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MSc Programme in Urban Management and Development

Rotterdam, The Netherlands

November 2018

Thesis

Title: Co-creation Enhancement Dynamics in EU Urban Labs

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Specialization: Urban Environment, Sustainability and Climate Change

UMD 14

MASTER'S PROGRAMME IN URBAN MANAGEMENT AND DEVELOPMENT

(October 2017 – November 2018)

Co-creation enhancement dynamics in EU urban labs

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UMD 14 Report number: 1238
Rotterdam, November 2018

Summary

Cities worldwide are currently undergoing sustainability challenges, that in combination with climate change and increasingly vulnerable systems, are inevitable, uncertain, and complex. Too significant to solve in isolation, these unstructured challenges necessitate a collaborative urban planning process, amongst multidisciplinary participants from professionalized fields, and the engagement of users and citizens in transition to provide new infrastructure for the co-creation and testing of sustainable services, legislation, and products (Regeer and Bunders 2009, Keyson et al. 2016, Bulkeley et al. 2016, Acuto et al. 2018, Menny et al. 2018, Puerari et al. 2018). It is essential that these new perspectives consider cross-scale and cross-sectoral interactions, interdisciplinary research, understand past, present, and future dynamics encompassing long-term periods, modify organizational methodology and develop new skills and ways of working (Klijn and Koppenjan 2000, Pelling et al. 2015, Den Ouden et al. 2016).

Urban labs have emerged as an innovative approach that fosters co-creation through the collaboration of multiple interdisciplinary actors aiming to co-create value which enables innovation for change processes (Veeckman et al. 2013). Aiming to empower various stakeholders and co-create experimental approaches, urban labs develop invaluable insights, used to form policies, inform social innovation design, and inspire participants while remaining participatory and open. This process forges co-creation, which is maintained by the four main urban lab characteristics: aims, activities, participation and context. The performance of which has the potential to facilitate the rate at which cities make ambitious sustainable transitions through co-created contributions. All characteristics are imperative for the success of urban labs; however, the literature does not provide consensus on the predominant urban lab characteristic for fostering high co-creation levels.

The main objective of this study was to contribute to the existing literature by furthering the understanding of co-creation enhancement in urban labs to improve contribution to urban sustainability. A quantitative analysis was performed to examine survey results derived from urban labs throughout Europe. Each characteristic of these urban labs were assessed through a series of survey questions and by an ordinal logistic regression analysis. This study revealed that all European urban labs exhibited at least one or more co-creation activity, and out of the four co-creation level classifications (high, medium (upper), medium (lower), and low), the majority of these labs occupied medium (upper) levels of co-creation. The findings determined the urban lab characteristic indicators most significant for the explanation of co-creation level variation to be lab focus, clarity of goals, degree of power struggles, predetermination of structure, visibility, and sense of community. After conducting the ordinal logistic regression analysis, it was concluded that the urban lab characteristic most imperative to sustaining high levels of co-creation is “Aims”. A more generalizable deduction could be attained through meta-analysis studies that examine a larger sample size of European urban labs. This research can be utilized to increase understanding of co-creation optimization through application of recommendations applied to current and future urban lab practices.

Keywords

Co-Creation, Urban Labs, Urban Sustainability, Climate Change, Sustainability Transitions

Acknowledgements

Firstly, I would like to express my utmost gratitude to my mother, Marleni Nicholas-Noble, for her encouragement to pursue this degree and her constant support throughout the year.

I am especially grateful to my partner, Boyan Slat, who has helped me to overcome difficult obstacles I have faced throughout the year and to keep my motivation running strong. And to his family, for also supporting me throughout the year and making the Netherlands my second home.

A very special thank you to my grandfather, Fausto Calderon, and uncle, Cesar Calderon, without whom, this master's degree would not have been possible. And I am also tremendously grateful for the lovely friends I have made from UMD 14 for sharing this adventure with me, and for their love and encouragement throughout the year.

Lastly, I would also like to acknowledge my supervisor Spyridon Stavropoulos and co-supervisor Elena Ensenado for their assistance and guidance throughout this journey. And to my second reader, Kounetas Kostas, for his valuable input.

Abbreviations

IHS	Institute for Housing and Urban Development
DRIFT	Dutch Research Institute for Transitions
ENoLL	European Network of Living Labs

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Chapter 1: Introduction

1.1 Background

Cities have been recognized as testing grounds for innovation and creativity due to the concentration of resources, institutional networks, labor, and infrastructure associated with cultural and social economies of agglomeration (Bulkeley and Broto, 2013). However, alongside these opportunities, cities struggle with systemic obstacles such as sustainability and climate governance, urbanization, competing priorities, short-term cycles of political leadership, budgetary concerns, and aging infrastructure not suitable to withstand the effects of a changing climate and its consequent sustainability issues (Naumann et al., 2018). These challenges are complex, as they necessitate interactions between the environment, culture, society, and the techno-sphere (König, 2015).

Sustainability challenges and climate change related concerns, the most pressing issues of the 21st century, demand an urgent agenda to mobilize new ecologically and socially sensitive approaches to urban management and development, necessitating accelerated levels of innovation and more profound economic, behavioral, and political transformations (Bulkeley and Broto 2013, IPCC 2018, Naumann et al. 2018). Climate change associated risks will coalesce in cities, hence, substantial technological and societal transformations, dependent on regional and global development pathways, must be taken to reduce human vulnerability and exposure to the destructive effects of climate change (IPCC, 2018). Responsible for the greater proportion of total global resource consumption and carbon dioxide emissions, cities are at the frontlines of climate mitigation and sustainable development (Rosado et al. 2015, IPCC 2018) due to their potential to act more quickly than national governments, as there is a proliferating number of urban interventions and initiatives aiming to address sustainability challenges and climate change (Bulkeley and Broto, 2013). Effective urban management and development of the urban transportation sector alone has the potential to reduce greenhouse gas emissions by 20% to 50% (IPCC, 2018). Conceptions for transformation in human-environment interactions, that recognize conflict, uncertainty, complexity, and ignorance, are being developed and implemented (König, 2015).

Studies argue that the key to such transformations is to reform how new knowledge is co-created in urban collaborative processes (König, 2015). Combined objectives of engagement, research, and learning can play a significant role in the establishment of these processes. Collaboration in a co-creation environment is a driving force for accelerating sustainable actions amongst networks, companies, experience sharing, and management tools (IPCC, 2018). The functional significance of co-creation is that it generates transformative knowledge, imperative for the strategies and conditions to change disruptive unsustainable processes (Keyson et al., 2016). Co-creation enables practice-based innovation through proactive networking, addressing problems of varying complexity, and co-designing experiments. In response to the uncertainty of climate change, urbanization, and lack of immediate governmental action experienced over the past two decades, actors across various institutional scales have been willing to collaborate through urban activism, combining transdisciplinary knowledge to better address complex sustainability issues, arranging agreements, exploring possibilities and visions amongst participants (Bulkeley et al. 2012, Bulkeley et al. 2016, Puerari et al. 2018). Interdisciplinary partnerships can serve as a catalyst for widespread reform in numerous ways through the provision of transparency, accountability, expertise with complexity, procurement, and flexibility (Yescombe, 2011). Actors leading these self-organized initiatives are working to reorganize urban practices

(Cadag and Gaillard, 2012) via urban labs, a new phenomenon rapidly spreading amongst global cities.

Proliferating amongst European cities since 2006, urban labs are based on independent rules, norms, procedures, and principles, urban labs have transformed conceptualizations of governance for sustainable urban management and development (Okereke et al. 2009, ENoLL 2018). Urban labs serve as a new instrument utilized by various actors to develop a long-term objective, guide detailed transformation efforts, and to directly intervene and alter traditional decision-making systems through real-world testing, co-production of knowledge, and co-creation induced innovations (Rosado et al. 2015, Bulkeley et al. 2016). This ensures a response to particular environmental and societal issues in a given urban location. The quantitative metrics collected in urban labs can be transmuted to create data driven policy making, enhancing governance efficiency by steering investments, refining policy choices, evaluating municipal services, and measuring success rates of initiatives (McCarney et al., 2011). The placement of interdisciplinary actors in charge of formulating new sustainable pathways represents the practical dimension of enhancing sustainability capacity in an urban area. Through co-creation of knowledge, services innovations, products, and technologies, urban labs have transcended a government centered, territorial based form of governance, establishing a new site for experimental, inclusive governance (Okereke et al., 2009, Puerari et al. 2018). Therefore, analyzing the potential of urban lab characteristics to harbor higher levels of co-creation is a necessary step in the study of urban labs within the urban sustainability context.

1.2 Problem Statement

As complex systems, cities operate with emergent properties which can stem from interactions from within the system. Repercussions stemmed from sustainability issues occur on two levels, the first is on a planetary level (e.g. climate change, environmental degradation, food security) which interact and threaten the well-being of humans, the second is on a local level (e.g. environmentally problematic ageing infrastructure, urbanization, ecological degradation, local economic decline) (Trencher et al., 2013). There is an urgent need to mitigate sustainability issues, as urban populations are forecasted to mount to 75% by 2050 (Bakıcı et al., 2013). The roots of these sustainability issues are deeply embedded in social, technological, cultural, environmental, political, and economic fabrics, solutions beyond the capacity of local and central governments alone (Trencher et al., 2013).

European cities have rapidly taken up urban labs as new collaborative sites to challenge conventional unsustainable trajectories and contribute to urban sustainability through their outputs derived from co-creation activities. Trencher et al. (2013) presents an overview of initiatives that have successfully utilized co-creation for sustainability throughout Europe which have aimed to mobilize and disperse knowledge, transform and restore natural and built environments, and develop new socio-technical configurations through innovation and multi-actor learning. Cities, such as Barcelona, have utilized numerous urban labs as a tool for the co-creation of innovation in “real-world” environments, resulting in new train services, motorways, and infrastructures, optimized delivery of public services, and improvement in quality of life (Bakıcı et al., 2013). These urban labs have been employed to inspire the testing, development, and implementation of innovative urban sustainability solutions through the creation of new knowledge, technologies, services and infrastructures.

Due to the recent emergence of this phenomenon, there is a lack of empirical data on the urban lab concept (Ståhlbröst 2012, Lucassen et al. 2014, Voytenko et al. 2016). Its understudied aspects include: procedures and mechanisms of urban labs to initiate effective interventions that impact urban areas, theoretical underpinnings, and its ability to establish arenas for co-creative transformations (Puerari et al., 2018). Hence, there is increased difficulty in determining a full comprehensive understanding of urban lab success factors that could potentially be up-scaled or used in different contexts. This situation necessitates more research regarding co-creation to fulfill desired sustainable outcomes, the goal of methodology development, and to bring urban lab initiators benefits of consistency in structured knowledge creation and build awareness of crucial lessons and issues experienced for the success of each urban lab (Lucassen et al., 2014).

Without further research into the conditions necessary for harnessing high co-creation levels, management and performance of urban labs will be averted from their full potential to make significant impacts. If the characteristics that best optimize conditions for co-creative outputs can be identified, urban labs can foster high co-creation levels to be utilized as an effective and efficient mechanism for sustainable change in urban areas. Hence, assessments must be made on the performance of their characteristics. The influence of these characteristics on co-creation levels must be analyzed to indicate the most important aspect for co-creation optimization to further the understanding of knowledge generation, co-creation outcomes, and the improvement of current and future urban labs for urban sustainability.

1.3 Research Objective

This research aims to identify the most significant urban lab characteristic that contributes to the enhancement of co-creation levels in European urban labs through empirical findings and analysis of the most prominent characteristics, interrelated with the co-creation dynamics that occur within urban labs.

1.4 Research Question

Main Research Question:
What is the predominant urban lab characteristic for enhanced levels of co-creation in Europe?

Research Sub-questions:

1. *Do self-proclaimed urban labs in Europe have co-creation activities?*
2. *Do these urban labs have high, medium (upper), medium (lower), or low co-creation levels?*
3. *How can varying levels of co-creation be explained based on urban lab characteristics?*

1.5 Significance of Study

This study was conducted to further the understanding of co-creation level enhancement in urban labs and reviews the conception of urban labs as vehicles for co-creation, and how they can potentially be an effective mechanism and instrument for institutional and systemic change (Puerari et al., 2018). Realizing the urban lab conditions necessary for successful co-creation outcomes, this study can assist to bridge research gaps in the literature through

evaluating actions that can be enhanced for more effective and efficient outcomes (Voytenko et al. 2016). Therefore, an investigation into the identification of the most crucial urban lab characteristic is imperative.

Linked to other transdisciplinary knowledge, the empirical data deduced from this research can potentially provide enhancement in co-creation levels of urban labs in various contexts, and an overview of necessary improvements for a successful urban lab initiative and the critical issues that can influence success outcomes. A greater capacity to foster co-creation can facilitate discussions and the alignment of actions in decision making processes through strengthening engagement, collaboration, and empowerment of participants (Lane 2005, Balducci 2013). It can yield information to enhance the relationship between institutions that produce knowledge and users of that knowledge, facilitating urban lab objectives carried out through the stimulation of cross-disciplinary research. Therefore, co-creation enhancement can further support the desired sustainability transitions and projects of urban labs (Puerari et al. 2018).

Moreover, this study represents an important step the identification of the role of urban lab characteristics in forging co-creation within urban lab initiatives for sustainability. There is no consensus on which urban lab characteristic is predominant, the literature portrays that all characteristics are amongst the most important characteristics for co-creation success. Therefore, this study evaluates the performance of each urban lab characteristic, regarding its importance, through the collection of empirical data from urban labs throughout Europe. In addition, a holistic analysis framework for urban labs spanning across diverse European contexts can reveal significant insights on the effectiveness of co-creation from multidisciplinary perspectives. The analysis of individual urban lab initiator perspectives on urban lab characteristics and co-creation levels can contribute to the scientific literature and development of a more holistic understanding of the urban lab components that can enhance co-creation levels. A properly developed urban lab framework can promote reflections and improvements for future and current urban labs (Lambert and Allen, 2016). Adjustments can enhance co-creation outcomes for a higher chance of success in achieving goals and aims for urban sustainability.

1.6 Scope and Limitations

The research will focus on European self-proclaimed urban labs that aim to increase urban sustainability. This includes urban labs that identify as local, city-level, or regional.
The quantity of urban labs to be analyzed presents a limited scope. Not all urban labs throughout Europe will be reached, due to a lack of visibility or a lack of self-proclamation. The quantity of respondents, during the data collection, presents another scope limitation regarding the analysis of urban labs across Europe. The extent of limitation will be determined by the interest urban labs have in participating in the study, accessibility of contact information, and rate at which emails are checked. Possible language barriers can be encountered when attempting to communicate with urban lab initiators, from different countries, to retrieve data.

Time presents further limitations as the time period for data collection is limited to one month. Furthermore, the acquirability of valid data can affect the quality of the research. Another limitation is the scarcity of empirical information on the correlation between co-creation dynamics and urban lab characteristics. The analysis of co-creation dynamics in this study is specifically intended for urban lab research, due to the diverse application range and

the lack of methodology for co-creation dynamics analysis (Puerari et al., 2018). To draw absolute conclusions for all European urban labs, these findings alone are not sufficient. However, the data establishes a solid foundation to further build on the knowledge of this research topic. This warrants more research and empirical data to further develop an understanding of the requisites to foster high co-creation levels.

Chapter 2: Literature Review / Theory

This section provides an evaluation of the literature to expand the understanding of the interrelationship between the main urban lab characteristics and co-creation elements, and their relation to co-creation levels. Analyzation of the elements that constitute co-creation dynamics within urban labs contributes to further developing the knowledge on co-creation as a multi-actor process in urban labs that consist of experimentation and development of new actions, strategies, and agendas towards sustainable cities.

2.1 Urban Labs

The novel concept of urban labs, credited to William J. Mitchell of the MIT Media Lab (Puerari et al., 2018), first emerged in literature in the 1990s and were complementary to human-centered, participatory, and user-driven approaches to design challenges. The need for new settings and methods that enabled additional integration of the work of frontrunners, people investigating open innovation theory, necessitated the emergence of urban labs (Chesbrough, 2003). Devised to expand the process of innovation through the inclusion of diverse actors in interactive and direct intervention processes, urban labs became an ongoing trend throughout Europe (Quak et al., 2016). In November 2006, the implementation of the international federation of living labs in Europe, initiated by the Finnish European Presidency (ENoLL, 2018), sparked the uptake of urban labs in European cities to tackle climate change impacts and sustainability issues.

Urban lab research has recently expanded from contexts of private sector research and development or knowledge institutions to complex socio-spatial contexts (Marsh et al., 2013). The concept has gained attention due to the collaboration, experimentation, and outcomes that occur within the real-life settings and daily lives of participants (Schliwa and McCormick 2016). In this regard, urban labs are considered possible innovation triggers in the urban environment, as they significantly advance the production of local knowledge relevant to relational capital development (Capello and Faggian, 2005), important to experimentation constituting of new relationships, government arrangements and practices (Puerari et al. 2018). Hence, urban labs can stimulate reflective and inquisitive processes, triggered by experimentations, that can instigate individual and collective change, transmuting the results and feedback of the lab into a source of learning for systemic change and behavioral changes (Concilio and Molinari 2014, Lambert and Allen 2016). For example, the iSCAPE network of urban labs throughout Europe, funded by the European Union, addresses the sustainability issues of poor air quality and carbon emissions through behavioral changes of citizens and policy intervention, stimulated by projections and real-world setting interventions in select cities that will represent future climate change scenarios and represent a multitude of various lifestyles and cultures (iSCAPE, 2018). Regime scholars have become increasingly sanguine of these new initiatives led by actors other than central governments in steering sustainability progress (Keohane 2002, Portney 2013).

Comprehending the means through which urban labs are designed, executed, and take effect draws from innovation studies related to the concepts of strategic niche management and socio-technical transitions. Urban labs are intervening, instrumental and alternative forms of innovation which constitute a means by which sustainability in urban areas is governed, and public support and political traction is created (Bulkeley et al., 2015). Urban labs often focus on a particular location and can be considered niche innovations operationalized through protected test beds, where actors of small networks support new alternatives based on visions and expectations (Bulkeley and Broto 2013, Luederitz et al. 2017). Niche innovations enable learning processes and networks away from mainstream and external factors that may hinder its development. Their interaction with changing environmental factors, pressures, and preferences can cause existing regimes to enter a process of destabilization, internal crisis, and increased stress, inevitably initiating systemic reconfiguration (Loorbach et al., 2017). The changes originating from urban labs are valuable for pressuring existing regimes and groups of people, however, it has not yet proven to be capable of changing overall systems. Urban labs are future oriented, developing experimental solutions for the future, and are diverse in context yet similar in methodology. These initiatives can render the visions and discourses, concerning the future wellbeing of cities, governable and practical (Bulkeley and Broto, 2013).

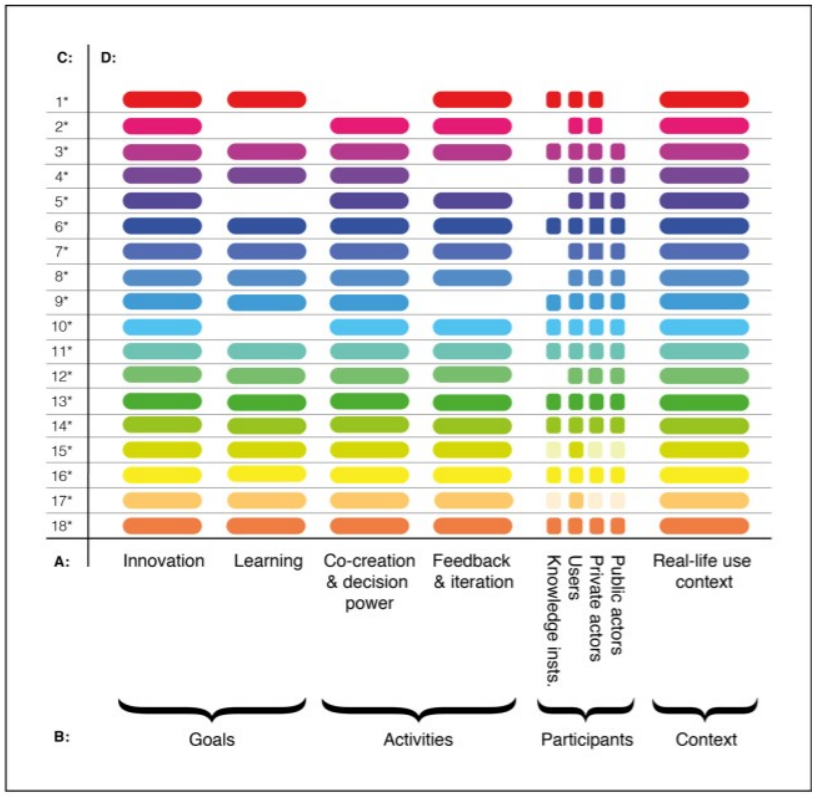
2.1.1 Definition

Research by Leminen (2015) identified 70 different definitions of the urban lab concept within existing literature, and concluded that titles of urban labs are used interchangeably and can be expressed with terms such as ‘living labbing’, ‘living laboratories’, ‘transition labs’, ‘social innovation labs’, ‘living labs’, ‘testing ground’, ‘hub’, and ‘field lab’ (McCormick and Kiss 2015, Steen and van Bueren 2017). There is no shared definition of urban labs, having been defined as a site, methodology, system, an organization, arena, and innovation approach (Følstad 2008, Bergvall-Kåreborn et al. 2009, McCormick and Hartmann 2017). However, they are usually conceptualized as the utilization of various methods and tools to co-create innovative solutions in a ‘real-world’ context with interacting participants that share experiences and set visions for the future (McCormick and Hartmann 2017, Elmqvist et al. 2018). This study will utilize this definition when referring to urban labs, as it fully encompasses the essential aspects.

The European Network of Living Labs (ENoLL), managed by the European Commission, has defined urban labs as ‘real-life’ research environments utilized to confront innovation challenges in various fields (Feurstein et al. 2008, Den Ouden 2016). They describe the main activities of urban labs to be co-creation, exploration, experimentation, and evaluation while the Dutch Institute for Sustainability Transitions (DRIFT) defines urban labs as “spatially embedded sites for the co-creation of knowledge and solutions by conducting local experiments,” (Puerari et al., 2018, pp. 1). These sites work as an arena for adaptive, multi-actor, reflexive learning environments, where novel infrastructures and self-organizing initiatives can be tested within a ‘real-world’ setting. Due to the diverse knowledge within the field of urban lab studies, it is difficult to find a common ground for the definition of the concept.

2.1.2 Main Characteristics

This study will refer to the framework developed by Steen and van Bueren (2017) to analyze the defining characteristics of urban labs. Steen and van Bueren (2017) concentrated on the four main aspects: aims, activities, participants, and context. This study aimed to improve conceptual clarity through an assessment of 90 sustainable innovation initiatives in Amsterdam. It was concluded that most projects labeled as urban labs did not consist of the defining characteristics of an urban lab. Specifically, development and co-creation activities were absent in a majority of these initiatives. This is due to the lack of consensus on a uniform definition of urban labs and their defining characteristics throughout the literature. Urban labs are comprised of different goals, actor, partnerships, and ways of working (Voytenko et al., 2016). The specific analysis of this research has resulted in an improved definition of urban labs and their characteristics, derived from the literature, along with methodological recommendations. An overview of the presence of the urban lab characteristics mentioned in definitions throughout the literature is presented in Figure 1.



A = Proposed defining characteristics of living labs
B = Dimensions applicable to the defining characteristics
C = The definitions of 'living lab' provided in literature
D = Presence of the proposed defining characteristics in the living lab definitions provided in literature

1*: William Mitchell (MIT), ca. 2003
2*: Niitamo, Kulkki, Eriksson & Hribernik, 2006
3*: Ballon, Pierson, & Delaere, 2005
4*: European Network of Living Labs, 2006
5*: Kusiak, 2007
6*: Schaffers, Cordoba, Hongisto, Kallai, Merz & Van Rensburg, 2007
7*: Almirall & Wareham, 2008
8*: Feurstein, Hesmer, Hribernik, Thoben & Schumacher, 2008
9*: Bergvall-Kåreborn & Ståhlbröst, 2009
10*: Westerlund & Leminen, 2011
11*: Higgins & Klein, 2011
12*: Pallot and Pawar, 2012
13*: Friedrich, Karlsson & Federley, 2013
14*: Leminen, 2015
15*: Franz, Tausz & Thiel, 2015C
16*: Voytenko, McCormick, Evans, & Schliwa, 2016
17*: Hakkarainen & Hyysalo, 2016
18*: GUST, 2016

Source: Steen and van Bueren, (2017, pp. 25)

Figure 1: Displays the overview of the suggested defining urban lab characteristics presented in the literature: aims, activities, participants, and context.

Figure 1 conveys the most prominent characteristics of urban labs exhibited in the literature. High levels of concurrence in the literature on the defining characteristics of urban labs has provided the framework at which this study will analyze the characteristics most influential to co-creation levels (Steen and van Bueren, 2017). The following sections will further elaborate on the definition and content of each characteristic.

Aims

Urban labs provide pathways to ensure ambitious changes through evidence-based interventions by the integration of innovation and research processes (Steen and van Bueren, 2017). The ultimate aim of urban labs is to learn, experiment, and innovate for the purpose of

increasing urban sustainability. The processes of learning and innovation derived from experimentation are fundamental to the function of urban labs.

Innovation

Innovation in urban labs refers to the discovery of new solutions for existing problems and the development of new products, such as a service, object, application, technology, or system. Diverse backgrounds constitute the ecosystems of urban labs, to co-create transdisciplinary and cross-sectoral innovations (Den Ouden et al., 2016). Experimentation is observed as a process of innovation, the innovation networks created by the urban labs emphasizes its distinct method of knowledge production, 'learning by doing' (Juujärvi and Pesso, 2013). Cultures of innovation are necessary when increasing urban sustainability in complex systems. The diversity within urban labs are valued because it enhances the possibility of radical and novel combinations. Any clash of interests and motivations between actors could lead to unexpected opportunities to generate new ideas to attract resources and achieve successful implementation (Den Ouden et al., 2016). The new technologies used by participants in urban labs enable them to quickly create and learn through experimentation. Political and financial support is mandatory in creating safe environments for safe-fail experimentation (Westley et al., 2011). Representing innovation and research processes within a private public partnership, urban labs can persuade government funding bodies and research organizations to be engaged in sustainable urban development, and address finance and knowledge gaps (Voytenko et al. 2016). However, it is possible for financial challenges to arise if an urban lab is considered too small to invest in (Juujärvi and Pesso, 2013).

Learning

Urban labs exhibit mode-2 knowledge production, where transdisciplinary teams unite in interaction-oriented processes to devise solutions to real world problems using scientific and experiential knowledge (Regeer and Bunders, 2009). The experimental feature of urban labs promotes the direct process of learning and innovation as an explicit result, rather than the side effect of a project, separating urban labs from other experimental projects (Bulkeley and Broto 2013). Experimentation and learning refers to knowledge production and exchange amongst participants (Cadag and Gaillard 2012, Pallot and Pawar 2012). Hence, urban labs also aim to recreate the innovation in a different location, advancing future innovation (Franz et al., 2015). Fostering innovative knowledge production, urban labs focus on the creation of knowledge in a learning arena (Evans and Karvonen, 2014). Effective learning is at the core of urban labs and requires the setting of clear aims, shared ambition, and frequent feedback and reflection on processes or results from all actors' perspectives (Ouden et al., 2016).

The extent and nature of learning can range from urban labs that perform reflexive and collective practices to those that collect data and are highly instrumented. Due to the complexity of urban labs, process outcomes can be difficult to predict due any unexpected changes in innovations, people, or challenges, which may result in new directions. The urban lab context enables first and second order learning (Luederitz et al., 2017). First order learning refers to modifications made to a process, making it more effective and efficient (Van de Kerkhof and Wieczorek 2005, Luederitz et al. 2017). When participants with diverse worldviews collaborate on an experiment, second order learning can occur. Critical for transformational change, second order learning refers to the development of new processes, and reinterpretation of the function and purpose of given activities (Van de Kerkhof and Wieczorek, 2005). Learning based on reflexivity refers to the iterative analysis of the experimental process and enables adoption processes to generate desired results. Participants benefit from reflection on their knowledge and learn from their involvement, enhancing the

efficiency and effectiveness of experimental processes (Lambert and Allen 2016, Luederitz et al. 2017, Ståhlbröst and Holst 2017). Data collection for monitoring and data-based policy formulation has been a challenge for cities, data and indicators created and monitored in urban labs can enhance the understanding of vulnerabilities stemming from ecological sustainability issues, shape policy, influence public behaviors and opinions, and set new priorities, thereby contributing to ecological rehabilitation and sustainability (McCarney et al. 2011, Archer et al. 2014). For example, a case study on the Apollon urban lab, by Ståhlbröst and Holst (2017), revealed that the involvement of users in innovation implementation and usage enhanced their understanding of the situation, which enabled behavioral changes through the attainment of new competencies. Participant commitment and confidence in the innovations enhance as they learn of the effectiveness of the innovation through actively participating in the experimentation process (Luederitz et al.,2017).

Successful learning processes between participants can form a pivotal yield for innovation, but it can be difficult to establish, even in the facilitating conditions of the lab setting, due to the many conflicts or unmet expectations that can arise from diverging interests (Naumann et al., 2018). Even though it is unlikely actors will have common perceptions of urban lab objectives, actor conflicts can provide important conditions for change, rather than convergence and alignment (Klijn and Koppenjan 2000, Markard et al. 2012). Long-term collaborative processes can be volatile and laborious, before effective learning can be executed in interactions, participants need to learn for that interaction and understand how to cater to the concerns of others (Hakkarainen and Hyysalo, 2013).

Urban Sustainability

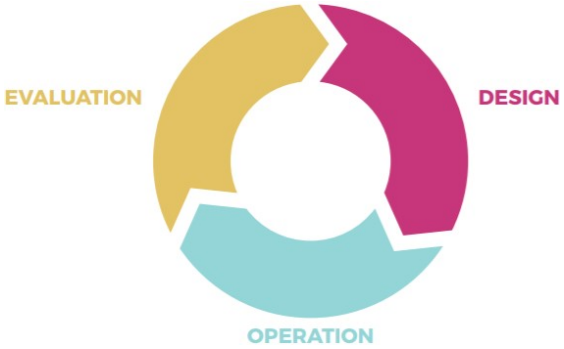
Cities make logical sites to engage in the complex, multifaceted, and ambitious task of sustainable action. They face unsustainable issues firsthand, concentrate future (and current) production and consumption, and serve as an operational unit to design, facilitate, and effectively carry out concrete actions (Nevens et al., 2013). Transitions needed for achieving urban sustainability revolve around the design, organization, and delivery in which systems of provision are carried out (Marvin, Bulkeley et al., 2018)., requiring the fusion of disciplinary boundaries and integrated knowledge. As a result, new effective and efficient technologies and infrastructures emerge, and shifts in practices, policies, markets and culture are mandatory.

Traditionally urban sustainability was pre-given to urban planners through processes of public consultation and environmental assessments, however, urban labs engage an incremental, interventionist, learning by doing approach where sustainability is emergent (Van de Kerkhof and Wieczorek 2005, Bulkeley et al. 2016). These learning processes contribute to the emergent experimental process of responding to sustainability issues and can be realized through forms of ongoing participant engagement and consultation or through data control and management systems and 'smart' applications (Bulkeley et al., 2016). Information technology can advance evidence-based policy making through quantitative performance metrics, therefore, urban labs can be utilized to inform investment decisions, refine policy choices, and measure success rates of implementation. The development of indicators for urban sustainability challenges can encourage more transparent and open urban governance, promote civic engagement, and aid decision-making in different levels to foster democracy, local information, and empowerment (McCarney et al. 2011, Yescombe 2011). Inclusion in these processes empowers citizens through community building, decision-making processes, learning with knowledge institutions and sharing experiences with stakeholders in real-life contexts. The degree of exposure of intellectual property rights to the

public can directly affect a city's contribution to sustainability through changes in social realms, such as, values, opinions, behaviors, norms, priorities, discourses, decision making processes and policies (Hezri and Dovers 2006, Veeckman et al. 2013, Luederitz et al. 2017). The lack of sustainable achievement in urban management and development practices demonstrates the need for innovative initiatives to intervene in the sustainable transitions of cities (Steen and Van Bueren, 2017).

Activities

Urban lab activities are comprised of the development of an artifact, co-creation, and iteration. Development of products are diverse and can range from process innovations to testing and implementation (Budweg et al. 2011, Coenen et al. 2014, Gray et al. 2014, Leminen 2015). Co-creation is a crucial component of the development process, the essence of the urban lab is that it applies a user centric process to realize solutions, rather than only involving the user to test a fixed solution that has been applied (Gómez-Barroso et al. 2009, Franz et al., 2015). Co-creation is recognized by the involvement of users in different development phases of the urban lab process: design, operation, and evaluation (Figure 2) (Prahalad and Ramaswamy 2004, McCormick and Hartmann 2017).



Source: McCormick and Hartmann, (2017, pp. 16)

Figure 2: Displays the design, operation, and evaluation stages that constitute the development phases of the urban lab process.

Inclusion of participants throughout the development process sustains the reflexivity exhibited by urban labs. The user-centric experimentation platform provides favorable circumstances for learning and unexpected discoveries, further distinguishing urban labs from other forms of urban experimentation. Co-created by users, urban labs enable actors to learn and gain experience by testing ideas and co-developing new skills and knowledge explicitly utilized to inform processes of forging urban sustainability (Karvonen and van Heur 2014, Evans et al. 2015, Voytenko et al. 2016). Important for successful concerted action, awareness is raised, for example, conflicts of interests, mutual dependencies, risks, and interaction costs (Klijn and Koppenjan, 2000). Users are more inclined to change beliefs or behaviors with new knowledge, especially if they have been included in the production and use of new knowledge. Moreover, the development process is iterative, subject to constant change as it is evaluated by participants after it is designed (Klijn and Koppenjan, 2000). In ideal circumstances, technical infrastructure for co-creating and assessing innovations should be available for participants to monitor the technical performance of the urban lab throughout the non-usage and usage of the innovation (Veeckman et al., 2013).

Recorded observations in urban lab experimentation enable an iterative process through continuous adjustments to the local context, keeping them in constant evolution. Evaluation of impact and actions underpins the urban lab's capacity to facilitate formalized learning (McCormick and Hartmann, 2017). Analyzing actions, data, impacts, and feedback by participants, is critical to enable the refinement of visions and goals over time (Pallot and Pawar, 2012). The results and feedback of these activities can reconstruct the perception of sustainability issues in the public realm as they are transformed into a source for learning for systemic change. Learning from exposure of information can result in direct behavioral changes towards sustainable action if embedded in the institutions, practices, and thoughts of participants (McCarney et al., 2011). Therefore, activities can be valuable for pressuring existing regimes. Urban labs challenge, reinterpret, and enhance urban governance, improving the process at which sustainability issues are addressed.

Participation

Not only are urban labs test beds, but they transform users into active co-creators of innovative concepts, giving opportunities to embed complex ideas in real-life settings, stimulating interactions, reducing innovation failures, and creating institutional support (Hakkarainen and Hyysalo, 2013). Urban labs take the concept of citizen involvement one step further, where an equitable collaboration environment is created, branching from the conventional top-down citizen inclusion strategies. The user-centric engagement process builds on the perspective of people having the democratic right to influence decisions that may affect them through new innovations, as all relevant stakeholders are included in experimentation and innovation processes (Archer et al. 2014, Ståhlbröst and Holst 2017).

Participants of the lab are viewed as competent, active domain experts and partners. Their influence and involvement in the development and innovation processes for sustainability is crucial (Luederitz et al., 2017). Expertise includes professional skills and techniques to devise, research, judge, and guide experimentation. Furthermore, expertise refers to the reflexive ability and capacity to learn from the experiment and provide knowledge on issues of transparency, ethics, and power relations (Lambert and Allen, 2016). Equally essential is to realize urban labs consist of a heterogeneous group and its processes should be based on participant's needs. The involvement of various stakeholders can improve the innovation process and quality of the development outcome with diverse ideas (Ståhlbröst 2012, Archer et al., 2014).

Literature has portrayed participation to be amongst the predominant elements for a successful performance of an urban lab (Feurstein et al. 2008, Cadag and Gaillard 2012). The diversity of the platform unites entrepreneurs, businesses, governments, academics, and citizens who can co-create, promote, and identify sustainable transformative innovations and link them to financial, cultural, and social capital to secure institutional durability, scale, and impact (Westley et al., 2011). The sustainability challenges cities currently face are too great to solve by individual organizations in isolation (Archer et al. 2014, Den Ouden et al. 2016). New partnerships forged between interdisciplinary sectors and civil society can support data collection of reliable, high-quality data relevant to the completion of their goals (IPCC, 2018), and create a synergy between actors for information sharing, knowledge co-production, and innovation. This key feature of urban labs is represented by the quadruple helix model of partnership where knowledge institutes, government, private actors, public institutions, and citizens work together to create innovative solutions (Voytenko et al. 2016, Steen and van Bueren 2017). Stemming from the efficient, multi-stakeholder concept of

collaborative planning, this aspect of urban labs addresses the quality of life through the integration of environmental, economic, social, and physical dimensions (Healey, 1998).

Due to context specific settings and actors, user role is a component responsible for the distinction of each lab disposition. Urban labs connect actors from diverse disciplines and sectors who complement each other with a variety of competences, skills, knowledge, political influence, and financial resources (Yescombe 2011, McCormick and Hartmann 2017). For example, the private sector excels in providing expertise in the management and maintenance of complex projects, therefore, delivering them on budget and on time, and maintaining services (Yescombe, 2011), while government involvement in policy change encourages investments and supports collaboration amongst actors that demand change (IPCC, 2018). Contradictions amongst actors can arise in participatory settings, therefore, differentiation of methodology and interactions are recommended to accommodate to the interests and backgrounds of participating stakeholders (Voytenko et al. 2016). However, the challenges encompassed in participation processes have the potential to result in tradeoffs and new inclusive priorities (Niitamo et al., 2006), thus, urban labs can become a means to collectively pursue successful ambitious goals.

Urban labs often include university led partnerships, emphasizing the aim of prioritizing formal knowledge production (Bulkeley et al., 2016), while the involvement of the private sector can enable the urban lab to gain traction, as they are tightly correlated to service deliveries and urban management and development practices (McCarney et al., 2011). Impacts from sustainability issues can be altered by the assessment of local conditions by local communities and by the utilization of local capacity to foster change and discussions to integrate top-down and bottom-up actions for confronting sustainability issues (Cadag and Gaillard, 2012). Local knowledge is invaluable in understanding means of protection for sustainable livelihood and informing scientific knowledge. When government authorities, urban planners, and scientists ignore local knowledge, the blending of knowledge with sustainable action can prove to be difficult (Cadag and Gaillard 2012, Lambert and Allen 2016). Community groups can hold various levels of governments accountable and represent marginalized groups, deepening the relationship between the government and civil society, enhancing negotiation capacity for just processes and outcomes, and facilitating the realization of sustainability goals (McCarney et al. 2011, Yescombe 2011, Cadag and Gaillard 2012, Lambert and Allen 2016, Luederitz et al. 2017). The inclusive dimension of participation can facilitate the restoration of public confidence and the legitimacy of governments with a skeptical civil society (McCarney et al., 2011).

Veeckman et al. (2013) asserts that establishing a sense of community is crucial for active participation. This can be done through frequent communication, such as, sharing results, mailing bi-monthly newsletters, or sharing pictures of the projects. The multi-contextual sphere aspect of its user-centric methodologies directly involves actors in the development process of urban labs (Feurstein et al. 2008, Steen and van Bueren 2017), utilizing unique perspectives and knowledge backgrounds to create opportunities for improving specific urban areas or service operations. Urban labs serve as a new form of practice that can potentially reform institutional procedures, effectively harnessing a culture of inclusiveness, essential for successful sustainability action in cities (McCarney et al., 2011). However, there are still major research gaps in the literature concerning the multiple roles of actors in urban labs, due to the recent development of this phenomenon, this aspect needs to be scrutinized in future studies.

Context

Urban labs are commonly bound to specific geographical areas, situated in a real urban context, as the experimental setting where conventional ways of organization and connection are questioned to deal with sustainability issues. The contextual space of the urban labs serves as a core advantage as a "real-life" use context, reducing limitations such as space or time, where co-creation, development, experimentation, and evaluation occurs outside of a laboratory setting (Mulder 2012, Veeckman et al. 2013).

Geographic configurations able to host an urban lab consists of either a region, agglomeration, city, district, neighborhood, road, corridor, or building (Bulkeley et al. 2015, Voytenko et al. 2016). The geographic aspect is important for the empowerment of discrete actors to challenge sustainability issues and monitor outcomes and effects of the experimental lab. Local scales, at which urban labs proliferate, territorialize urban innovation at a manageable scale and enhance accountability and trust between participants (Yescombe 2011, Archer et al. 2014). Trust makes collaborative experiments and the joint addressing of difficult challenges possible through the mutual willingness to reconcile divergent worldviews, collaborate truthfully on equal terms, and acknowledge different interests (Luederitz et al., 2017). Engendering trust among participants is important to build confidence in the potential output of the experiment because experiments can be susceptible to failure (Cadag and Gaillard, 2012). Projects, constituting the core of urban labs, are context specific and enable stakeholders to develop local solutions. Successful solutions in certain contexts may not be applicable to other contexts, therefore, it is important to identify ways solutions can be scaled-up through using similar structures and different scenarios, services, and settings (Den Ouden et al., 2016). An area of inquiry that has yet to be systematically analyzed is the degree to which urban labs can be upscaled and applied to wider geographic areas (Bulkeley et al., 2016). Impacts of sustainability initiatives can also be monitored on local scales, providing transparency on service performance. If an abundance of data is harvested by urban labs, it can facilitate the creation of sustainability indicators unique to the city, enabling the evaluation of sustainability performance. Assessment of documentation of actions, impacts, and data can also be utilized to identify research gaps of urban labs and refine goals and visions over time.

In practice, the "real-life" context reflects the multi-contextuality and complexity of the natural environment to the fullest extent. It is contested whether urban labs are limited to physical settings or can also exist in virtual realities (Feurstein et al. 2008, Leminen 2015). The literature indicates that the 'real-life' environment in which urban labs take place are a defining characteristic (Steen and van Bueren 2017). The increased use of urban labs has emphasized the desire and need of participants to holistically include the "real-life" environment, with its complexities and uncontrolled conditions, in experiments to create transformative, valuable knowledge (Evans and Karvonen, 2014). Participants provide feedback (on potential design improvements, thoughts on innovations, etc.) based on their true use experiences (Ståhlbröst and Holst, 2017). Previous research, by Yoo (2010), deducted that users have difficulty providing innovation feedback without the experience of using it. Therefore, to acquire deep insights and an understanding of "real-life" experiences, the approach of urban labs is useful (Ståhlbröst and Holst, 2017).

2.2 Co-Creation in Urban Labs

Co-creation is an activity that occurs within the umbrella concept of co-production, in which lay, and state actors work together to create benefits (Nesti, 2018). Co-creation is generally

defined as the action of making value with two or more actors, however, the literature recognizes co-creation as a process that stimulates mutual value creation and enables creativity and innovative solutions by linking multiple streams of knowledge through partnership interactions (Tanev et al. 2011, Veeckman et al. 2013, Puerari et al. 2018). Haukipuro et al. (2018) further elaborate on the concept of co-creation, stating that this process is where the creativity of citizens and that of interdisciplinary experts are conjoined to realize effective and meaningful change processes. The concept of co-creation is presumed to be capable of reforming the public sector through its positive effects. Used in diverse application settings (sectors such as public management, innovation, transition studies, design, regional planning, and urban planning), the understanding of co-creation elements is differentiated (Puerari et al., 2018).

In the urban lab context, meaningful innovative solutions developed by diverse actors creates value amongst participants (Den Ouden et al., 2016). Co-creation contributes to the maintenance of reflexivity and can render opportunities for participants, through ongoing interactions, iterative cycles of implementation, testing, development, and research (Keyson et al., 2016). Co-creation by public institutions, community actors, the private sector and research organizations, enable actors to learn and gain experience by testing ideas and co-developing new skills and knowledge explicitly utilized to inform processes of forging urban sustainability (Karvonen and van Heur 2014, Evans et al. 2015, Voytenko et al. 2016, Bulkeley et al. 2016).

A study conducted by Puerari et al. (2018) provides a clear overview, derived from a comprehensive literature review, of the five most common elements of co-creation fostered in urban labs: purpose of co-creation, degree of informality, ownership of co-creation process, motivations and incentives for co-creation, and element of places and spaces for co-creation. The following section will provide an overview of the co-creation elements and the urban lab characteristics they can potentially be fostered by.

2.2.1 Purpose of Co-Creation

Urban labs foster a participatory urban planning context, where communication, debates, arguments, and engagement in discourse are fundamental to define possible actions and align attention (Forester, 1988). In this setting, co-creation will usually have one or both of two purposes. The first is to *make* something, which constitutes as a situation where actors work towards an output or product, process innovation, or service. Often, when *making* is the primary purpose, the goal is to innovate for specific outcomes that also meet the needs of participants, generating value creation (Prahalad and Ramaswamy 2004, Puerari et al. 2018). Value is the experienced difference between the sacrifices and benefits of using a service (Ståhlbröst, 2012). Value creation is important for the attraction, retainment, and long-term engagement of participants (Veeckman et al., 2013). The second purpose is to learn, which constitutes as a situation where actors collaborate together to create networks, learn, and build knowledge. In this case, co-creation prioritizes the creation of knowledge and innovation. Frequently, both purposes are sought after, though usually one is further developed.

Relation to Urban Lab Characteristics

The purpose of co-creation plays a role in the determination of methods and techniques used in the urban lab. Different methods such as prototyping, surveys, future workshops,

evaluation, and tests combined with a variety of techniques such as scenarios, interviews, and mock-up serve as a foundation for the generation of ideas and render them tangible in a 'real-life' context through usage (Eriksson and Svensson, 2009). Eriksson and Svensson (2009) found that the purpose of co-creation can also be determined by participation, specifically, the degree of user involvement, whether it is decision, information, or creation. The decision degree of user involvement is easiest to apply to methods and techniques, such as surveys or evaluations, that are less resource dependent, straight forward, and ask questions regarding preferences of designs or use behavior. The information degree requires a higher amount of resources, and generates a rich set of data through diaries, observations, and interviews. These two degrees correlate with the intentions to generate knowledge and learn through co-creation processes. The creation degree correlates with the purpose of making something through co-creation processes. It is challenging to incorporate in technique and methods and usually require resources for prototyping methods or future workshops. If successful, the co-creation activities generated with this degree of user involvement can guide and inform design decisions made in the operation phase.

Purpose provides a link between knowledge production and learning, hence, clarity of the goals sought by the urban lab and the implementation of experimental trials in protected spaces that allow successes and failures enable actors to surpass business as usual interactions and presents unique opportunities to further the urban lab's level of co-creation. This can foster different forms of empowerment, a means by which existing regimes can be stretched and reformed (Smith and Raven, 2012). In traditional urban management and development, empowerment and participation were goals to be obtained, rather than a procedure to be utilized (Lane, 2005). Current socio-technical systems exist within stable regimes due to path dependency, entrapment, and lock-in processes (Schot and Geels 2008, Grin et al. 2010, Markard et al. 2012) hence, innovative initiatives may encounter limitations when confronted with stable regimes. Therefore, the aims of the urban lab and the methods at which urban labs determine visions, forms of learning, networks, and expectations may significantly impact the outcome and potential for successful sustainability initiatives. A posed challenge for the aim and participation characteristics of urban labs is the usage of proper techniques and methods that delivers the information or data necessary for certain innovation processes (Eriksson and Svensson 2009).

The consideration of context research before the development of the urban lab can also influence its purpose due to the importance of contextual understanding, of the environmental setting, for deep comprehension of the subject to be focused on (Baxter and Jack 2008, Veeckman et al. 2013). All labs are specific to each site and heterogenous (Evans and Karvonen, 2014). Contextual framework factors in a particular location and time contribute to the variations in urban lab design, knowledge production, and innovation outcomes (Jordan and Lenschow 2009, Mulder 2012).

2.2.2 Degree of Informality

This dynamic relates to the complexity of city systems in which the organizational level is beyond direct control, to varying degrees (Roo and Boelens 2014, Boelens and Roo 2014). Its characteristics are emergent, unintentionally manifested by self-organization processes. Hence, these processes induce unplanned co-creation and interaction through unplanned action. Therefore, there will always be a degree of informality in urban co-creation processes (Moroni, 2015).

Formal co-creation processes are commonly characterized by pre-defined timing, participants, audiences, and procedural steps (Puerari et al., 2018). Deliberately structured by facilitators, these processes often encompass selected participation forms, where actors considered valuable to the co-creation process are chosen to participate (Von Hippel 2005, Seybold 2006). However, this selection process requires additional effort to distinguish the appropriate stakeholders (Healey, 2002).

Informal co-creation processes refer to emergent collaborations with shared goals or a need for group collaboration. These processes are non-selected and characterized by short-term engagement and less official planning strategies that develop over time (Puerari et al., 2018). Non-selected participation encompasses a broad sample of actors, requiring less effort in determining actor selection, as it identifies everyone as possible valuable stakeholders for co-creation activities (Manzini 2005, Sanders and Stappers 2008).

Relation to Urban Lab Characteristics

Degree of informality relates to the participants and activities characteristic of urban labs, through its development and structure. Forms of informal and formal co-creation processes are indicated by selected and non-selected participation forms and participant engagement intensity, ranging from short-term engagement to heavy engagement (Fisher et al., 2015). Puerari et al. (2018) categorized urban lab participants into three main groups: core, inner circle, and outer circle. The initiators represent the core group which handles legal responsibilities within the organization of the urban lab. The inner circle is occupied by dedicated members that have an active role in the organization of the lab and are usually formally invited by the core group as experts, entrepreneurs, or users in different settings of the lab, such as an advice group or workshop participants (Von Hippel, 2005). These actors may have specific formal and legal responsibilities within the urban lab. The outer circle holds the form of informal co-creation and is constituted by actors not officially or strongly connected to the urban lab, such as visitors of the lab, institutions imperative to an experiment's survival, or open event participants. However, not all participants of the informal co-creation process are motivated to engage in urban lab activities since they were not specifically chosen for determined ideas, motivations, or shared values (Evers and Laville 2004, Moulaert et al. 2010). Engagement of these three groups to the same extent has proven difficult. Scholars have recently debated the co-creation potential of frontrunners and lead users (Manzini 2005, Sanders and Stappers 2008). In regard to this debate, Puerari et al. (2018) has shown these actors to be in the core group of urban labs, and occasionally the inner circle. Therefore, participants could limit potential outputs of urban labs due to their motivations, whether or not there is more drive from self-interests or moral obligation (Naustdalslid, 2011). Hence, informal processes may require the acquisition of stimuli to motivate and engage stakeholders.

The co-production of knowledge between the users is indispensable when working on a solution that requires change in behavior of actors. Knowledge generated by a higher degree of engagement within the urban lab can bring about transformative changes to actor behaviors and co-creation processes, this emphasizes the importance of long-term commitment. Engagement, collaboration, and interdisciplinary interaction must be encouraged to enable support and experimentation. These factors are imperative to identifying stakeholder goals and defining the needs, visions, design, planning, implementation, evaluation, and refinement procedures to be used in the urban lab (Voytenko et al. 2016, McCormick and Hartmann 2017). If actors do not participate in interactions, it is likely that their preferences and interests are not fulfilled (Klijn and Koppenjan, 2000).

Participation can significantly influence co-creation outcomes through the various methods used to identify these factors.

2.2.3 Ownership of Co-Creation Process

Effective coordination and management roles of co-creation processes have a delicate balance between controlling and steering, urban labs must be kept flexible for inclusive stakeholder involvement and development direction (Eriksson and Svensson 2009, McCormick and Hartmann 2017). This necessitates certain skills such as, presenting proper tools at the proper moment, defining roles, and stepping in and out of roles (Mattelmäki and Visser, 2011). Consensus and dynamics of a user group is sensitive and can be easily influenced by any individual member of the group (Eriksson and Svensson, 2009), therefore, pressure is placed on the facilitator to balance participation, so all members can be heard and included in discussions. The variety of co-creation models in the literature infers that ownership is a complex dynamic of co-creation when applied to the unique contexts of urban labs and requires nuanced understandings (Voytenko et al. 2016). Clarity on ownership and emphasis on the balance between controlling and steering is critical for successful co-creation outcomes.

Relation to Urban Lab Characteristics

Urban labs are unique in the way they are flexible to numerous interests and ideas to achieve collective results, however, a practical challenge faced by urban labs is the inclusion of all participants and accounting for their interests (McCormick and Hartmann, 2017). Success in fostering ownership can facilitate in understanding social fabrics, identifying the needs of citizens, informing design concepts, generating ideas, and providing insights (Mudler, 2012). Clarity on aims and incentives can benefit the community aspect of urban labs, through alignment of shared motivations for collaboration and increased engagement (Veeckman et al., 2013).

The techniques and methods utilized in the lab can affect the extent to which the facilitator can provide a creative environment (Eriksson and Svensson, 2009). Shared and open ownership for the full duration of the urban lab process enables the lab to remain flexible to various interests and ideas to create collective innovative outcomes and redevelop itself to link to knowledge and action (Campos et al. 2016, McCormick and Hartmann 2017). More actors would be willing to engage with other participants, disseminating knowledge and creating knowledge networks between the public, businesses, interest groups, and researchers, further enabling co-creation for developing solutions to sustainability issues within their environment (Keyson et al., 2016). However, deliberation will be necessary to develop consensus on co-creation process procedures (Bäcklund and Mäntysalo 2010, Robertson and Choi 2012). This requires extra steps, in the aim, participation, and activity aspect of urban labs, to discuss individual perceptions of co-creation and more time to align any different views (Voytenko et al. 2015).

It is possible that consistent work with various degrees of user involvement can be proven difficult to sustain throughout different innovation phases to secure the development of functional services or products (Eriksson and Svensson 2009). Urban labs can re-politicize urban management and development, rather than strictly being a scientifically determined mode of governance or corporate led (Evans and Karvonen 2014, McCormick and Hartmann 2017). Actions and results of urban labs have the potential to be restricted due to battles for power within participatory settings or preferences of more powerful actors, if power

distribution is not regulated to the fullest extent. The lack of trust or conflict regulating mechanisms makes it difficult to prevent non-cooperative outcomes or exploitative behavior (Klijn and Koppenjan 2000, Lambert and Allen 2016). Usually in cases where there is no openness, there is no creation value for participants, and stakeholders are reluctant to share agendas or results. Openness is critical in urban labs because it enables the combination of different perspectives to achieve rapid progress, strengthening the development process. However, more research is needed on the extent to which openness is beneficial (Ståhlbröst, 2012).

2.2.4 Motivation and Incentives

The motivation and incentive for participants to be involved and contribute in the co-creation process can be influenced by several factors. The comparison of costs and benefits can affect the engagement of a participant in the co-creation process. Another factor is related to their resources, expected value of outputs, and goals (Vivek et al., 2012). This also includes cultural, social, psychological, monetary, and technical factors that have the capacity to effect motivations (Zwass 2010, Füller et al. 2008). Puerari et al. (2018) explain the difference between extrinsic and intrinsic motivation, an important distinction in identifying motivation. Extrinsic motivation is initiated by an intention to avoid an unwanted outcome or acquire a desired outcome. This is commonly linked to external incentives apart from the co-creation activity itself, such as recognition amongst others or monetary compensation. In contrast, intrinsic motivation is the engagement in an activity for the benefit of oneself, with no apparent external stimuli. High intrinsic motivation can indicate a sense of community where participants were interested in making a valuable contribution to the urban lab innovations (Veeckman et al., 2013).

Relation to Urban Lab Characteristics

It is emphasized in the literature that motivation, commitment to long-term development, and strategic leadership are essential for successful urban labs (Juujärvi and Pesso, 2013).

Apart from representatives from diverse sectors of society and professional backgrounds, representatives with innovative and unorthodox viewpoints and opinions should play an active role throughout the urban lab process. However, a heterogenous group of motivated and engaged participants that complement one another is difficult to identify (Eriksson and Svensson 2009). A heterogenous, dedicated group of participants can improve results of co-creation activities and maximize learning opportunities, hence, urban lab outcomes, although a small degree of homogeneity is necessary amongst participants to provide a common ground for action and discussion (Van de Kerkhof and Wieczorek 2005, Eriksson and Svensson 2009). Therefore, it is important to identify these participants and support them throughout co-creation processes to keep them motivated. Overcoming sustainability conflicts requires engaged communities, stakeholders, municipalities, and interdisciplinary coordination and collaboration across the city.

In the co-creation process, the clarity of incentives can range from clear amongst all participants, to unequal and unclear for all participants. The policy-making area acknowledges this as a plurality of interests. When benefits and interests are identified by plurality (especially those that are extrinsic), there can be increased difficulty in motivating groups where interests of participants are unclear. For example, when there is no shared ownership, when co-creation is a form of feedback, or there is no direct change for participants (Puerari et al., 2018). Frequently, in these cases, facilitators offer to lower the participation threshold or provide compensation. An understanding of participant's

motivations can facilitate the process of value creation, and therefore, the innovation that occurs within the urban lab (Ståhlbröst, 2012).

2.2.5 Space and Place

Co-creation always takes place in socio-spatial contexts and is closely related to place-based innovation literature. The concept of place-based innovation is linked to literature on policy innovation and regional development, it is also linked to industrial cluster and districts development (Asheim et al. 2008, Tuuli 2012). The relationship between space and innovation has been utilized for analysis of the particular conditions from which innovation emerges.

Proximity has been determined to be a significant condition which facilitates the access and interaction of participants that supply innovative resources and ideas (Kilpatrick and Wilson, 2013). Places and spaces can serve as catalysts for innovation and interactive learning (Caniëls and Bosch, 2011). Place-based innovation have been affirmed to lead to an uptake of ideas emerged as behavioral guidelines and resources from and by situated innovation communities (Concilio and Molinari, 2015). An imperative condition for fundamental change is mental and physical space for experimenting and learning. Places and spaces enable visionary collaboration for learning and making with others through co-creation activities (Brundiers et al., 2010). They facilitate collaborating actors to deliberately and systematically investigate solutions across various sectoral boundaries, constituting direct interventions within socio-spatial contexts (Puerari et al., 2018). Influencing socio-spatial settings, places and spaces of co-creation can create visibility for local sustainability problems, provide meeting spaces, or become vehicles for innovation in urban management and development practices (Scholl and Kemp, 2016).

Relation to Urban Lab Characteristics

Urban labs can increase the visibility and functionality of sustainable innovations. This is accomplished through the testing and demonstration of new technologies, policies, and solutions in 'real-life' contextual settings. Through workshops, urban labs can show various target groups how the future impacts their daily lives or work and provide insights into changes of lifestyles and business arenas. (Den Ouden et al., 2016). This extends the labs reach and can expand relevant network connections, such as opportunities for financial support, participation, and innovation (Niitamo et al., 2006). High visibility of urban lab initiatives is critical for fostering long-term innovation processes and highlights the research, range of disciplines, and can evoke radical technical and societal transformation.

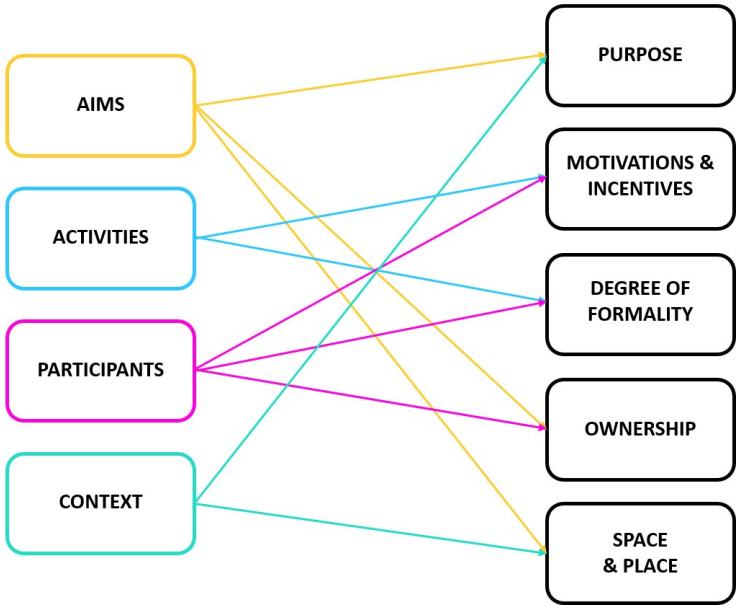
The context of urban labs may limit co-creation depending on whether they are based in newly built or already existing urban areas. In newly built areas, research opportunities are provided, novel infrastructure is developed, and innovation is co-created with engaged actors (Hebbert and Jankovic 2013, Juujärvi and Pesso 2013). In existing urban areas, urban labs have the potential to be a mechanism to disrupt strong path dependencies and lock-ins observed in the domains of which sustainability issues exist in (Markard et al., 2012).

Aims and context can alter place-based innovation acquired from proximity. Continuous participation and co-design throughout the lab process is utilized as vehicles for decision-making and gaining insights. This enables participants to generate distinct, unexpected knowledge and exposes intricacies of political and planning processes, and strongly considers context specific challenges (Campos et al., 2016). A challenge identified stemming from the

context characteristic is the ability to increase user involvement from their real-life environments, this necessitates the translation of techniques and methods to function in a distributed manner over the internet (Eriksson and Svensson 2009).

Overview: Correlation to Urban Lab Characteristics

Together, these elements interrelate and are affected by urban lab characteristics, affecting the overall dynamics and outcomes of the urban lab process.



Source: Researcher's own adaption of principles and concepts

Figure 3: A visualization of the interrelationships between urban lab characteristics and the co-creation elements they have the potential to influence.

2.3 Co-Creation Levels

Co-creation is the key element of the urban lab process, the development of new products, services, systems, and processes within urban labs are utilized to employ people as co-creators to examine, explore, test, and evaluate novel ideas, systems, scenarios, services, and creative solutions in complex 'real life' contexts. The employment of co-creation in urban labs broadens engagement, empowerment, and collaboration of citizens. Co-creation is significant for the alignment of ideas and definitions, and to facilitate discussions about possible actions in decision making processes (Lane, 2005). Hence, the optimization of urban lab characteristics, to foster co-creation, can positively affect co-creation levels, ultimately improving the outcome of the urban lab.

This section in the literature review aims to provide information regarding the third research question, "How can varying levels of co-creation be explained based on urban lab characteristics?". Derived from previous studies reviewed in the previous section, Puerari et al. (2018) and Eriksson and Svensson (2009), a framework was devised to explicitly identify the qualities of urban lab characteristics. These studies classified co-creation levels as intense,

active, and passive. However, in this study, this classification will be altered to include four co-creation level classification types: high, medium (upper), medium (lower), and low. The quality and composition of urban lab characteristics, assessed and cross referenced to co-creation elements in the literature review, were categorized into these three groups to signify what each level of co-creation encompasses. This is important for the development of future urban sustainability initiatives that cultivate co-creation strategies in interdisciplinary arenas.

2.3.1 Classification of Co-Creation Levels

In this study, the conceptualization of high co-creation levels in urban labs is identified as the containment of specific co-creation elements that have the most positive effects on co-creation outcomes and can be fostered within the urban lab characteristics, as presented in previous sections. Co-creation in urban labs can be shaped by the kinds of competencies and knowledge prioritized, and the outcomes and impact realized by initiatives (McCormick and Hartmann, 2017).

Co-creation level is classified as high when the core group of the urban lab consists of the initiators and driving participants of the co-creation process, capable of involving participants from the inner or outer circle, reach their target of co-creation that has been successfully implemented, evaluated, improved and replicated in different locations to be used over time. Intense links, sense of community, and connections are required in the participation aspect of the lab for actors to stay motivated and effectively draw on each other's resources, knowledge, and capacities (Veeckman et al., 2013). Long-term processes can lead to enhanced co-creation level due to the interaction of participants increasing networks, trust, relationships, and knowledge of expectation and needs (Tanev et al., 2011). The literature also depicted place and space to have an important role in the stimulation of co-creation processes. The transformation of buildings into symbols for sustainable innovation creates an engaging platform to encourage co-creation. High visibility of an urban lab can trigger a broader audience reach, which can attract activities and support beyond the vision and purpose of the urban lab, catalyzing the uptake of innovative sustainable solutions amongst users (Luederitz et al. 2017, McCormick and Hartmann 2017). The recognition held, by place and space, for innovative processes can further urge participants to learn more about co-creation processes within the context of the urban lab. Physical artifacts produced by co-creation activities have the potential to inspire and serve as a demonstration site for initiating further co-creation activities. Therefore, context dependency is not a barrier to the diffusion or upscale of innovative outcomes. Niche urban labs have the potential to up-scale or accelerate experiments to broader practices across geographical locations.

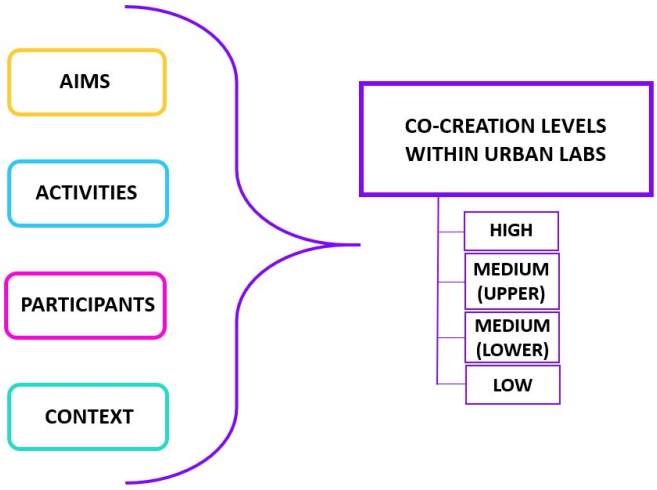
Medium co-creation levels exist when the inner circle of the urban lab consists of non-selected and selected actors (Puerari et al.,2018). A semi-formal form of co-creation is occupied where there is regular interaction and a mix of formal and informal collaboration. This level of co-creation is made up of mixture of attributes from high and low co-creation levels. There is limited information in the literature aimed at the identification of urban labs with medium co-creation levels, most information regarding co-creation level is concentrated on the identification of either high or low levels.

Low co-creation levels ensue when the urban lab arranges sporadic interactions and informal collaboration, usually coupled with short term goals (Puerari et al.,2018). Emerging urban labs focused on short term engagements and informal participants frequently encountered difficulties to establish co-creation practices. This level of co-creation commonly occurs

when the core group attempts to increase involvement of the outside community or involve participants from the outer circle. Co-creation activities in urban labs have commonly focused on the creativity and potential from the outer circle, however, in recent literature has found that this process of co-creation is difficult to attain (Puerari et al.,2018) and co-creation during these circumstances is considered low. However, for some urban labs, the openness of activities can prove to be critical for speeding up development processes and increasing the amount of innovative ideas through a multitude of perspectives (Veeckman et al., 2013). This study will focus on the two levels of openness introduced by Veeckman et al. (2013), the degree to which new participants are accepted, and the extent of knowledge sharing through intellectual property rights. Motivations and incentives to contribute in co-creation activities are tightly correlated to ownership of the co-creation processes. Incentives for participating in co-creation activities is related to the potential benefits that can be received from the participation. It is difficult for a strong sense of ownership to transfer or extend beyond the core group due to difficulties encountered in broader co-creation activities, these are predominantly reliant on voluntary efforts and are commonly non-binding.

2.4 Conceptual Framework

The main characteristics of urban labs include aims, activities, participants, and context. The relationship between these characteristics and their potential to harness high levels of co-creation has yet to be analyzed in the literature on a large scale. To advance the research in this sector, this study proposes to analyze the composition of urban lab characteristics that have been applied in practice throughout Europe, through the co-creation elements they encompass, interrelate to, and to identify the characteristics most positively influential for high co-creation levels.



Source: Researcher's own adaption of principles and concepts

Figure 4: This figure portrays the analysis framework of the study, the relationships between urban lab characteristics and co-creation elements that are encompassed in the different levels of co-creation in urban labs within the dimension of urban sustainability.

Chapter 3: Research Design and Methods

3.1 Operationalization: Variables and Indicators

The quantification of the main concepts reviewed in Chapter 2 necessitates a conversion from theoretical to empirical research. This section will summarize and define concepts into quantifiable variables and indicators regarding the components of co-creation levels in urban labs. The aim of the literature review was to develop a framework to analyze the levels of co-creation in urban labs, through its constituents and the characteristics of urban labs which have the potential to harbor and further develop them. Urban labs encompass the five main elements of co-creation within their characteristics: purpose, degree of informality, ownership, motivation and incentives, and space and place. These elements will be operationalized as sub-variables of urban lab characteristics to quantify the level of co-creation exhibited within the urban labs due to its interconnected relationship to urban lab characteristics. Concepts, indicators, and questions, formulated by the research questions and literature review, are presented below in Table 1, which consists of the two main concepts of the literature, urban lab characteristics and co-creation levels. The concept of co-creation levels were based on the theoretical findings of Puerari et al. (2018), as introduced in Chapter 2.

Table 1: Demonstrates the operationalization of the concepts and its translation into questions that comprise the survey.

Variable (Independent)	Sub-Variable	Definition	Indicators	Questions
Aims	Purpose	Urban labs comprise of either one or both distinct goals: (1) to collectively work towards an innovation output (e.g., service, product, etc.) and (2) to build knowledge, learn, and create networks through collaboration	- Lab Lifespan - Lab Focus - Context Research - Goal Clarity - Open Events	- What identifies most with the degree of usage context research considered before the start of the lab? - What was the lifespan of the urban lab? - Which identifies most with the focus of the lab? - Which identifies most with the clarity of urban lab goals? - Which identifies most with the frequency at which the urban lab held events? (e.g., meetings, workshops, open events, etc.) - Were the goals of the lab met?
Activities	Development	The design, testing and implementation of innovations is devised together with users	- Methods - Technical Infrastructure	- What strategies of engagement were used for stakeholders? - Which identifies most with the technical infrastructure of the lab? - Which identifies most with the degree of value creation in the lab?
	Iteration	Users evaluate resulting innovations for future, continuous improvements	- Value Creation	
Participants	Motivations / Incentives	Reason for participants to engage in co-creation processes	- Resources - Personal Benefits - Consensus	- Which identifies most with the lab's availability to resources? - Which identifies most with the consensus on co-creation activities amongst participants? - Which identifies most with the motivations of participants in the lab? - Which identifies most with the degree at which participants were included? - Which identifies most with the degree to which the lab structure was predetermined? (e.g., events, audiences, procedural steps, participants, etc.) - Which identifies most with the exclusivity of the lab's partnerships? - Which identifies most with the extent of intellectual property rights? - Which identifies most with the degree of power struggles amongst participants? - Which sectors were involved in the lab? - What sector initiated/led the urban lab? - Which identifies most with the scale of the lab?
	Degree of Formality	The extent to which participants are selected and urban lab structure is predetermined	- Interaction Frequency - Engagement Intensity - Structural Planning - Actor Selection Process	
	Ownership	The extent to which co-creation processes are steered or controlled	- Leadership - Openness	
	Actors	Stakeholders that actively contribute to co-creation processes within the urban lab	- Scale - Sector Diversity	
Context	Real-life Setting	Urban lab activities occur outside of laboratory setting, within socio-spatial use contexts embedded in geographical areas	- Site - Visibility - Proximity	- Which identifies most with the degree of real-world context experienced within the lab - Which identifies most with the sense of community within the lab? - Which identifies most with the lab's degree of fixed space? - Which identifies most with the visibility of the lab within the community?

Variable (Dependent)	Sub-variable	Definition	Indicators	Questions
Co-Creation Level	High	High co-creation levels will consist of ranks from 10 to 9 on the 1 to 10 scale. User feedback is captured (iteratively); user can make changes to the innovation themselves; the user is part of the innovation process.	The perceived score of co-creation level by initiator	- Which answer identifies most with the co-creation level achieved by urban lab activities?
	Medium (Upper)	Medium (Upper) co-creation levels will consist of ranks from 7-8 on the 1 to 10 scale. User feedback is captured (iterative), which may lead to some modifications/alterations of the innovation.		
	Medium (Lower)	Medium (Lower) co-creation levels will consist of ranks from 6 to 4 on the 1 to 10 scale. In the lower end of the medium level, user feedback is captured, but users have no decision-making power in the innovation process.		
	Low	Passive co-creation levels will consist of ranks from 3 to 1 on the 1 to 10 scale. In this level there is rare to no interaction with users		

Source: Researcher's own adaption of principles and concepts

3.2 Research Strategy

This research aims to obtain empirical data, on a large-scale approach, related to the co-creation that occurs within urban lab initiatives that intend to directly affect urban sustainability throughout Europe. A deductive research approach has been applied to this study as a basis for research design. The survey research strategy was employed in this study due to the empirical inquiry concerning the sizable number of indicators associated with

urban lab characteristics responsible for inducing higher co-creation levels in urban labs (Van Theil, 2014). The large-scale approach of the study and quantity of urban labs examined, allowing for the collection of substantial data, also supported the decision of the survey research strategy (Van Theil, 2014). There is ambiguity in the literature regarding which urban lab characteristic is predominant for co-creation level enhancement, hence, data collection of this scope and geographical scale permitted a novel quantitative investigation for this research study. The survey research strategy was also backed by a pilot study to ensure reliability and validity of the questions.

3.3 Data Collection and Methods

Frameworks from three previous studies (Eriksson and Svensson 2009, Veeckman et al. 2013, Puerari et al. 2018) have been combined to develop a survey of 29 questions to obtain quantitative data on co-creation levels in urban labs. This data was collected through the online survey service, Qualtrics. Variables analyzed in the literature review were operationalized and transformed into closed-ended questions. Predetermined answer scales were used as a standardized form of measurement, all but two answers (regarding the identification of participating sectors) lacked the option 'other' to maintain standardization level and increase options for statistical analysis (Van Theil, 2014). All quantitative data was analyzed on a Likert scale of one to four, one scoring high and four scoring low regarding the degree to which the respondent agrees with the statement.

3.4 Reliability and Validity

Due to the survey research strategy, the data can be easily generalized, and external validity enhanced, however, dishonesty or subjectivity can contribute superficiality to the data due to personal perceptions and opinions relevant to survey questions (Van Theil, 2014). A large sample size was selected to improve the reliability of the explanatory research concepts. To better the accuracy and secure external validity of the survey (Van Theil, 2014), the framework for the measurement of observed indicators was modified to closely frame those of two previous studies mentioned in the literature review. These two studies provided valuable insights from their urban lab experiences and present analysis frameworks that can be converged to operationalize co-creativity in labs. The first, by Eriksson and Svensson (2009), conducted a study analyzing co-creation in urban labs through 100 user involvement activities, over a span of about three years, involving about 500 participants in 'real life' contexts and over 7,000 participants in online surveys to analyze co-creation in living labs. All activities were related to diverse innovation processes regarding both services and products and involved interdisciplinary stakeholders. Second, is the study by Puerari et al. (2018), which provided a basis for studying co-creation elements, specifically in urban lab practices. This framework was developed with intentions for replication, therefore the steps to be taken in this analysis have been explicitly specified and aligned with methods of previous studies.

An overview of urban labs in Europe were chosen to identify if results from labs remained consistent with theory due to the input from different groups, in different situations, over repeated analysis. The reliability and validity of the survey findings cannot be 100% certain due to subjective human interpretation that can affect final answers, even if the survey is fully completed. For example, it is possible for respondents to adapt answers due to their awareness of participating in a research study, or take questions too literally leading to logical mistakes (Van Theil, 2014). To enhance internal validity, operationalizations were

sufficiently translated from the theoretical context (Van Theil, 2014). The analyzation framework for this study has been modified to further improve the clarity and exclusivity of measurements and observations, it is not sufficient for the measurements of other constructs. The external validity of the study is strengthened due to the generalization of the analysis framework, application is possible for different locations, groups of people, situations, and sectors of urban sustainability at different moments in time. Results and methods of the study cannot always be generalized to all global urban regions; however, best practices and emerging patterns can be utilized for theoretical generalization and conceptual elaboration (Warbroek and Hoppe, 2017). External validity can potentially be reduced by any non-response issues the online survey may encounter, such as, a low response rate, decreasing the representativeness of the sample (Van Theil, 2014). To counter this common challenge experienced with online surveys, participation reminder emails were sent to the urban labs asked to participate in the survey. Inter-researcher reliability and validation (Van Theil, 2014) has been applied to this study to further reliability and validity through consultation of the analysis framework, operationalization process, and survey structure with the coordinator of the iSCAPE urban lab network. A pilot study was also conducted with an urban lab situated in Rotterdam to test the survey and contribute to the reliability and validity of the survey and gain insights on any improvements needed to ensure clarity and user-friendliness (Van Theil, 2014). Respondents of the pilot study were asked to provide any extra information or suggestions to further enhance the flow and clarity of the survey questions and their order. The results of this preliminary study confirmed that the chosen research strategy is applicable to the research situation.

3.5 Sample Size and Selection

The target sample size was comprised of 80 European urban labs affiliated with the networks of ENoLL, iSCAPE, and DRIFT, situated in the context of urban sustainability, were sent a survey for analysis. The final sample size of the study depends on the number of respondents in the qualitative data collection. The geographical range of contacted labs spans across the countries of Belgium, Turkey, Portugal, Finland, United Kingdom, Sweden, Netherlands, Estonia, Denmark, Ireland, France, Greece, Serbia, Croatia, Slovenia, Switzerland, Germany, Italy, Austria, Spain, and Germany. After a waiting period of two weeks, a final count of 41 urban labs responded to the survey, however, only 29 responses were valid to use for the study.

Projects of the labs can range from various sustainability initiatives and sectors that involve co-creation activities, such as transitioning towards a circular economy, greening of an urban space, or taking up sustainable governance and development. The sample size refers to the respondents of the contacted urban labs. It was not possible to contact and locate each urban lab in Europe due to the diversity of urban lab titles, lack of contact information or response, and possible low visibility of the urban labs. Established from theoretically relevant criteria, a non-probability, purposive sample was selected (Van Theil, 2014). Initiators and facilitators were chosen to be surveyed to identify the state of co-creation levels in their urban labs because they constitute the ‘core group’ of urban labs. Each urban lab had a total of one respondent for the survey. This decision was based off of a study by Puerari et al. (2018) which analyzed co-creation elements and dynamics in six urban labs throughout Rotterdam, the Netherlands. Participants were interviewed on their perception of co-creation dynamics within the lab, the results found that for all core groups of the labs, the perceived and actual target of co-creation were matched, while the groups that included the rest of participants were not matching. Hence, the perspectives of co-creation dynamics by the initiators were the

most reliable when measuring the actual results of successful co-creation dynamics and outcomes.

3.5 Data Analysis Methods

The survey was composed of a total of 29 questions (Table 3), each independent variable had a specific number of questions assigned to each indicator (Table 4). For each set of questions, an average of the answers was taken to create four indexes.

Table 2: The number of survey questions per independent variable is displayed.

Independent Variable	Number of Questions
Aims	6
Activities	3
Participants	11
Context	4

Source: Researcher's own adaption of principles and concepts

Urban lab characteristics were best measured with multiple questions, therefore, data reduction for the independent variables was performed. The "Aims" characteristic had a set of six questions, "Activities" had a set of three questions, "Participation" had a set of eleven questions, and "Context" had a set of four questions (Table 4). The answers for each indicator were translated into scores, of which the averages for each of the four independent variables were taken, then an index for each urban lab characteristic was created. After averages were taken, the independent variable became continuous, although there was no expectation for the indication of range of outcomes to be greater than a value of four. This total of four indexes were used to conduct an ordinal regression analysis. Data reduction was also performed to optimize data management due to the large number of questions.

All models, needed to answer the main research question, were estimated using ordinal logistic regressions. The data was manipulated using the SPSS software. This method was chosen due to the utilization of a categorical, ordinal dependent variable measured at the Likert scale, and the usage of four continuous independent variables which lacked multicollinearity. The outcome does not result in natural ordering (Wooldridge, 2015); therefore, the following values were created for the dependent variable of this study:

1 = High
2 = Medium (Upper)
3 = Medium (Lower)
4 = Low

The binary response of this logit model implies the probability of the response is the logit function, which is assessed at a linear function of the independent variables, urban lab characteristics (Wooldridge, 2015). The following equation depicts the probabilities in ordered logit model form, as depicted by Wooldridge (2015):

$$\Pr(y_i = 1|\boldsymbol{x}_i) = \frac{\exp(\boldsymbol{x}_i\boldsymbol{\beta}_1)}{1 + \exp(\boldsymbol{x}_i\boldsymbol{\beta}_1) + \exp(\boldsymbol{x}_i\boldsymbol{\beta}_2)},$$

$$\Pr(y_i = 2|\boldsymbol{x}_i) = \frac{\exp(\boldsymbol{x}_i\boldsymbol{\beta}_2)}{1 + \exp(\boldsymbol{x}_i\boldsymbol{\beta}_1) + \exp(\boldsymbol{x}_i\boldsymbol{\beta}_2)},$$

$$\begin{aligned}\Pr(y_i = 0|\boldsymbol{x}_i) &= 1 - \Pr(y_i = 1|\boldsymbol{x}_i) - \Pr(y_i = 2|\boldsymbol{x}_i) \\ &= \frac{1}{1 + \exp(\boldsymbol{x}_i\boldsymbol{\beta}_1) + \exp(\boldsymbol{x}_i\boldsymbol{\beta}_2)}.\end{aligned} \quad \text{(Eq. 1)}$$

The ordinal logistic regression analysis determined which independent variable had a statistically significant effect on co-creation levels. The regression outputs were cumulatively presented where the four variables "Aims", "Activities", "Participation", and "Context" were examined individually, then simultaneously for a comparative analysis.

Chapter 4: Research Findings

4.1 Introduction

The empirical findings of this study were established from the data collected through the urban lab survey and are limited to urban labs that participated in the three largest urban lab networks within Europe. The labs were chosen due to their focus on various projects regarding urban sustainability. The case processing summary (Table 3) presents the number of urban labs, *N*, that were reported for each score level of co-creation. The marginal percentage displays the proportion of observed urban labs found in each level of co-creation, the outcome variable.

Table 3: Displays the total number of urban lab survey respondents, *N*, for each level of co-creation and the corresponding marginal percentage.

Case Processing Summary			
		N	Marginal Percentage
Co-Creation Level	1	7	24.1%
	2	18	62.1%
	3	3	10.3%
	4	1	3.4%
Valid		29	100.0%
Missing		1	
Total		30	

Source: Researcher's own adaption of principles and concepts

Each urban lab was represented by one respondent. To improve the response rates and sample size, surveys were sent to 80 urban labs, with weekly reminder emails over a period of three weeks. A total response rate of 51.25% was recorded, however, out of the 41 responses 11 were incomplete leaving a total of 30 responses (Table 3). Of the 30, one score is missing

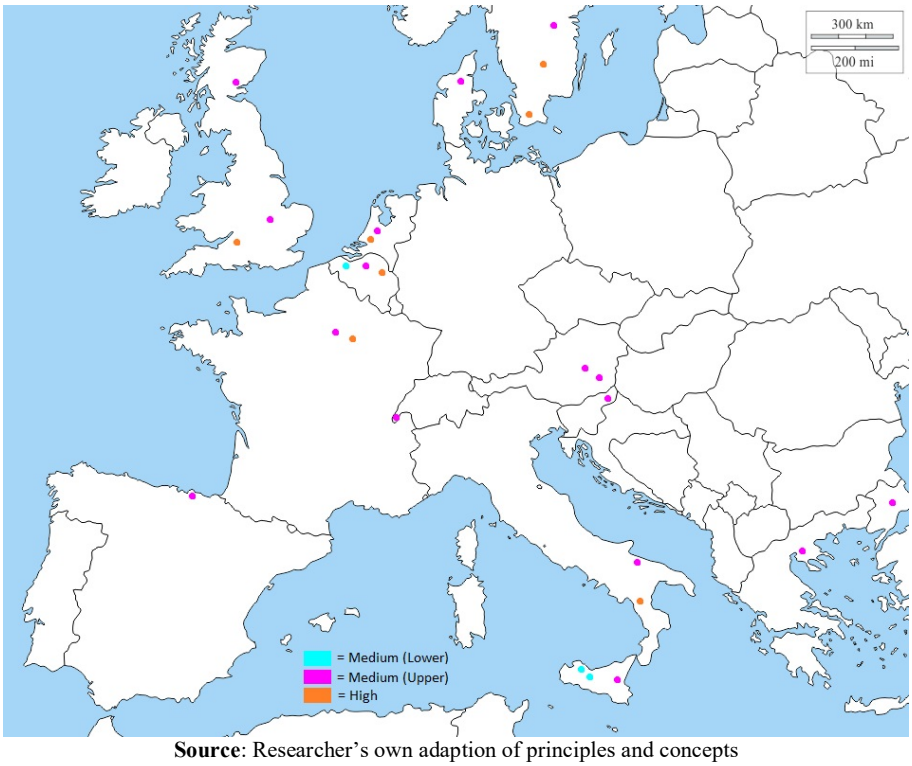
from the data set due to partial completion of the survey, therefore, it will be excluded from data analysis processes leaving a total of 29 valid answers available for full analysis and a response rate of 36.3%. Demographic data, consisting of gender, age, and educational level, was obtained through the first section of the survey. Percentage distribution among the following parameters gender, age, and education level are presented in Table 4.

Table 4: Displays the gender, age, and education level count of respondents and the percentages of this demographic data.

Parameter	Count	Percentage
Gender		
-	2	6.7%
Female	8	26.7%
Male	20	66.7%
Age		
-	1	3.3%
<30	3	10.0%
30-40	9	30.0%
41-50	7	23.3%
>50	10	33.3%
Education Level		
-	1	3.3%
PhD/Doctorate	12	40.0%
Master's Degree	14	46.7%
Bachelor's Degree	2	6.7%
Secondary Level	1	3.3%

Source: Researcher's own adaption of principles and concepts

In regard to gender, a majority of respondents were male (66.7%) while 26.7% were female, and 6.7% remained anonymous. It was observed that most urban lab initiators that participated in this study were 30 years old or older, with most respondents over the age of 50 (33.3%). Almost all participants (93.3%) reached a tertiary level of education, with the exception of one respondent who completed a secondary level of education and one respondent who preferred to keep the information private. A total of 30 respondents were considered in the demographic data because the overview of the demographics was not applied to the analysis of empirical data regarding co-creation and urban lab characteristics.



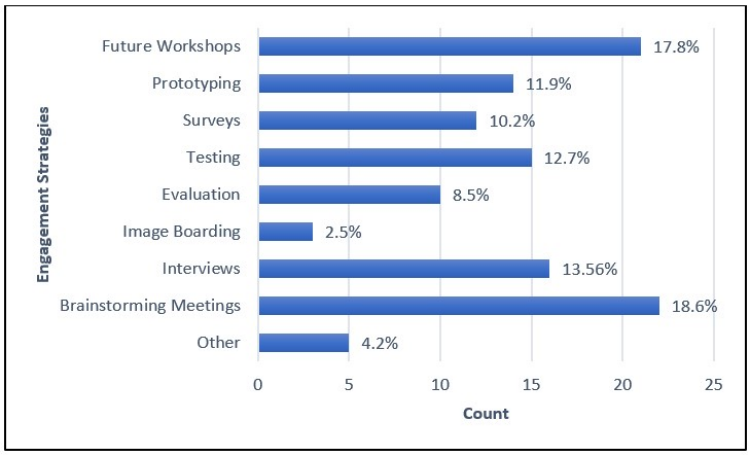
Source: Researcher's own adaption of principles and concepts

Figure 5: Displays the geographical range of the European urban labs included in the study and corresponding co-creation levels.

A visualization was created to present the geographical range and co-creation levels of the examined urban labs (Figure 5). A total of 13 countries participated in the study. Of the respondents that disclosed geographic information, urban labs from Switzerland, Spain, Italy, Sweden, Netherlands, United Kingdom, Belgium, Turkey, Greece, France, Austria, Slovenia, and Denmark contributed to the findings of this research. Not all urban labs are represented on this map due to anonymity, specifically 13.3% of urban labs were not accounted for.

4.2 Co-Creation Activities of Examined European Urban Labs

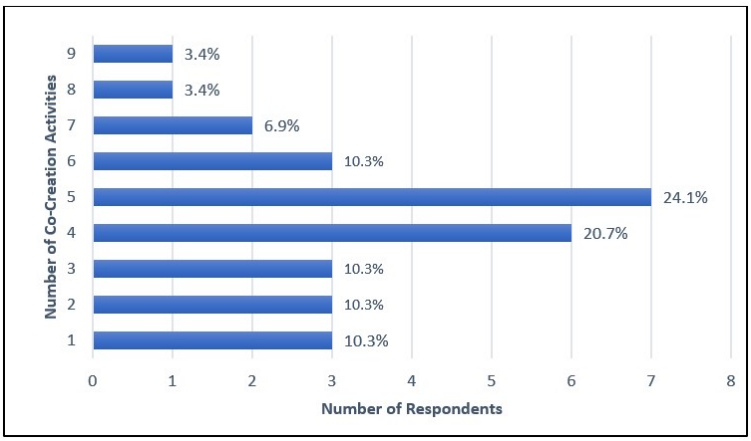
To answer the first research sub-question, respondents were asked to answer questions regarding co-creation activities within their urban labs. All answer options were compiled from co-creation activities commonly used throughout the literature. The pre-selected answers included: future workshops, prototyping, surveys, testing, evaluation, image boarding, interviews, brainstorm meetings, and other (Figure 6). The option "other" was included in pre-selected answers to gain more insight on the diversity of co-creation activities within urban labs.



Source: Researcher's own adaption of principles and concepts

Figure 6: Displays the percentage of engagement strategies utilized in the urban labs

Within this sample group, brainstorming meetings (18.6%) and future workshops (17.8%) were the most utilized as co-creation activities. Interviews, testing, prototyping, and surveys were shortly behind, making up 10.2% to 13.56% of total strategies used. The remaining 4.2% specified "other" engagement strategies to be placemaking, all of above and more, focus groups, social safaris, and symposia. All urban labs reported to have engaged their participants in at least one or more co-creation activities (Figure 7).



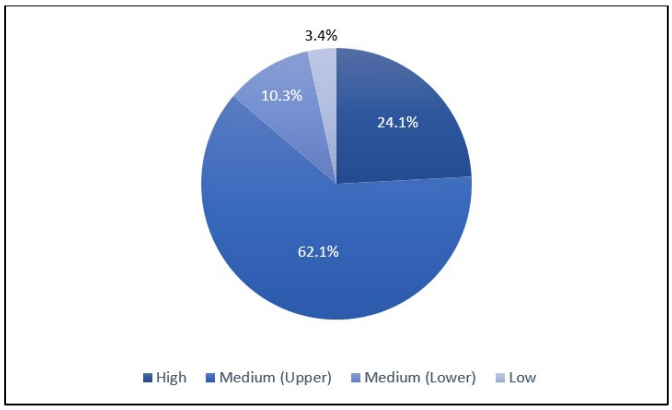
Source: Researcher's own adaption of principles and concepts

Figure 7: Displays the count of co-creation activities utilized by survey respondents (number of respondents).

A majority of urban labs reported the utilization of either four (20.7%) or five (24.1%) co-creation activities within the duration of the co-creation process. Urban labs that utilized either one, two, three, or six co-creation activities during the co-creation process each consisted 10.3% of total respondents, while urban labs with 7 co-creation activities consisted of 6.9% of total respondents. Each making up 3.4% of total respondents were urban labs that utilized either 8 or 9 co-creation activities throughout the co-creation process. One of which, was reported to have the highest co-creation level of all labs.

4.3 Co-Creation Levels of Examined European Urban Labs

To answer the second sub-question, the total distribution of co-creation levels amongst urban labs were reviewed and represented in Figure 8.



Source: Researcher's own adaption of principles and concepts

Figure 8: Presents the distribution of High, Medium (Upper), Medium (Lower), and Low co-creation levels amongst urban labs.

Due to the large sample size classified with medium co-creation levels, this level was split into medium (upper) and medium (lower) to provide a better visualization of which level most medium co-creation level classified urban labs lean towards. Of the total sample size, one urban lab reported a low co-creation level (3.4%). Seven urban labs had experience high co-creation levels (24.1%), while over half of urban labs (62.1%) displayed co-creation levels classified as medium (upper). The remaining 10.3% was occupied by urban labs classified to have medium (lower) co-creation levels.

The next section will provide an assessment of possible explanations for co-creation level variation based on urban lab characteristics. Due to similar data results amongst the urban labs identified with medium (upper) co-creation levels, data results of the urban labs classified with the highest and lowest co-creation levels will be investigated.

4.4 Co-Creation Level Variation of Examined European Urban Labs

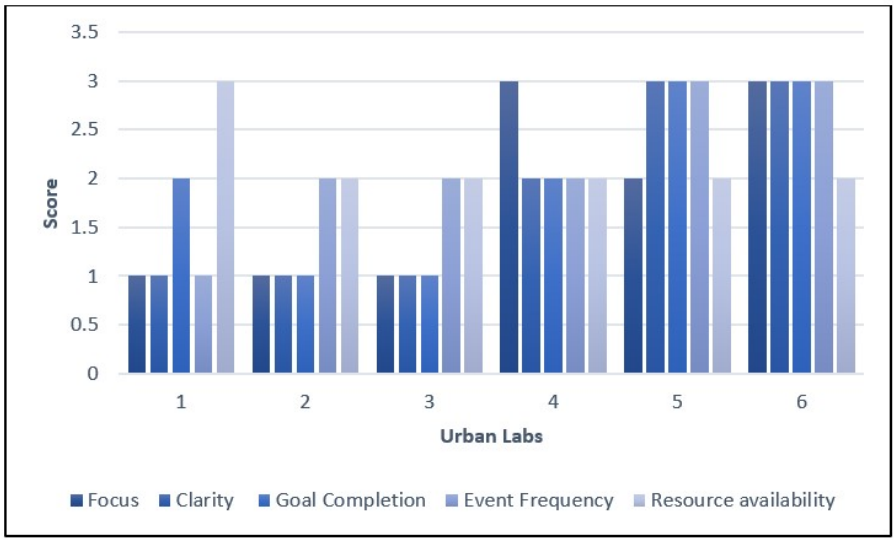
The analysis framework derived from Eriksson and Svensson (2009) and Puerari et al. (2018), was utilized to review the empirical data from survey results and the most significant indicators that can provide explanation for co-creation level variation based on urban lab characteristics, answering the third sub-question. The first indicators analyzed were associated with the urban characteristics of "Aims" and "Activities" and referred to the usage of activities presented in Figure 6. These results were examined with the framework derived from Eriksson and Svensson (2009) due to their analysis regarding degree of user type, which encompasses indicators that are most influential regarding the "Aims" and "Activities" urban lab characteristic scores. Subsequent to this was the analysis of the most important indicators associated with the urban characteristics "Participants" and "Context", which utilized framework derived from Eriksson and Svensson (2009) and Puerari et al. (2018). This analysis will determine if the indicators remain consistent with the literature by occupying the co-creation levels the literature predicts it to have.

Aims and Activities

The number of engagement strategies utilized within urban labs as co-creation activities (Figure 7) and any relations to the indicators encompassed by the degree of user involvement were examined (Eriksson and Svensson, 2009). Degree of user involvement was utilized to evaluate co-creation level variation associated with indicators of goal clarity, lab focus, resource availability, event frequency, engagement strategies, and goal completion. This section will provide an overview of the degree of user involvement utilized in the observed urban labs and corresponding correlations to its associated indicators.

There are three degrees of user involvement according to Eriksson and Svensson (2009). The first, decision degree of user involvement, encompasses the engagement strategies of surveys (10.2%) and evaluations (8.5%). This degree does not require many resources and has the goals of generating knowledge and learning through co-creation. The second, information degree of user involvement correlates to interviews (13.56%), testing (12.7%), and image boarding (2.5%) and requires a higher amount of resources. The main goals of this degree are to learn through co-creation and generate knowledge. The third, creation degree of user involvement, utilizes brainstorming meetings (18.6%), future workshops (17.8%), and prototyping (11.9%), the best techniques for co-creation activities that can inform and guide design decisions in the operation phase of the urban lab. This degree occupies a high dependency on resources and its goals are oriented around the purpose to either physically make something with participants and innovate (e.g., product, service, process innovation, etc.) or to both learn while co-creating knowledge and to innovate, physically making something with participants. According to the theory reviewed in Eriksson and Svensson (2009), the urban labs with highest levels of co-creation should utilize the creation degree of user involvement. Therefore, the urban labs that employed the engagement strategies of the creation degree of user involvement were evaluated to identify any correlations between its properties and co-creation level.

Of the 29 urban labs, ten were concluded to employ the properties of the creation degree of user involvement. Four of which reported high levels of co-creation, and the remaining six reported medium (upper) co-creation levels. Moreover, there were an additional three remaining urban labs reported to have high co-creation levels but did not fully encompass the qualities of the creation degree of user involvement. However, these labs used a variation of two out of the three co-creation activities within the creation degree of user involvement classification and additional activities from the information degree of user involvement. Urban labs that encompassed the creation degree of user involvement and did not report high co-creation levels may have encountered limitations in resource availability, goal completion, lab focus or goal clarity. Therefore, it can be speculated that there are more influential indicators that can impact the potential for urban labs to foster high co-creation levels. These indicators were evaluated further through an analysis of indicator performance of the top three urban labs with highest co-creation levels were compared to the three urban labs with the lowest co-creation levels (Figure 9).



Source: Researcher's own adaption of principles and concepts

Figure 9: Displays the performance scores of the indicators, lab focus, goal clarity, goal completion, event frequency, and resource availability, for the three labs that performed with the highest co-creation levels (3 = high, 2 = higher, 1 = highest) and the three labs that performed with the lowest co-creation levels (4 = low, 5 = lower, and 6 = lowest).

The study of Eriksson and Svenssons (2009) correlated lab focus, goal clarity, goal completion, event frequency, and resource availability to co-creation level variations. Hence, these indicators were chosen to be compared amongst the best and worst performing labs in the study. Low numeric scores of independent indicators indicated a higher performance associated with high co-creation levels. These two categories are examined because 62.1% of urban labs were classified with medium (upper) co-creation levels (Figure 8) and have similar quantitative results. Therefore, only the urban labs with the highest and lowest co-creation values exhibited distinct differences that could explain the variation of co-creation levels based on urban lab characteristics.

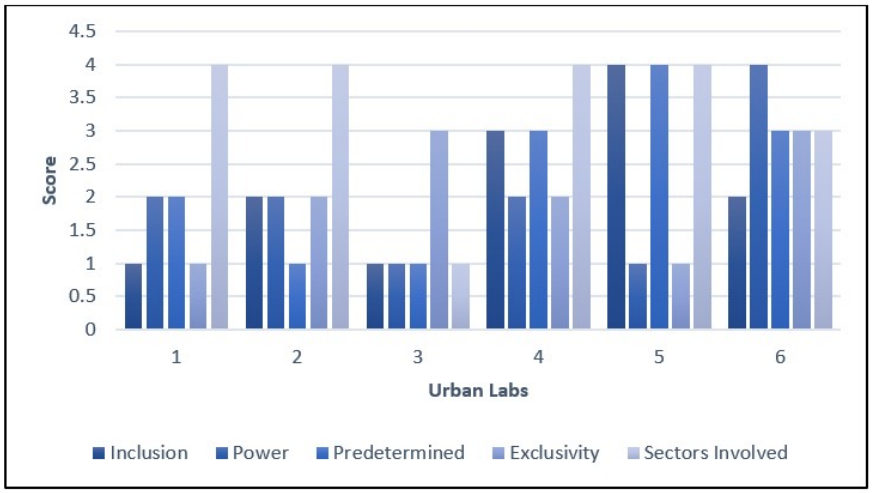
Urban lab "1" had the best co-creation level of all labs examined in the study. Urban labs "2" and "3" were the next two labs with the best co-creation levels. Urban labs "4", "5", and "6" were ranked 27th, 28th, and 29th for co-creation levels, urban lab "6" having the lowest co-creation performance. Urban labs "1", "2", and "3", experienced lab focus and clarity of goals as the best performing indicators, where for each indicator, $\bar{x} = 1.83$ and $\sigma = 0.98$. This indicates that were goals were made extremely clear to each individual participant, and the goal was both, to learn and co-create knowledge, and to innovate, physically make something with participants. Urban labs "4", "5" and "6" scored either a two or three for lab focus, indicating there was only one focus of the lab, to either learn and co-create knowledge with participants, or to innovate and physically make something with participants. Regarding goal clarity, labs "5" and "6" had the lowest performance, indicating that goals were clear to less than half of all participants.

The next best scoring indicator, amongst high co-creation labs, was goal completion, where $\bar{x} = 2.00$ and $\sigma = 0.89$. Labs "2" and "3" obtained a score of one, indicating all lab goals were completed. Due to its score of two, Lab "1" identified to have completed more than half of its goals. Urban labs "5" and "6" reported low performance scores of three for goal completion, were less than half of total goals were completed. In regard to co-creation variation, the least

significant of all indicators was event frequency ($\bar{x}$ = 2.17, σ = 0.75) and resource availability ($\bar{x}$ = 2.17, σ = 0.41). This is due to the lack of impact from low performances, indicated by higher numeric scores, that did not hinder the co-creation success of the urban labs with high co-creation levels. The three urban labs with lowest co-creation levels, "4", "5", and "6", were observed to have better access to resources than the urban lab with the highest co-creation level, whereas urban lab "1", indicated to have low resource availability. This analysis leads to the conclusion that the variation of co-creation level is not dependent solely on the amount or types of co-creation activities and indicators associated with differentiating degrees of user involvement. To further investigate explanations for varying levels of co-creation, the indicators associated with the "Participation" and "Context" urban lab characteristics will be evaluated in the following section

Participation and Context

Evaluated next were the empirical results of the indicators participant inclusion, power struggles, predetermined structure, exclusivity, and involved sectors.



Source: Researcher's own adaption of principles and concepts

Figure 10: Displays the performance scores of the indicators, participant inclusion, power struggles, predetermined structure, exclusivity, and sectors involved, for the three labs that performed with the highest co-creation levels (3 = high, 2 = higher, 1 = highest) and the three labs that performed with the lowest co-creation levels (4 = low, 5 = lower, and 6 = lowest).

First to be evaluated was the duration participants were included throughout the lab process. A score of one indicates that urban lab "1" and "3" continuously included participants throughout more than half of all phases of the urban lab process. With a score of two, urban labs "2" and "6" included their participants sporadically, throughout more than half of the urban lab process. Participants from urban lab "4" were included continuously, throughout less than half of urban lab phases, indicated by a score of three, while participants from urban lab "5" were included sporadically, throughout less than have of urban lab phases, indicated by a score of four. The mean and standard deviation of these six labs for the inclusion indicator was $\bar{x}$ = 2.17 and σ = 1.17. High and low variation in score did not match consistently to the levels of co-creation.

The indicator partnership exclusivity had a mean of $\bar{x}$ = 2.00, and a standard deviation of σ = 0.89. The urban labs with highest co-creation levels, labs "1", "2", and "3", scored a wide

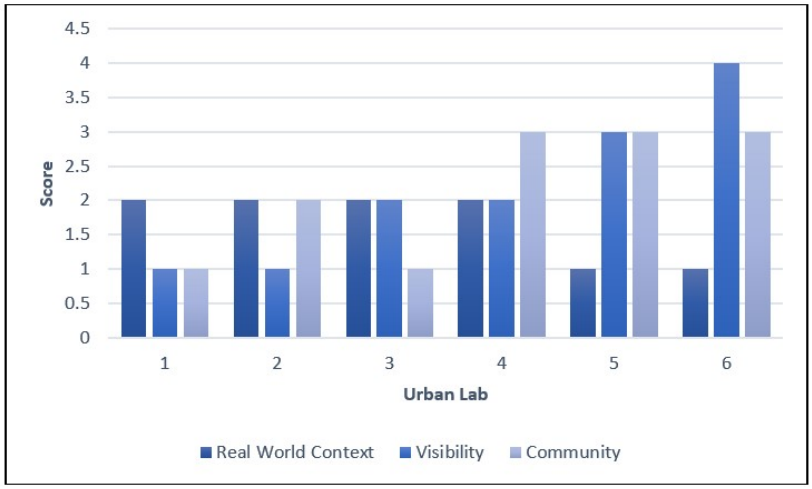
range of one to three for partnership exclusivity. This indicates that the labs with the highest co-creation scores had partnerships that ranged from inclusive where everyone is welcome to use the platform with no time or space limitation, inclusive where everyone is welcome to use the platform, but access is limited in time and space, to semi-exclusive partnerships (e.g., open only to members of a consortium). The urban labs with lowest co-creation levels, labs "4", "5", and "6", also scored from one to three, indicating that neither the highest nor lowest urban labs had completely exclusive partnerships (e.g., exclusively controlled by a single actor). Hence, a lack of completely exclusive partnerships could be beneficial for urban labs, but possibly not enough to fully impact the outcome of co-creation level.

All urban labs had at least three or more sectors involved, with a mean of $\bar{x} = 3.33$, and standard deviation of $\sigma = 0.89$. All urban labs, except lab "3" and "6", involved all sectors (knowledge institutions, government, private, and citizen). Urban lab "6" involved three sectors, knowledge institutions, private, and government. Urban lab "3" only consisted of one sector, knowledge institutions. Therefore, the involvement of most sectors will not secure high co-creation levels within an urban lab. There are other indicators to be investigated that can better explain the variation of co-creation levels. Inconsistency in the scores of inclusion, exclusivity, and sectors involved, where an urban lab with low co-creation levels receives the same score as an urban lab with high co-creation levels, postulates that these indicators may not serve as a secure determinants of co-creation level variation.

Participants were asked to identify the degree of power struggles encountered amongst participants within the lab. A score of one indicated that there were no power struggles experienced within the lab, all members were heard and included equally in all discussions. A score of four indicated that there was a high degree of power struggles, to the extent that certain actors frequently dominated discussions, preventing all participants from expressing their ideas in discussions with little to no intervention by initiators to settle power struggles. The mean answer for this question was $\bar{x} = 2.00$ and $\sigma = 0.98$, indicating that there was mostly a low degree of power struggles due to quick intervention by initiators to restore balance in discussions if a participant seemed to dominate the discussion. Of these six urban labs, urban lab "6" was the only lab to score a four for degree of power struggle. Urban labs "3" and "5" scored a one, while the remaining scored a two. Therefore, it can be speculated that this indicator has great influence of co-creation level variation.

Predetermination of urban lab structure was examined to determine the extent to which urban labs preorganized their events, audiences, participants, and procedural steps. The results of the six urban labs had a mean of $\bar{x} = 2.33$, and a standard deviation of $\sigma = 1.21$. Urban labs "2" and "3" scored a one, indicating that the whole urban lab structure was predetermined (e.g., events, participants, etc. were purposely selected), while urban lab "1" identified with a score of two, were more than half of the urban lab structure was predetermined. Urban lab "4" was the only lab, of the six, to have a score of three, indicating that less than half of the urban lab structure was predetermined. The structure of urban labs "5" and "6" was not predetermined (e.g., events, participants, etc., were selected randomly), indicated by the score of four. These results enforce the speculation that there is a delicate balance between flexibility and structure that would best enable an urban lab to foster high levels of co-creation. The results derived from predetermined structure and power struggles data can serve as possible explanations for variation in urban lab co-creation levels stemming from the "Participation" urban lab characteristic.

The last examined urban lab characteristic was "Context". Of all its indicators, degree of real-world context, visibility, and sense of community were the most significant to be analyzed because they best represented the aspects of the characteristic (Figure 11).



Source: Researcher's own adaption of principles and concepts

Figure 11: Displays the performance scores of the indicators, real world context, visibility, and sense of community, for the three labs that performed with the highest co-creation levels (3 = high, 2 = higher, 1 = highest) and the three labs that performed with the lowest co-creation levels (4 = low, 5 = lower, and 6 = lowest).

First analyzed was the real-world context indicator. All urban labs, with the exception of labs "5" and "6", scored a two for degree of real-world context, indicating the urban labs experienced a real-world context with some time or space limitations. The two urban labs with lowest co-creation levels, labs "5" and "6", reported a score of one, indicating the urban labs experienced a real-world context without any time or space limitations. With a mean of $\bar{x}$ =1.67, and a standard deviation of σ =0.52, there is not much variation of this indicator amongst the urban labs with lowest and highest co-creation levels, therefore, it can be speculated that this indicator does not provide a significant explanation for variation co-creation levels.

Second analyzed was the visibility indicator, were urban labs were asked to identify which prewritten answer identified most with the visibility of the urban lab within the community. The top two urban labs with highest co-creations, labs "1" and "2", reported scores of one, revealing that these labs identified their work as a well-known symbol of sustainability within the surrounding community. Experiencing expanded opportunities, such as, networks, financial support, participation, and innovation, the two urban labs had multiple projects and partnerships with large private actors and the government. Indicated by the scores of two, urban labs "3" and "4" reported the artifacts from the urban lab had moderate exposure in the real-life setting, and had stand-alone projects involving partnerships with universities, urban developers, and city governments. Urban labs "5", scored a three, reported hosting micro projects, not well known to anyone outside of the lab participants, and struggling to find opportunities for networks, financial support, participation, and innovation. Only the urban lab with lowest co-creation levels scored a four, indicating that urban lab "6" reported to have no exposure in the community. Hence, high exposure within the community can correspond to high co-creation levels in urban labs. Yielding a mean of $\bar{x}$ = 2.17, and a standard deviation

of σ = 1.17, this indicator can prove to provide a significant explanation of variation in co-creation levels.

The last indicator of Figure 11 to be evaluated was degree of sense of community within the urban labs. None of the labs disclosed having no sense of community. Reporting a mostly active community, urban labs "1" and "3" scored a one for this indicator. Urban lab "2" scored a two, revealing a neutral sense of community, were there was neither a passive nor active community. The three labs with lowest co-creation levels, urban labs "4", "5", and "6" scored a three, reporting that there was mostly a passive community. A mean of $\bar{x} = 2.17$, and a standard deviation of σ =0.98, can indicate that this indicator can possible secure an explanation for co-creation level variation. However, of all "Context" indicators, degree of visibility could have the most potential for the explanation of variation in co-creation levels of urban labs. Supplementary information on urban labs with highest and lowest co-creation levels can be found in Annex 1.

4.5 The Predominant Urban Lab Characteristic for Co-Creation Level Enhancement

This section provides an overview of the analysis conducted in SPSS to answer the main research question through the identification of any relationships between the independent variable, urban lab characteristics, and the dependent variable, co-creation level. The level of co-creation was determined to correlate to the performance of the urban lab characteristics. The means and standard deviations of the urban lab characteristics can be found in Table 5.

Table 5: Exhibits the means and standard deviation of each independent variable (Aims, Activities, Participation, and Context).

Characteristic	$\bar{x}$	σ
Aims	1.68	0.38
Activities	1.85	0.60
Participation	1.88	0.29
Context	1.97	0.45

Source: Researcher's own adaption of principles and concepts

This model interpreted how a single unit decrease or increase in the independent variables were associated with the odds of co-creation levels having a lower or higher value. Of the data gathered through the SPSS analysis, special attention is concentrated on the coefficient, standard error, and significance results. Estimate coefficients with a value lower than zero suggests lower cumulative scores are more likely. All models were confirmed to fit the data, through the model fitting information, which improved the ability to predict outcomes (Norušis, 2011). Outputs were interpreted based on a threshold of p = 0 .01.

Table 6: Presents the estimate coefficients, standard errors, and significance of the independent variables in the individual analysis and comparative analysis of the ordinal logistic regression analysis.

Characteristics	Coefficient
Individual Analysis	
Aims	-4.295**
	(1.386)
Activities	-0.297
	(0.641)
Participation	-4.964**
	(1.728)
Context	-1.800*
	(0.939)
Integrated Analysis	
Aims	-3.645**
	(1.795)
Activities	0.990
	(0.858)
Participation	-3.053
	(2.030)
Context	-1.063
	(1.342)

Source: Researcher's own adaption of principles and concepts

Each urban lab characteristic was first analyzed individually to determine the statistical significance (Table 6). It was revealed that "Aims", "Participation", and "Context" were statistically significant, thus confirming that there is indeed a relationship between these independent variables and co-creation levels. However, when all indicators were simultaneously analyzed in the model (Table 6), the "Aims" characteristic was concluded to have overall importance of the remaining characteristics, having a statistically significant relationship ($p = 0.042$) to the dependent variable, co-creation level. Its estimate coefficient of -3.645 indicates that lower cumulative scores are more likely, therefore, high levels of co-creation are more likely when the indicators of the "Aims" characteristic has a low score, hence, when performance is most efficient.

Chapter 5: Conclusions and Recommendations

With the European urban population expected to rise to 80% by 2020 (Voytenko et al., 2016), it is imperative that cities take collaborative action to subdue current sustainability challenges and prevent their exacerbation. Co-creation is a key component to the transformative changes that are necessary to sustain technological and societal transformations for urban sustainability. Collaborative planning initiatives that form enabling conditions and incentives, developed by formal and informal actors, stimulate co-creation processes that reconnect society to the biosphere (Westley et al., 2011). Often framed differently, urban labs generate

a range of sustainability solutions through participation, experimentation, collaboration, and learning-by-doing in a 'real-life' context (Höflehner et al., 2016). This approach holds great potential for catalyzing sustainable transitions by fostering co-creation dynamics that contribute to the continuous evaluation for the improvement and refinement of an initiative (Mulder 2012, Kronsell and Mukhtar-Landgren 2018). The development of a meta-analysis of urban labs across Europe can enable more in-depth comparative studies to refine and realize any generalizations or improvements that can be applicable to any urban lab context.

Underpinned by theoretical knowledge of co-creation dynamics and their interrelationships to urban lab characteristics, the primary objective of this thesis was to gain new insights on the most valuable urban lab characteristics in forging high levels of co-creation. Supporting the main research question were three sub-research questions (RQ), which served to guide the research. The following sections address the main findings of the sub-research questions, with the main research question answered at the end.

RQ1: Do self-proclaimed urban labs in Europe have co-creation activities?

The first sub-question was answered with a survey question which required the respondent to identify the activities utilized. This question examined the distribution of co-creation activities which took place within the urban labs and identified the co-creation activities. It is common for self-proclaim urban labs to lack characteristics that are deemed as defining characteristics (Steen and van Bueren, 2017) due to the lack of shared definition in the urban lab literature (Bergvall-Kåreborn et al. 2009, McCormick and Hartmann 2017). However, the urban labs examined in this study employed each aspect of the four main urban labs characteristics (aims, activities, participation, and context) as defined in Steen and van Bueren (2017).

All urban labs assessed in this study were concluded to engage their participants in at least one of the co-creation activities mentioned in Eriksson and Svensson (2009). These activities consisted of future workshops, prototyping, surveys, testing, evaluation, image boarding, interviews, and brainstorm meetings. Extra activities not mentioned in the study but were collected through the survey included symposia, social safaris, focus groups, and placemaking. The literature did not establish an ideal number of co-creation activities for urban labs to utilize, although it mentioned high frequency collaboration could help the success of co-creation outcomes, however, the results derived from the quantitative analysis conclude that the majority of examined urban labs utilized an average of four to five co-creation activities.

The most frequently used co-creation activities were those which the literature depicted to have the highest success for co-creation and knowledge generation, such as future workshops, prototyping, brainstorming meetings, interviews and testing (Eriksson and Svensson, 2009). These are the activities that not only serve as a foundation for the generation of valuable ideas but also make them tangible, leading to new innovative solutions designed to be iterative (Veeckman et al., 2013). Thus, the lack of activities can be problematic for innovation and the impact of urban labs on urban sustainability.

RQ2: Do these urban labs have high, medium (upper), medium (lower), or low co-creation levels?

Urban labs positively impact cities through co-creation as a way to form more robust socio-technical systems and practices (McCormick and Hartmann, 2017). It was requested of the initiators to rate the co-creation levels of the lab. The utilization of initiator perspective would present a most accurate depiction between the target of co-creation focus and the actual reach. The second sub-question was briefly answered through a visual representation of the distribution of co-creation levels was constructed for all urban labs. Most of the observed labs exhibited medium (upper) co-creation levels, while low percentages exhibited either high or low levels of co-creation.

RQ3: How can varying levels of co-creation be explained based on urban lab characteristics?

The third sub-question addresses the broader concept of co-creation level variation explanation based on the four main urban lab characteristics. Differences amongst the impact of the different urban lab characteristics were evident in the analysis of co-creation level variation. Each characteristic had at least one or two indicators that influenced co-creation level, there was no characteristic where all indicators were influential enough to make a significant impact on the variation of co-creation level. To answer this research question, each characteristic of the urban labs with highest and lowest co-creation levels were examined to identify any correlation between performance scores and co-creation levels. The indicators which can best provide explanations for co-creation level variation, as determined by the data analysis, will be further discussed.

Aims and Activities

Co- creation processes have been examined in the literature that reflects upon co-creation experiences in urban labs through methods and techniques, user types, and degree of user involvement. According to the literature, Eriksson and Svensson (2009), urban labs that occupy the methods and techniques, and user types of the creation degree of user involvement should result in high co-creation levels. A high level of co-creation pertains to user feedback being captured iteratively, where participants can make changes to the innovation themselves, and is part of the innovation process (Puerari et al., 2018). However, the research findings did not fully verify this theory of Eriksson and Svensson (2009). The findings reported that out of the ten labs that were found to employ this degree of user involvement, only four were categorized with high co-creation levels, the remaining six urban labs were classified as medium (upper). Not all urban labs that encompassed aspects of this degree of user involvement were classified to have high co-creation levels. Of all labs examined in the study, seven were classified to have high co-creation levels. The three remaining labs that had high co-creation levels but did not fully encompass the qualities of the creation degree, used a variation of two or three co-creation activities utilized in the creation degree of user involvement classification. Explanations for this result could be that the variation in co-creation level, when using the aspects of the creation degree of user involvement, may depend on the capabilities of the initiator to provide a creative environment and group composition that will generate successful outcomes of the co-creation activities utilized to guide future or optimize current designs. Although some labs were found to exhibit high co-creation levels with these qualities, no explanations were provided in the literature for the urban labs which exhibited different qualities with high co-creation levels. Another finding for the analysis of the "Activities" characteristic concluded that the number of activities had no correlation to the level of co-creation. The amount of co-creation

activities of urban labs classified with high levels of co-creation ranged from one activity to nine. The majority of the labs, which engaged in four to five activities, had varying co-creation levels, exhibiting no correlation between number of activities and co-creation success. These results also contradict a point made in the research of Veeckman et al. (2013) which discusses the importance of technical infrastructure for co-creation and innovation assessment, and its availability to participants for monitoring performance throughout urban lab processes. A point verified in this research refers to the importance of value creation for the attraction, retainment, and engagement of participants, but not for co-creation enhancement. Although participant inclusion throughout the urban lab process is crucial for sustaining reflexivity and creates knowledge to inform processes of forging urban sustainability, it does not have enough influence to have a significant influence on overall co-creation levels, contradicting Karvonen and van Heur (2014), Ståhlbröst, (2012), and Voytenko et al. (2016).

The ultimate aim of urban labs is to learn, experiment, and innovate for the purpose of increasing urban sustainability. Determining the aim of the lab sets important conditions for pathways that ensure ambitious innovative solutions developed through co-creation (Klijn and Koppenjan 2000, Markard et al. 2012, Steen and van Bueren 2017). This study reveals that the indicator performances of lab focus, clarity of goals, and goal completion remained most consistent with associated co-creation levels fostered by urban labs. When goals are clear to all participants, and the goal is to both learn and co-create knowledge and physically make something, it creates conditions that significantly effects co-creation levels. This finding is supported by Smith and Raven (2012), Veeckman et al. (2013), and Puerari et al. (2018). The empirical data demonstrated a pronounced degree of correlation between well performing indicators and high co-creation levels. The scores of these three indicators remained most consistent with associated co-creation level. Urban labs that scored well on indicator performance also exhibited high co-creation levels, and vice versa, urban labs with poor indicator performance occupied the low co-creation levels.

The indicator of event frequency and resource availability did not exhibit significant impacts on co-creation levels, as urban labs with poor indicator performance managed to sustain high co-creation levels. Interestingly, this finding did not verify the literature, which portrayed these indicators to have high levels of importance (Eriksson and Svensson 2009, Veeckman et al. 2013). Urban labs which possessed low co-creation levels that had exceptional performance for these indicators were observed in the analysis. This occurrence demonstrates no direct correlation or impact significant enough for the indicators to provide explanation for the variation of co-creation levels within urban labs. Another contradiction to the literature was concluded; the indicators of lab lifespan and usage context research also did not have a direct correlation to co-creation level variation. The literature implies that a longer time period will enable participants to interact and generate additional knowledge, expand audience reach, increase networks, trust and develop relationships that will lead to enhanced co-creation levels (Tanev et al. 2011, Luederitz et al. 2017, McCormick and Hartmann 2017). Another contradiction to the literature is the consideration of context research before the development of the urban lab process, expressed to be an important factor to influence knowledge production and innovative co-creation outcomes (Baxter and Jack 2008, Veeckman et al. 2013). This claim is underpinned by the depiction of urban labs as specific to each site and heterogeneous, easily altered by particular time and location, contributing to the variations of urban lab co-creation experiences and outputs (Jordan and Lenschow 2009, Mulder 2012, Evans and Karvonen 2014). However, no direct correlations were made to high co-creation levels and performance scores of this indicator.

Participation and Context

A total of three indicators were found to have significant influence on the variation of co-creation levels based on urban labs. In the analysis of the partnership exclusivity indicator, neither the urban labs with the highest or lowest co-creation levels had completely exclusive partnerships. This finding was in accordance with existing literature (McCormick and Hartmann 2017, Puerari et al. 2018), regarding the value of obtaining a careful balance between inclusivity and leaderships, exclusivity controlled by a single actor. As suggested in the literature (Tanev et al. 2011, Veeckman et al. 2013, Puerari et al. 2018), it is recommended to avoid fully exclusive partnerships, although this will not guarantee high co-creation levels. A lack of completely exclusive partnerships can benefit the co-creation outcomes of urban labs but may not be sufficient to fully impact the outcome of co-creation level. Further supporting previous studies that emphasize the importance of balance and flexibility in the ownership of urban labs, the findings of the power struggles indicator presents a minor correlation between performance and co-creation level variation. It was determined that poor performance of this indicator can have great influence on co-creation levels due to the higher degree of power struggles with little to no interference from initiators. Thus, it is recommended that there be enough supervision over co-creation activities to ensure there are no power struggles occurring within the urban lab that can hinder co-creation outcomes such as knowledge co-production, learning processes, or innovation ideas. High performance for this indicator alone will not secure high co-creation levels but the prevention of power struggles in co-creation activities will facilitate the urban lab's ability to reach high co-creation levels.

The results derived from the analysis of the predetermination of urban lab structure indicator also reinforced the consensus in the literature that there is a delicate balance between flexibility and structure that would best enable an urban lab to foster high levels of co-creation (Eriksson and Svensson 2009, Mattelmäki and Visser 2011, McCormick and Hartmann 2017). The results derived from these three indicators can serve as possible explanations for variation in urban lab co-creation levels stemming from the “Participation” urban lab characteristic. Participant inclusion did not render as a determining indicator for the explanation of co-creation level variation, important indicator for the enhancement of co-creation levels as suggested by the existing literature (Feurstein et al. 2008, Cadag and Gaillard 2012, Veeckman et al. 2013, Puerari et al. 2018). Whether collaboration was arranged sporadically or continuously was concluded to not have a direct influence on co-creation level variation. This observation challenges the claim made by Puerari et al. (2018), regarding that coupling of sporadic participant inclusion with short term goals will have a negative impact on co-creation levels and urban lab success. The finding derived from the analysis of involved sectors infers that the diversity of sectors involved will not ensure high co-creation levels for the urban labs, opposing remarks from the literature declaring sectoral diversity is crucial for co-creation outputs supporting urban sustainability (Tanev et al. 2011, Westley et al. 2011, Lambert and Allen 2016). All urban labs included at least three sectors throughout the co-creation process, however, no direct correlations were made between the initiating sector, diversity of sectors involved and the variation of co-creation levels. Thus, while diversity of sectors can provide expertise knowledge to forge innovative solutions, it is not a determinant of co-creation level variation. Exposure of intellectual property rights was also not found to directly affect co-creation outcomes that contribute to sustainability, refuting the research of Hezri and Dovers (2006), Veeckman et al. (2013), and Luederitz et al. (2017). Counter to Vivek et al. (2012), the study found that co-creation level variation will not necessarily be limited due to the lack or presence of participant motivation.

Of the context indicators, visibility was determined to be a significant determinant of co-creation level variation. To optimize co-creation processes and overall co-creation level, the existing literature suggests visibility can attract activities, intensify links and connections, and create support beyond the vision and purpose of the urban lab, catalyzing the uptake of innovative sustainable solutions amongst users (Veeckman et al. 2013, Luederitz et al. 2017, McCormick and Hartmann 2017). Substantiating the literature on urban lab visibility, this finding revealed that the better the performance score for these indicators, the higher the co-creation level fostered by the urban lab. Conversely, the urban labs with poor indicator performance occupied the lowest co-creation levels. Due to the consistency between indicator performance and associated co-creation level, it is recommended that urban labs focus extra refinement or improvement efforts on urban lab visibility. High visibility through physical artifacts produced by co-creation activities can help overcome barriers, such as context dependency, to upscale and diffuse co-creation outputs, thereby delivering a well-known symbol of sustainability within the surrounding community to inspire and serve as a demonstration site for initiating further co-creation activities. All urban labs in the study sustained a sense of community ranging from active to passive. While high co-creation levels were not directly correlated with an active sense of community, urban labs that maintained a passive sense of community were associated with low co-creation levels. Although high co-creation levels will not be guaranteed from the successful performance of this one indicator alone, it is recommended to establish an active sense of community, through alignment of shared motivations for collaboration and increased engagement to sustain motivation and encourage valuable interactions, as a foundation to support the performances of the indicators capable of delivering high co-creation levels, such goal clarity (Veeckman et al., 2013).

One of the most prominent features of urban labs is the "real-world" context in which they emerge. Therefore, it was interesting to find that the results of this indicator contradicted studies that communicated high importance of this indicator for generating the necessary urban lab conditions for co-creation success (Yescombe 2011, Veeckman et al. 2013, Archer et al. 2014, Steen and van Bueren 2017). While there may be a need or desire of participants to experience the "real-world" environment, there is no correlation found between the performance of this indicator and the level of co-creation variation. Possible explanation for this occurrence could be that the "real-world" environment contains many complexities and uncontrolled conditions, not necessarily facilitating the co-creation process, but provides a suitable environment for experiments to take place and valuable knowledge to be generated (Evans and Karvonen, 2014). Thus, it can be speculated that this indicator does not provide a significant explanation for variation co-creation levels. Indicators that do not significantly influence co-creation levels should not be discredited, as these indicators could play a significant role in the underpinning of impactful indicators.

MRQ: What is the predominant urban lab characteristic for enhanced levels of co-creation in Europe?

With the guidance of the three research sub-questions, the findings of the main research question were obtained utilizing ordinal logistic regression analysis, first analyzing the significance of each individual characteristic, then a compiled analysis of all characteristics together. Paired with data from the co-creation level variation explanation, these finding suggests that the predominant characteristic for co-creation level enhancement is "Aims". The indicators encompassed within this characteristic are lab focus, goal clarity, goal completion, frequency of open events, lab lifespan, and usage context research. Hence, a

distinct focus on the shaping and planning of the "Aims" aspect in urban lab processes can provide benefits that will enhance co-creation experiences, outputs, and overall levels.

This analysis verifies the research by Voytenko et al. (2015), where the capacity of co-created sustainable contribution by urban labs largely depends on practice design and execution. "Aims" is the characteristic in which participants learn to interact with others in laborious and volatile collaborative processes and understand how to cater to the concerns of others (Mudler 2012, Hakkarainen and Hyysalo 2013). It can determine the extent of learning, success of learning processes that form a pivotal yield for co-creation outcomes (Naumann et al., 2018). The processes of learning and innovation derived from experimentation are fundamental to the function of urban labs. Therefore, the urban lab planning process should assess the quality of the "Aims" aspect when creating or optimizing urban lab processes, paying considerable attention to its six indicators and brief all participants on goals and focus of the urban lab. Responsible for the organizational planning of the lab, the "Aims" characteristic sets the stage for the structure of the urban lab, determining the lab focus, goals, frequency of open events, methods, techniques, and infrastructure (Eriksson and Svensson 2009, Juujärvi and Pesso 2013, Den Ouden et al. 2016, Steen and van Bueren 2017). Without organizational clarity, the successful delivery of co-creation outputs will prove to be difficult.

5.1 Limitations

Based on the research findings and data analysis process, several limitations can be addressed. Apart from contributing to the literature and knowledge on co-creation in urban labs in Europe, this study also provides a new analytical framework for the evaluation of characteristic performance. This strategy can be used to evaluate and measure the levels of co-creation within labs, contributing to refinement and improvement of urban lab processes. However, due to a small sample size and diverse context of urban labs, these demographic observations cannot be confirmed as the general averages of all urban labs throughout Europe.

Time limitations were emergent and influenced the scope of the research. The depth at which variables were examined was limited and made general due to the wide variety of variables that could have been considered urban lab characteristics and the scale of urban labs observed. Regarding the third research sub-question, three limitations were encountered in respect to the measurement of co-creation levels. First, the lack of literature regarding consensus on co-creation levels and its measurement impedes the accuracy at which co-creation level is measured. Future studies on this research topic would either have to utilize the same methodology and analysis framework as this study or further elaborate upon it. Second, the analysis approach for this sub-question was dependent on the study of Puerari et al. (2018). Due to the wide geographical range of this study, it would be difficult to visit and assess each urban lab through a researcher lens, therefore, a limitation exists due to the dependency on urban lab initiators to record and deliver empirical data, which is also limited by a Likert scale with the option of four answer choices. Third, this dependency further inhibits the research due to subjective human perception, which can hinder the accuracy of the empirical data. Therefore, pre-selected answers of the survey were made to be as detailed as possible to increase the accuracy of the answer the initiator identified with. Lastly, each urban lab is unique in composition, therefore, it is possible that these results may not substantiate all urban labs.

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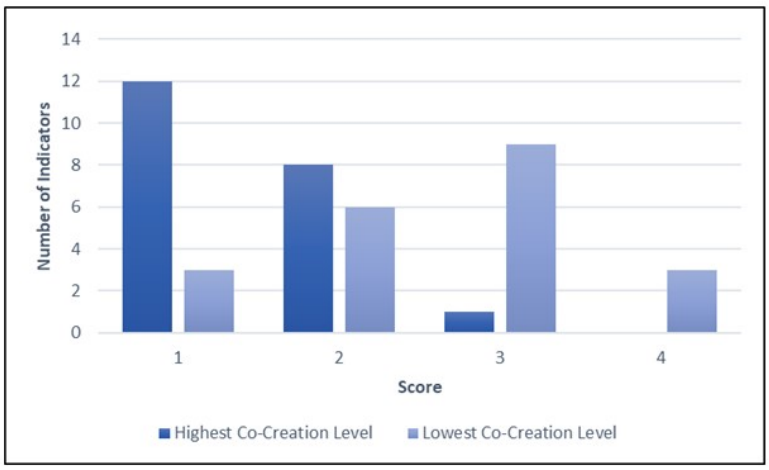
Annex 1: Indicator Score Distribution

Figure 12 provides a visual comparison of the characteristic indicator scores for the urban lab highest and lowest co-creation levels. All scores for urban lab characteristics were analyzed on a Likert scale where a score of 1 is best performance and a score of 4 is poor performance.



Source: Researcher's own adaption of principles and concepts

Figure 12: Displays the distribution of indicator scores for the urban lab with highest co-creation levels and the urban lab with lowest co-creation levels.

First, the urban lab with highest co-creation levels was analyzed. The first set of indicators with the best performance outcomes, with a score of one, included 57% of the "Aims" indicators. Other indicators exhibited were value creation, sharing of intellectual property rights, duration of participant inclusion, large scale, high visibility, and active sense of community. 50% of total indicators scored a one. The next set of indicators with the best performance outcomes, with a score of two, are comprised of 33% of total indicators. These included goal completion, technical infrastructure (basic monitoring and technical testing), predetermination of structure, low degree of power struggles, motivations, consensus on co-creation activities, and "real-world" context. Only one indicator, resource availability scored a three, indicating a low availability of resources. No indicators performed with a score of four. This high co-creation level urban lab participated in over nine co-creation activities (All mentioned in the study and more), involved all four sectors, and was initiated by the private sector.

Second, the urban lab with lowest co-creation levels was examined. About 14 % of total indicators scored a one for indicator performance. This included lifespan of lab (over two years), degree of usage context research, and "real-world" context. The second set of best performing indicators, which scored a two, encompasses the resource availability, participant inclusion, degree of intellectual property rights shared, value creation and technical infrastructure. Most indicators, 42%, scored a three for performance, comprised by low visibility, passive sense of community, exclusivity, frequency of open events, goal completion, clarity of goals, lab focus, and predetermination of structure. The poor performing indicators, occupying a score of one, included high degrees of power struggles, scale, and consensus of co-creation activities. This urban lab participated in three co-creation activities, had three sectors involved (omitted citizens), and was initiated by knowledge institutions.

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