here, experiments with AV public vehicles are carried out to define the changes before and after the trial within intention to use (Paddeu et al., 2020; Bernhard et al., 2020; Hilgarter and Granig, 2020). In some cases, when the experiment is not allowed, simulators help in detecting the changes over BI due to the experience toward the AVs (Cho et al., 2017). However, the use of different methodologies does not always significantly influence the results (Rahman et al., 2017). Rahman et al. (2017) perform two different kinds of methodologies for analysing the acceptance toward ADAS: a first methodology provided the use of a driving simulator before answering to a questionnaire, while the second study was based on an online survey. Albeit the lack of interaction with the technology during the survey, results suggest that both of the approaches obtained similar ratings in measuring the variables effects, probably due to the differences in sampling that, in the case of experiment, does not always reach high number of respondents (see as example: Cho et al., 2017).

Another relevant decision as for method regards the specific technology studied within the field of automation in vehicles. According to Table 4.1, until 2015, the focus of research was primarily on single ADAS technologies, often recognized as the precursors of AVs (Rödel et al., 2014). However, since 2015, an increasing number of studies have turned their focus to AVs, analysing them as a whole set of technologies rather than just in terms of a single technology perspective. Therefore, a

search for more precise data collection techniques could be also a response to a technology analysis whose explanation was much more complex than the one of a single ADAS.

### 4.3 Research model and hypotheses

The analysis of the acceptance models used for AVs defines some aspects guiding us in the construction of the model. Firstly, based on the existing literature, we believe that the use of the TAM (Davis, 1989; Venkatesh and Davis, 2008) to study driver acceptance could provide more actionable information in BI compared to the other models. A potential and more advanced substitute to the TAM for the analysis of acceptance could be indeed recognized in the UTAUT (Venkatesh, 2003; 2012). Nevertheless, the originality of the UTAUT lies in some specific variables such as: Facilitating Conditions, Hedonic motivation, Habit, and Price Value, while the core variable constructs of the model, such as Behavioural Intention, Effort Expectancy, Performance Expectancy, and Social Influence, do not see within the literature on AVs significant differences from the TAM constructs. Since this is a technology not yet in use, we believe the application of variables such as Habit and Price Value to AVs is not still measurable, due to the inability to use the technology. This is in line with the analysis carried out by Rahaman et al. (2017) that confronts TAM and UTAUT models to see which perform better when applied to ADAS. Results suggest that the first version of the TAM model (Davis, 1985), based on PU and PEOU as main explaining variables, had resulted as the best performing model in the AVs domain. Whereas, literature contributions involving the use of increasingly specific variables, as well as those included in the UTAUT model, have demonstrated a lower degree of explanation of the phenomenon (Rahaman et al., 2017). In particular, TAM explained from 73% (Venkatesh and Davis, 2000) to 82% (Davis, 1989) of the variance in BI, while UTAUT explain the 71% (Venkatesh, 2003). Secondly, considering the still highly experimental nature of the technology and, consequently, the lack of experience of consumers, the intention to use AVs (or AVs BI) has been selected as final dependent variable, thus renouncing to measure the actual system use construct, as required by the TAM. In fact, BI is seen as a person's subjective probability for

performing some behaviours and is assumed as the strongest predictor guiding the actual system use (Davis, 1989). Therefore, we argue that a thorough analysis of intention to use AVs could represent a robust test of effective future adoption behaviour. Thirdly, among the other TAM variables, PU and PEOU are considered as the strongest predictors of intention to use. Also, the process of social influence acquires a relevant role for those technologies which are not yet widespread. For this reason, we believe that the Subjective Norm variable answers well to this need, fitting coherently within the technological context analysed and not being strictly related to a workplace context as the other TAM 2 variables (Image and Voluntariness) are. As concerns TAM 3, no variable has been included. The main reason for this choice is related to the technological context, which is still at too embryonic stage both to appreciate any conceptual nuances between the Self-Efficacy variable and PEOU and to be adapted to constructs such as Playfulness and Enjoyment that require a certain degree of experience to be evaluated more effectively. Finally, while the TAM offers a useful tool for analysing the acceptance of AVs, it lacks linking the technologies under consideration with the adoption environment within which they should be introduced. Differently, the Innovation Diffusion Theory (IDT) (Rogers, 1995) is considered a model more related to the external environment (Zhang et al., 2008). However, we believe that applying the IDT variables to technologies that are only present at an experimental level, such as AVs, can lead to biased findings (Yuen et al., 2021). Nevertheless, we argue that the IDT variable Compatibility could be fruitfully used to capture users' attitudes toward other technologies or services which are actually in use and to determine whether the latter may influence, or be associated to, the future adoption of the emerging technologies under consideration. This is the case of carsharing service, which is growing in popularity and is seen as a synergetic model with respect to AVs (Teece, 2018), raising the question of whether using an AV as a private or shared mobility mode may influence intent to use (Kaye et al., 2021). For this reason, respondents' compatibility related to a carsharing model is integrated within the model as a moderating variable. In the following section, variables and hypotheses of our model are presented.

*Perceived Usefulness and Perceived Ease of Use*

Within the TAM framework, PU and PEOU are considered as the most important predictors of BI (Davis, 1989); likewise, the beneficial effects of PEOU to PU are also assumed. In the AVs context, PU defines the utility related to the AV use, while PEOU refers to the degree to which a person believes using AVs will be free from significant effort. Within the literature about AVs' acceptance both variables have been frequently analysed (e.g.: Rahman et al., 2017; Koul and Eydgahi, 2018). In line with the TAM model, studies demonstrated that the intention to use AVs mainly depends on how easy and useful AVs are perceived to be (e.g.: Zhang et al., 2019; Nastjuk, et al. 2020; Panagiotopoulos and Dimitrakopoulos, 2018; Wu et al., 2019). However, some authors have found that PU does not have a favourable influence on BI, but just on attitude (Man et al., 2020), whereas PEOU has no significant effect on attitude and BI (Man et al., 2020; Lee et al., 2019).

The intention to use AV may be affected by the extent to which people believe AV will help them performing their task more efficiently (such as: reducing the time spent in the car, allowing them to perform other tasks while moving from one place to another). At the same time, being the effort a finite resource that people could allocate to various activities for which they are responsible (Radner and Rothschild, 1975), if AV is perceived to be easier to use than a traditional car, it is more likely to be accepted by users. On the other hand, if the system is too hard to use, the performance benefits of usage could be overshadowed by the effort of using the AV, no matter if potential users believe a given application is useful. Therefore, we expect that, also for AVs, PEOU will reinforce PU. This means that PEOU has both a direct and indirect effect on intention, thus PU can be considered a mediator of PEOU-Intention relationship. According to the TAM model, we then hypothesize the following:

H1. *Perceived usefulness positively affects intention to use AVs*
H2. *Perceived ease of use positively affects intention to use AVs*
H3. *Perceived ease of use positively affects perceived usefulness AVs*

*Subjective norm*

Subjective norm (SN) construct reflects *"perceptions that significant referents desire the individual to perform or not perform a behaviour*" (Taylor and Todd, 1995, p.149), meaning that the judgment of individuals toward a certain technology tends to follow what people who are important for them actually do or think. Taken by the TRA model (Fishbein and Ajzen, 1975), SN has been incorporated within TAM2 (Venkatesh and Davis, 2000) as determinant of BI to explain the importance of social influence processes in determining the intention to use a technology. As a social factor, SN consists of the perceived opinions of other people or groups that are close or important to the person and can influence his/her decision-making (Fishbein and Ajzen, 1975). Within the AVs context, we intend SN as the extent to which a person perceives that other (e.g.: family, friends, colleagues) think he/she should use AVs. In the literature there is a consensus about the fact that the positive opinion of others about the usefulness of AV can influence people's own perception (e.g.: Buckley et al., 2018; Panagiotopoulos and Dimitrakopoulus, 2018). For instance, the peer-to-peer pressure has been demonstrated to play an important role in the decision to adopt AVs (Zhu et al., 2020; Bansal et al., 2012). Bansal et al (2012) conducted a study examining social factors influencing adoption of AVs, discovering that 50% of the population were more likely to try them if they were adopted by family members, friends, or neighbours, showing that future AV adoption rates could depend on the adoption rates of a close set of intimate individuals. In accordance with previous studies, which demonstrated that SN has a positive effect on behavioural intention, using both TAM extensions (Panagiotopoulos and Dimitrakopoulus, 2018) and UTAUT (Madigan et al., 2017; Morrison and Van Belle, 2020), we then hypothesize that:

H4. *Subjective norm positively affects intention to use AVs.*

*Perceived safety risk*

Perceived risk refers to the perceived uncertainty in a given situation and the expectation to bear losses due to uncertainty (Bauer, 1967). We intend the perceived safety risk (PR) associated at the AVs as the extent to which a person believes that the AV will not behave as expected, reducing the

intention to use AVs. Although a large number of studies demonstrate the decrease of the incidents due to the AVs and the subsequently enhancement in traffic safety levels (Liu et al., 2018), the perceived safety risk associated to AVs among potential users has been found as still high (Schoettle and Sivak, 2015). Some studies aiming to understanding the impact of system safety, cost of technology and liability issues related to AVs, showed how the majority of respondents ranked safety as the most influencing aspect in AVs adoption, with almost the totality of them expressing concerns about the safety of the AVs (Othman, 2021). Despite its declared importance and lack of agreement, few studies have focused on the perceived safety risk associated with AVs (Man et al., 2020), analysing perceived safety risk as a predictor of trust (Bleneumi and Blecker, 2019; Zhang et al., 2019) or PU (Man et al., 2020), rather than Intention. Then, we can consider the following hypothesis:

H5 *Perceived safety risk negatively affects intention to use AVs*

*Model moderator: carsharing compatibility*

Carsharing is often described as an alternative to car ownership (e.g.: Baptista et al, 2014; Peterson and Simkins, 2019), where people do not use their own car, but they use hourly rental services of the vehicle (Han et al., 2019). The paradigm of private ownership related to the vehicle is then switching toward a Transportation as a service business model where consumers rent the usage of the vehicle as needed rather than owing the vehicles themselves (Teece, 2018). Some studies estimate that, just in the United States, the development of sharing economies related to the automotive sector could lead to a decline in annual sales on the order of several million units of cars (Clements and Kockelman, 2017). Scholars expect a strict contamination of carsharing services with AVs business model (Teece, 2018; Paddeu et al., 2020), due to the expected high initial prices for the AVs and the fact that a vehicle able to go from one place to another without human intervention suits well with a sharing business model (Wachenfeld et al., 2016). The concept of car ownership itself has already been analysed within the AVs context. For instance, Lee et al. (2019), having investigated under a psychological perspective those factors influencing the AV adoption that can affect user-vehicle

relationship, argue that a desire of ownership is still important in relation to AVs, even if people can potentially go anywhere without their own vehicles. Applied to the carsharing concept, the compatibility defines the degree to which a carsharing model fits with persons' own lifestyle and values (Han et al., 2019). Some studies demonstrate that those ones with carsharing experiences have higher PU and Intention to use sharing AVs (Xiao and Goulias, 2022). Similarly, people with a high carsharing compatibility could see in AV a potential solution for the problems related with carsharing services, leading to a stronger positive effect of PU on intention to use AVs. Introducing AV technology in a carsharing business model would indeed allow for the technology to gain in popularity as it would be able to provide on-demand mobility at a low price and facilitate multi-modality by providing last-mile travel solutions, while lowering the barriers associated with traditional carsharing services, such as inconveniences caused by users' travel to access available vehicles and vehicle availability problems (Wachenfeld et al., 2016; Paddeu et al., 2020). Following this:

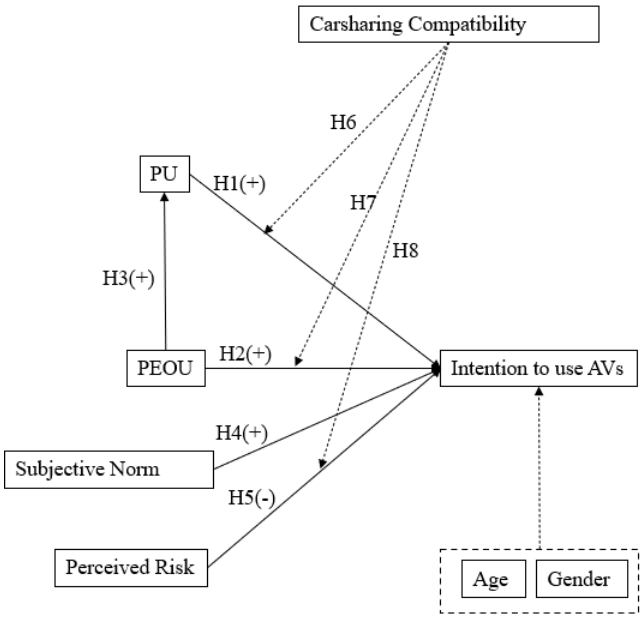
H6 *People with high/low carsharing compatibility may give higher/lower relevance to the effect of PU on the intention to use AVs*

Rogers (1995) defines people with high degree of innovativeness as those ones able to handle the complexity involved in the use of new technology and to overcome more easily the problems related to the use of that. In addition, they are more likely to handle uncertainty and to take risks, assuming that they will have more enthusiastic intentions for using an innovation (Rogers, 1995). At the same time, some studies define a positive relationship between innovativeness and carsharing services (Kim et al., 2017; Han et al., 2019) stating that individuals who have a high innovative propensity are more likely to have a positive opinion toward carsharing (Kim et al., 2017). We believe, by analogy, that people with a positive mind attitude toward carsharing services may perceive AVs as less hard to utilize and see less risks associated with them. Then, we assume that a higher/lower compatibility with carsharing services could lead to the following hypotheses:

H7 *People with high/low carsharing compatibility may give lower/higher relevance to the effect of PEOU on the intention to use AVs*

H8 *People with high/low carsharing compatibility may give lower/higher relevance to the effect of Perceived Safety Risk on the intention to use AVs*

Fig.4.1 Research model




Source: Authors' elaboration

## 4.4 Empirical research

### 4.4.1 Panel of experts

In order to gain a better understanding of the AVs and the context of use, a preliminary analysis based on a panel of experts was carried out. Respondents were chosen based on their affinities with respect to the automotive and AVs topic, with the final goal of gathering opinions and viewpoints that could offer different perspectives related to end-user acceptance of AVs. Table C1 in the appendix presents the characteristics of the respondents and their field of interest in relation to AVs. Twelve semi-structured interviews with an average duration of one hour were conducted. At the beginning of each interview the interviewees were asked to introduce themselves and their backgrounds related to automotive sector, AVs and ADAS and from what perspective they were

studying them. The introduction was followed by a generic framework question: "*what do you see as the main barriers and benefits associated with the future adoption of self-driving vehicle*s?" The question was aimed to let respondents express their point of views as fully and completely as possible. More specific questions addressing the interviewees to certain variables were then asked if some aspects needed to be explored in more detail. At the end of each interview an internal discussion among the authors followed highlighting the most interesting points that were emerged and defining what kind of information from experts could be considered as a useful complement to the literature in refining the acceptance model to test an emerging technology. For instance, it was from this panel that the indication to connect the AVs phenomenon to the carsharing business model emerged, then supported by the literature analysis.

### 4.4.2 Survey

*Participants and data collection*

The first part of the questionnaire was filled with participants' demographic information, while in the second part they were asked to respond to 30 items on the seven constructs included in the model. We conducted the survey in two phases. In the first phase a convenience sample of master students was used gathering a total of 70 answers. Preliminary analysis to measure convergent validity and internal consistency of the constructs were carried on. Once we were sure about the constructs, the questionnaire was shared through social media (Facebook and LinkedIn) using groups related to automotive topics to increase the possibility to get more answers. Data from 373 respondents were collected in Italy from the students' sample and online survey. Among them, we eliminated respondents who had missing data (for instance, respondents who did not have driving license could not fill in the questionnaire). As a result, a total of 361 respondents were selected, whose profile is shown in Table 4.3. The majority of them were younger than 33 years old (60%). However, as these technologies will not be available in the near future, we believe it is reasonable to concentrate the majority of respondents in the younger age group as potential future users of AVs.

Table 4.3 - Demographic characteristics

| Variable | Category | Freq | In% |
|---|---|---|---|
| **Gender** | Female | 155 | 42.9% |
| | Male | 206 | 57.1% |
| **Age** | Younger than 33 | 219 | 60% |
| | 33 and older | 142 | 40% |
| **Education** | Middle school | 4 | 1.1% |
| | High school | 101 | 28.0% |
| | Bachelor's degree | 115 | 31.9% |
| | Master's degree | 112 | 31.0% |
| | PhD/second level master's degree | 29 | 8.0% |
| **Driving Experience** | 1-5 years | 111 | 30.7% |
| | 6-10 years | 82 | 22.7% |
| | 11-15 years | 60 | 16.6% |
| | More than 15 | 108 | 29.9% |
| **Family members** | 1 member | 32 | 8.9% |
| | 2 members | 86 | 23.8% |
| | 3 members | 95 | 26.3% |
| | 4 members | 122 | 33.8% |
| | 5 or more members | 26 | 7.2% |

Source: Authors' elaboration

*Measurement development and test results*

Each construct was measured with multiple items and each item was borrowed from the literature to improve content validity. To measure PU, PEOU, and the intention to use, variable scale items from Davis (1989) were used. The scale items for SN was adopted from Taylor and Todd (1995), while Featherman and Pavlou (2003) and Choi and Ji (2015) were used for the safety perceived risk scale. Finally, the carsharing compatibility items were adopted by Han et al. (2019). All items are based on a seven-point Likert scale ranging from 1 (totally disagree) to 7 (totally agree). Table C2 in the appendix shows the items and sources from which they have been adopted. Years and gender were used as control variables of the model.

*Data analysis*

Confirmatory factor analysis (CFA) was applied to analyse the measurement model, using Lisrel, considered among the most comprehensive packages (Iacobucci, 2009). Construct validity is achieved when fitness indices of the model meet with required levels. The model so specified showed a reasonably good fit with the data: $\chi 2$ (degrees of freedom) = 361 (174), goodness of fit index (GFI) =.91; root mean square error of approximation (RMSEA) =.05; Standardized Root Mean Square Residual (SRMSR) =.04. All items loaded significantly on the hypothesized latent variables, indicating convergent validity. All constructs showed acceptable values of composite reliability (CR ≥.897), average variance extracted (AVE≥.744) and Cronbach's alpha (CA≥.831).

To test for discriminant validity, for each construct we compared the square root of its AVE with its highest correlation with other constructs (Fornell and Larcker,1981). The square root of a construct's AVE was always greater than its highest correlation with other constructs, indicating discriminant validity. Table 4.5 reports the results from CFA.

Table 4.5 - CFA results, convergent validity and internal consistency

| | | CA | AVE | CR | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Intention to use** | 0,972 | 0,922 | 0,979 | **0,960** | | | | | |
| 2 | **PU** | 0,866 | 0,789 | 0,918 | 0,7 | **0,888** | | | | |
| 3 | **PEOU** | 0,844 | 0,763 | 0,906 | 0,614 | 0,63 | **0,873** | | | |
| 4 | **Risk** | 0,831 | 0,744 | 0,897 | -0,335 | -0,19 | -0,081 | **0,862** | | |
| 5 | **Subjective norm** | 0,953 | 0,877 | 0,966 | 0,601 | 0,538 | 0,47 | -0,16 | **0,936** | |
| 6 | **Carsharing compatibility** | 0,937 | 0,887 | 0,959 | 0,306 | 0,26 | 0,25 | 0,096 | 0,33 | **0,941** |

Source: Authors' elaboration

*4.2.4 Structural model results*

The partial least squares structural equation modelling (PLS-SEM) results are acquired through the software of SmartPLS4.0. The structural model is tested based on bootstrapping with 5000 subsamples. With the path coefficient and its corresponding t value, we can assess statistical conclusion validity by testing the null hypothesis for each path coefficient (Table 4.6). All path coefficients are significant with the exceptions of H8. Of the seven supported hypotheses, five of

them were found to be significant at p<.01, and the others to be significant at p<.05 (H7) and p<.10 (H6). Specifically, PU has a positive effect on intention to use (β= .32, p< 0.001), while PEOU has a positive effect on both intention to use (β = .25, p<0.001) and PU (β= .62, p<0.001). Subjective Norm also has a positive effect on intention to use (β= .24, p<0.001). Conversely, risk has a negative effect on intention to use (β=- .22, p<0.001). Finally, carsharing compatibility positively influences the relation between PU and intention to use (β= .09, p<0.1), while negatively influences the relation between PEOU and intention to use (β= - .09, p<0.05). Finally, both indirect effect and direct effect of PEOU on BI are significant and have the same direction, leading to a complementary partial mediation (Table 4.7). Results will be discussed in detail in the next section.

Table 4.6 – Path coefficients

| Hypothesis | Path | b | T value | P-values | Supported or not |
|---|---|---|---|---|---|
| H1 | PU → BI | 0.323 | 6.147 | 0.000 | Supported |
| H2 | PEOU → BI | 0.246 | 9.089 | 0.000 | Supported |
| H3 | PEOU → PU | 0.624 | 15.412 | 0.000 | Supported |
| H4 | SN → BI | 0.237 | 5.006 | 0.000 | Supported |
| H5 | Risk → BI | -0,223 | 6.176 | 0.000 | Supported |
| H6 | Carsh.Comp x PU → BI | 0.092 | 1.932 | 0.053 | Supported |
| H7 | Carsh.Comp x PEOU → BI | -0.092 | 2.110 | 0.035 | Supported |
| H8 | Carsh.Comp x Risk → BI | 0.042 | 1.136 | 0.256 | Not supported |

Source: Author's elaboration

Table 4.7 – Indirect effect

| Indirect Effect | b | T statistics | P values | Type of mediation |
|---|---|---|---|---|
| H3xH2 | 0.201 | 5.766 | 0.000 | Complementary partial mediation |

Source: Author's elaboration

## Discussion

In AVs adoption modelling, it is critical to understand the formation mechanisms of potential users' willingness and their evolution at the early stage of introducing AVs. This paper attempts to study the factors that may affect consumers' intention to use AVs. To identify the variables that influence BI toward AVs, we built a model drawing on two different theories: TAM and IDT.

TAM (Davis, 1989) is one of the most used theories for investigating the acceptance of new technologies, as the wide numbers of studies using the model for different technologies or services

suggest. Recently the model has been applied also to ADAS and AVs. Results show that all the hypotheses predicted by the TAM are confirmed. In particular, results show that PU and PEOU contribute significantly to define the consumer intention in using AVs. On the one hand, respondents believe using AVs would be useful for improving their performance allowing to do other tasks while on the vehicle, increasing the productivity and reliving the stress of driving. On the other hand, the perception about the effort that is needed to learn how to use AVs may increase the intention to use them, probably due to the fact that people entrust the driving task to the system. At the same time, the belief that a certain system easier to be used may enhance the performance with the same amount of effort positively affects the PU. In line with the TAM 2, the Subjective Norm variable has a significant impact on the Intention to use, meaning that when social groups of reference, such as family and friends, have a positive opinion over AVs, the latter are more likely to be assumed to encounter individuals' expectations. In case of still not experienced technologies, the opinion given by others assumes a strong relevance indeed, as inexperienced individuals are more likely to be influenced by the opinion of third parties in the formation process of acceptance (Venkatesh and Davis, 2000).

Adding the perceived safety risk, our findings show that it has a significant and negative effect on intention to use. The driving job is inextricably linked to a safety perception indeed, and it is one of the most essential critical points in determining the AV user adoption (Fagnant and Kockelman, 2015; Othman, 2021). People must commit their safety to the automated system when utilizing AVs, elevating the standard for autonomous driving safety above the one related to traditional driving (Fagnant and Kockelman, 2015; Xu et al., 2018). Hence, in line with previous studies that found that the perceived safety risk is a negative determinant of initial trust of AVs (Benleulmi and Blecker, 2017; Zhang et al., 2019), our results, show that people who perceive AVs as having a higher safety risk are less likely to show an actual intention to use them.

Although the TAM is a consolidated and effective model for analysing the acceptance of AVs, it places emphasis above all on the end-user and individual characteristics belonging to his/her intimate

sphere. However, little focus is given on the context of use, as the external conditions in the adoption environment. This could lead to synergies with other already existing business models, such as the carsharing, which may result very important in analysing individual's intention to use AVs. The context of use defines indeed a crucial element for the adoption, especially for technologies whose use affects the external environment as well, pointing out the need for an integration of variables allowing to define aspects that go beyond the singular human-machine relation. To overcome these limitations, this study made some key theoretical advances by drawing from the IDT theory (Rogers, 1995) the compatibility variable as a moderating factor affecting AVs' acceptance. IDT analyses how a technology is disseminated within society, thus looking at the processes that lead people to talk about that technology and use it. Compatibility has been identified as the sole variable in Rogers' model still absent in the TAM studies (Moore and Benbasat, 1991). Its connection to the context of use is precisely what makes it appropriate for investigating how users' prior experiences with related or similar technologies can influence their intention to use a particular technology (Min et al., 2018). Although the compatibility has been already taken into account in earlier studies as a predictor of PEOU and PU, no studies have directly investigated its moderating effect till now. We believe that the introduction of a context-of-use variable may enrich the interpretation of a TAM model used to predict the acceptance of an emerging technology, such as AV, which are not yet commercially available and whose future introduction is far from being clearly conceptualized. Our model, therefore, relies on the assumption that future AVs use is likely to be integrated with a business model based on carsharing services, which is consistent with the scenario emerging from the expert panel interviews and with some preliminary findings emerged in the literature. According to this, AVs could provide a possible solution to the limitations that currently affect the diffusion of carsharing services, for instance situations where consumers are left without a car nearby and cannot have access to the service. In addition to this, there is a general change in the concept of vehicle ownership whereby vehicles are increasingly being used in a service-oriented manner (Teece, 2018). Our results partly support the existence of a moderating effect of carsharing compatibility, which positively moderates

the relationship between PU and Intention to use, indicating that those whose lifestyle and values fit well with carsharing services perceive the utility associated with AVs as a higher significant determinant towards intention to use. This is likely due to the fact that they see the AV as a potential solution to mitigate problems related to the access to vehicles currently experienced in mobility systems based on carsharing business model. Conversely, carsharing compatibility has a negative moderation effect on the relation between PEOU and intention to use, thus showing that people who consider carsharing services as useful tools for their mobility lifestyle perceive the ease of use of an AV as less relevant in determining their intention to use it. This is also probably linked to the fact that, because carsharing is a phenomenon that is not yet widely diffused, carsharing users are still compatible with the Rogers' (1995) categorization of early adopters. The early adopter profile, driven by the enthusiasm of novelty, is naturally inclined to put out with higher level of complexity.

Nevertheless, contrary to what predicted in our theoretical model, the carsharing compatibility does not have any effect on perceived safety risk. Similar to the moderation effect of carsharing compatibility on PEOU, the assumption of moderation between perceived safety risk and carsharing compatibility has been based on the significantly positive relationship between innovativeness and carsharing service (Kim et al., 2017). However, in using AVs, users may consider themselves to be only involved in few parts of driving. Consequently, they are likely to feel themselves hardly responsible for any accidental situations that occur while driving. Rather than elements relating to individual characteristics, such as the propensity to handle risky situations, the perceived safety risk associated with AVs may be primarily linked to external causes, such as failures related to the system (Choi and Ji, 2015) or accidental events (Lee et al., 2019; Man et al., 2020).

## 4.6 Conclusion

The following study aims to analyse end-user acceptance toward AVs by taking into account possible synergies with the carsharing business model. From a theoretical point of view, the implications are fourfold. First of all, applying the TAM model to the context of AVs, an emerging

literature - where results are still not completely homogeneous - is enriched with additional data demonstrating a positive significant relationship between PEOU and PU and SN toward intention to use. In addition, further originality of the study lies in the use of an Italian sample, which, to our knowledge, had not yet been investigated in the literature. Secondly, the still under-explored relationship between perceived safety risk and intention to use is demonstrated. Finally, an integration between IDT and TAM is demonstrated by analysing carsharing compatibility as a moderator of the model and showing that it influences the relationship between PU, PEOU and Intention to use. In particular, this study contributes to enrich the acceptance model theory adding the compatibility as moderator of the TAM, a type of integration that, to our knowledge, has never been applied before within the literature.

Beside the research implications, results offer plenty of food for thought for stakeholders interested in experimenting with AVs. Firstly, the model implies that the PU and PEOU may play a crucial role to adopt AVs. On the one hand, communications should be addressed in order to highlight the benefits related to AVs, on the other hand, a human – friendly, simple design could make the user more confident in trying the AV, enhancing the probability to adopt it. Moreover, considering that the opinion other people have on AVs positively affects the intention to use them (Subjective norm – Intention to use relation), marketers should pay special attention to word-of-mouth marketing when the new technology becomes available on the market, preventing and contrasting the spread of false news. In particular, the fact that consumers associate the hazards of operating an AV with circumstances beyond their control, highlights the need to provide adequate information regarding the controls carried out on the vehicle prior its release on the market. Some effective strategies should be addressed to decrease perceived safety risks by communicating, for instance, the improvement of AVs in reliability when compared to conventional vehicles. Furthermore, we believe that diffusion of AVs will be the result of a slow and gradual process that can be facilitated through existing business models. Thus, an overall rethinking of automotive industries' value chains and policy makers'

strategies is required to ensure the AVs diffusion (Teece, 2017). The model depicts a scenario in which carsharing and autonomous driving technologies show some interactions from an end-user perspective, showing, for example, that carsharing compatibility can increase the effect of PU over intention to use AVs, while decreasing the PEOU one. Marketers should thus segment their target audiences accordingly, which means that customers whose lifestyle fits well with carsharing services are likely to play a critical role in the diffusion of AVs. Moreover, collaborations with policy makers, manufacturing companies and local carsharing services operators could help in the experimentation with higher levels of automation and the subsequent adaptation of infrastructure. Policy makers should consider current mobility preferences, providing the necessary infrastructure to allow shared AVs to circulate on the road and enhancing the benefits of AVs to overcome some of the barriers currently perceived in carsharing, making it more attractive.

This study has some limitations that could be addressed for future research. First of all, when we talk about AV, we are referring to technologies that are not yet commercially available. This, therefore, does not allow the use of the complete TAM model, as the actual use variable was not included. Moreover, the high technical complexity makes it difficult for the respondents to understand, for instance, the different levels of automation and the ADAS involved for each level such as the implications these technologies could have on the daily life. Future research could consider to analyse the actual usage exploiting experimentation fields, such as living labs, that are emerging as a valuable mean to test new innovations and their impact within the society. This would allow, for example, to integrate the following data by proposing the same questionnaire in a road test context in order to capture the differences pre and post use of the technology and improve the respondent's awareness. Moreover, as these technologies are evolving, it could be interesting for future studies to apply a longitudinal lens of analysis, by investigating how the user acceptance changes over time as technology evolves. The road test would also allow the integration of other IDT variables that were not analysed in this study, with new forms of integration between the two models

(TAM and IDT) to be explored. In addition to this, the experimental context and the integration with the external environment could help for a deeper analysis of perceived safety risk antecedents, as they have not been analysed in our model, and of the other kinds of risks associated to AVs. Some limitations related to the sampling are outlined as well. Firstly, the following study focuses only on an Italian sample. Future research could enlarge the sample to other countries, analysing how cultural and contextual differences may affect the adoption of AVs. Secondly, although younger generations are in line with the potential users of AVs, a sample more representative by age classes could be reached, improving the universality of the results.

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## Appendix C

Table C1 – Participants' characteristics

| Field | N. | Job Title | AVs topics |
|---|---|---|---|
| Engineering | **I1** | Project Manager | Algorithms supporting autonomous driving |
| | **I2** | Professor | Phases of design of vehicle systems and production of vehicles, especially through robotic systems<br>Coordination of ACVs experimentation in public environment |
| | **I3** | Professor | In vehicles embedded computers for planning autonomous driving use cases |
| Philosophy | **I4** | Researcher | Ethics of technology applied on AVs |
| | **I5** | Professor | Ethics of artificial intelligence and robotics |
| Sales | **I6** | Car Dealer | Sale of ADAS and level 2 vehicles |
| Economics | **I7** | Transport economist | New Technologies acceptance models – focus on AVs |
| Psychology | **I8** | Traffic psychologist | Analysis of psychological aspects related to AVs |
| Law | **I9** | Professor | AVs inclusiveness and administrative problems for on road experimentation |
| Safety | **I10** | Director at environmental research centre | Safe and sustainable mobility, road education over 65 |
| | **I11** | Think Thank on AVs coordinator | AVs safety on road |
| Education | **I12** | Driving instructor | Driving training plans at European level |

Source: Authors' elaboration

Table C2 – Items

| Construct (n. of item) | Item | Conceptualization | Source |
|---|---|---|---|
| Intention to use (4) | **INT1** I intend to use autonomous vehicles in the future..<br>**INT2** Assuming I had access to an autonomous vehicle, I intend to use it.<br>**INT3** If I had access to an autonomous vehicle, I predict that I would use it.<br>**INT4** I will intend to use an AV in the future | The degree to which an individual intends to useAVs in the future | Davis (1989) |
| Perceived Usefulness (5) | **PU1** Autonomous vehicles will let me do other tasks, such as eating, watching a movie, being on a cell phone on my trip.<br>**PU2** Using AVs will decrease my accident risk<br>**PU3** Using AVs will relieve my stress of driving<br>**PU4** Using AVs would increase my productivity<br>I find AVs to be useful when I'm impaired (e.g. drowsy, drunk, drugs). | The degree to which a person believes that using AVs would be useful for improving his/her performance. | Davis (1989) |
| Perceived ease of use (3) | **PEOU1** I expect AVs will be easy to use.<br>**PEOU2** I will find it easy to get AVs to do what I want it to do.<br>**PEOU3** It will be easy for me to become skilful at using AVs | The degree to which a person believes using the AVs will be free from effort | Davis (1989) |
| Subjective Norm(5) | **SN1** In general, people who I like would encourage me to use the system.<br>**SN2** People who influence me would think that I should use AVs.<br>**SN3** People who influence my behaviour would think that I should use AVs.<br>**SN4** People who are important to me think that I should use AVs. | The extent to which a person perceives that others (e.g.: family, friends, colleagues) believe he/she should use AVs | Taylor and Todd (1995) |

| | | | |
|---|---|---|---|
| | **SN5** In general, people who I like would encourage me to use the system. | | |
| Perceived safety risk (5) | **PR1** Using AV would be risky.<br>**PR2** The safety of AVs may not meet my expectations<br>**PR3** I worry about whether AVs will provide the level of benefits I expect<br>**PR4** AVs may not be safe, i.e., may be (or become) harmful or injurious<br>**PR5** Danger may occur due to user misuse of AVs. | The extent to which a person believes that the AV will behave as expected | Pavlou (2003)<br>Choi and Ji (2015) |
| Carsharing Compatibility (3) | **CS1** Carsharing is compatible with all aspects of my life.<br>**CS2** Carsharing fits into my life style<br>**CS3** Carsharing fits well with my needs. | The degree to which a person's lifestyle fits into carsharing | Han et al., 2019 |

Source: Authors' elaboration

# 5. Conclusions

The purpose of the following thesis was to analyse the processes of acceptance and diffusion of a particular emerging technology: Autonomous Vehicles (AVs). The literature defines an emerging technology as combining high engineering complexity with social complexity (Porter et al., 2002). In this sense, the topics presented within this thesis have analysed some of the perspectives that can be used to prepare the ground for future acceptance and deployment of AVs. To do that, the study is developed as a pathway going from LLs, as environments for experimentation and testing of AVs until acceptance models, focusing on the end user. Some final reflections can be determined based on the common thread that follows the logic of the thesis.

A reorganization under three different perspectives – namely, actor-based, methodological and environmental - of the literature on LLs has been presented, as tools that originate from the practice and are framed in theoretical definitions only later (Leminen and Westerlund, 2019). The issues addressed by LLs try to prepare the social and productive frameworks for new solutions and different sectors. In a socio-technical system perspective, LLs are thus an attempt to balance and coordinate the interests of the social groups involved, by reconstructing a possible context of adaptation that anticipates the issues related to the integration between the emerging technology and society. In this view, LLs are innovation ecosystems which reflect the characteristics of AVs, establishing a continuous interaction between technological and social regime, where practice and theory dialogue through mechanisms of mutual adaptation.

Looking specifically at the two case studies of automotive LLs analysed in the second paper, the multidimensionality inherent in the emerging technology is reflected in a multidimensionality of the space itself. The Enabler Space becomes the theoretical apparatus through which the diversity of the aspects of the LLs, starting from the physical dimension, is analysed, and their different evolutions, through an analysis of the social and organizational dimensions, are depicted. The setting of the physical space involves a different definition of the social space, where the groups of actors on whom

the technology will have an impact try to balance their interests. An open physical space requires the concentration of different actors responding to specific roles for the functioning of LL and an inclusion of each referent for different social groups in the governance, based on a Triple or Quadruple Helix Model. In contrast, a closed physical space, although facilitating the interaction between user and technology, leads to a stricter selection of actors taking part in the LL and, consequently, a centralization of the decision-making power, with the exclusion from it of some of the key referents of innovation processes. Consequently, we obtain two different possible managements of technology diffusion processes, which face different problems. On the one hand, issues from the regulatory point of view, not allowing experimentation to progress because of the existing regulations; on the other hand, a governance issue that does not allow the LL to take full advantage of those characteristics which are peculiar for an innovation ecosystem, such as the network of relationships that can be established among different actors.

As highlighted in the first paper, the diversity of the theoretical perspectives applied to LLs points out also the fact that social adaptation cannot be separated from the technological characteristics of the innovation that is tested, and vice-versa. This reflection, in case of LLs applied to AVs, underlines the need for a deeper consideration of the end-user within their diffusion process. Therefore, while the need for spaces of experimentation emerges, being either them integrated in a real environment or trying to replace the complexity of it, the processes of acceptance of future users, whose evaluation mechanisms also make possible to propose a clearer integration of them as stakeholders and social group of reference, assume relevance. In the AVs case, experimentation allows us to grasp the main gaps between the social and technological regime, helping, for example, in the definition of a new regulatory framework, in the rethinking of the city's infrastructure and transportation system, but it does not allow us to fully grasp the user's point of view, which sometimes remains more peripheral than the technical and institutional actors involved. In this regard, we believe that integration with models focusing on end-user perceptions toward technology may help in the attempt to include future

customer's point of view. Despite this, while TAM has been proven to be one of the most robust models in analysing the acceptance of technologies within different sectors, it requires some integrations when used with technologies not yet available in the market. In this regard, the IDT captures more of the contextual dynamics of a technology, allowing an AV technology to be tied to a specific context of use. For this very reason, the inclusion of the carsharing compatibility as moderator allows AVs to be anchored to possible uses, highlighting a possible future path to take in the process of AV diffusion.

This thesis offers some practical implications as well. First of all, some guidelines for managers and practitioners who want to perform innovative activities, projects or management tools are presented. It has been pointed out how the construction of a LL should come with a deep reflection about the physical space and how the latter can influence mechanisms supporting the relationship with the other actors and the governance of the LL. Albeit LLs offer themselves as effective tools for a contextual analysis of AVs as emerging technologies, they must be managed by looking at the different key aspects that make up the very definition of LLs. In this sense, it should be integrated an environmental perspective, which highlights the importance of a realistic context of use, with an actor-based perspective, which allows for the inclusion of the stakeholders necessary for the success of the experimentation, and with a methodological perspective, which helps to define the appropriate tools to enable the coordination of space with actors and the organization of the environment. Furthermore, some practical implications for facilitating future users' acceptance processes are offered, addressing automakers and new entrants of the automotive industry who are interested in AVs or ADAS technology development. In particular, marketers should incentivize business models and market segmentations which exploit the synergies between carsharing and AVs. To do that, collaborations with policy makers and local carsharing services operators could help in the experimentation with higher levels of automation and the subsequent adaptation of infrastructure. On the other hand, communication should highlight the benefits of sharing AVs over traditional

carsharing services and market strategy experts should explore this particular market niche for the AVs diffusion.

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