UNIVERSIDADE DE SÃO PAULO
FACULDADE DE ECONOMIA ADMINISTRAÇÃO E CONTABILIDADE

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Living labs contributions to smart cities from a quadruple-helix perspective

Contribuições dos living labs para cidades inteligentes sob a perspectiva da quádrupla-helix

São Paulo
2020

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Tese apresentada ao Programa de Pós-Graduação em Administração do Departamento de Economia/Administração/Contabilidade da Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo, como requisito parcial para obtenção do título de título de Doutor em Ciências.

Área de Concentração: Administração Geral

Orientador: Prof. Dr. Gilmar Masiero

Versão Corrigida

(versão original disponível na Biblioteca da Faculdade de Economia, Administração e Contabilidade)

São Paulo
2020

Catalogação na Publicação (CIP)
Ficha Catalográfica com dados inseridos pelo autor

Esashika, Daniel.
Living labs contributions to smart cities from a quadruple-helix perspective / Daniel Esashika. - São Paulo, 2020.
88 p.

Tese (Doutorado) - Universidade de São Paulo, 2020.
Orientador: Gilmar Masiero.

1. Administração Pública. 2. Desenvolvimento Urbano. 3. Inovação. I. Universidade de São Paulo. Faculdade de Economia, Administração e Contabilidade. II. Título.

Banca examinadora

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I dedicate this study to my family,

who supported me throughout this journey.

ACKNOWLEDGMENTS

I owe a debt of gratitude to my advisor, Gilmar Masiero. His help was undoubtedly crucial for me to become a more critical researcher in my work.

A special thanks to all the teachers I had during the doctorate in the University of São Paulo: João Maurício Boaventura (USP), Eduardo Vasconcellos (USP), Gilmar Masiero (USP), Adolpho Canton (USP), Maria Aparecida (USP), Max von Zedtwitz (the University of St. Gallen), Derek Beach (University of Aarhus), Eric van Heck (Erasmus University), and Nathalie Mitev (King's College London).

I thank each of them for the lessons learned.

Finally, I thank the Chamber of Deputies for having authorised me to attend this doctorate. My retribution to this effort is embodied in this dissertation and in the collaborations I made with the Brazilian Charter of Smart Cities and the Chamber of Deputies' study, "Smart Cities: a human and sustainable approach".

ABSTRACT

This dissertation offers an assessment of the living labs' contributions to smart cities from a quadruple-helix perspective presented in five chapters: introduction, three papers, and a conclusion. The first paper addresses the controversy over the definition of a smart city. In this sense, we offer a meta-synthesis of studies that revised smart cities' concepts. There are five characteristics found in the literature to describe a smart city: a) advanced ICT technology; b) sustainability; c) innovative and high skilled society; d) high tech governance and citizen participation; and e) knowledge-based economy. The second paper addresses the different approaches to assessing smart cities. We carried out a systematic review of the literature to describe models for evaluating smart cities. Besides the rankings approach, highlighted in the academic literature and specialised media, we identified three other approaches: data-driven management, maturity level, and innovation ecosystems. Finally, in the third paper, we explore the living labs' contributions to smart cities from a quadruple-helix perspective, the central aspect of this dissertation. We conduct exploratory case studies. The selected cases (Living Lab Florianópolis, Living Lab of the Itaipu Technological Park, and Porto Digital) are part of an institutional context characterised by a low interaction between the quadruple-helix components. The data were obtained through documentary analysis and interviews with the organisers and participants of the living labs. The results suggest that living labs can contribute by a) selecting the most promising projects to be promoted; b) connecting quadruple helix components through collaborative practices and events; c) facilitating mediation between participants in living labs and government agencies, universities, and local companies to conduct tests; and d) insertion of the fourth helix as a tester, but not as a co-creator. These results contradict the notion that living labs are based on user-oriented innovation processes and suggest a producer-oriented trajectory.

Keywords: smart cities, living labs, quadruple-helix, innovation

RESUMO

A presente tese oferece uma avaliação das contribuições dos laboratórios vivos para o as cidades inteligentes sob a perspectiva da hélice quádrupla. A tese possui cinco capítulos: introdução, três artigos, e uma conclusão. O primeiro artigo aborda a controvérsia sobre uma definição de cidade inteligente. Destacam-se cinco características encontradas na literatura para descrever cidade inteligente: a) tecnologia avançada em TIC; b) sustentabilidade; c) sociedade inovadora e altamente qualificada; d) governança de alta tecnologia e participação social; e e) economia baseada no conhecimento. O segundo artigo debate as diferentes abordagens sobre avaliação de cidades inteligentes. Realizamos uma revisão sistemática da literatura com o intuito de descrever as existentes em relação à avaliação de cidades inteligentes. Para além de rankings, destacados na literatura acadêmica e mídia especializada, identificamos outras três abordagens: da gestão orientada a dados, do nível de maturidade; e, dos ecossistemas de inovação. Por fim, no terceiro artigo exploramos as contribuições dos laboratórios vivos para cidades inteligentes a partir de uma perspectiva de hélice quádrupla, sendo este o aspecto central desta tese. Nesse sentido, realizamos estudos de caso exploratórios. Os casos selecionados (Living Lab Florianópolis, Living Lab do Parque Tecnológico Itaipu e Porto Digital) fazem parte de um contexto institucional caracterizado pela baixa interação entre os componentes da hélice quádrupla. Os dados foram obtidos por meio de análise documental e entrevistas com os organizadores e participantes dos laboratórios vivos. Os resultados sugerem que os laboratórios vivos podem contribuir a) selecionando os projetos mais promissores a serem promovidos; b) conectando componentes de hélice quádrupla por meio de práticas e eventos colaborativos; c) facilitando a mediação entre participantes de laboratórios vivos e órgãos governamentais, universidades e empresas locais para realização de testes; e d) inserindo a quarta hélice como testadora no processo de inovação, mas não como co-criadora. Esses resultados contradizem a noção de que os laboratórios vivos se baseiam em processos de inovação orientados para o usuário e sugerem uma trajetória orientada para o produtor.

Palavras-chave: cidades inteligentes, laboratórios vivos, hélice quádrupla, inovação.

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SUMMARY

1. INTRODUCTION

According to the World Urbanization Prospects report (UN, 2018), in 2018, 55% of the world's population was living in metropolitan areas, a significant growth compared to the 1950 survey that presented the urban population representing 30% of the global population. For Henderson (2000), the process of urbanisation and economic growth are strongly related due to the transition from an agriculture-based economy to one based on industry and services. Among the challenges is the scarcity of resources, inadequacy, and deterioration of cities' infrastructure, economic and social demands, concerns with environmental issues, and society (Washburn *et al.*, 2010; Debnath *et al.*, 2014; Jong *et al.*, 2015).

Regarding the scarcity of resources, the most important is the limitation of access to services such as energy (Lee & Lee, 2014), health (Zubizarreta *et al.*, 2016), housing (Yigitcanlar *et al.*, 2018), and water (Anda *et al.*, 2013). Access to essential services can be hampered not only by the absence of natural resources but also by the mismanagement of resources. Cities around the world are becoming bigger and much more complex to be effectively managed.

Concerning the deterioration of urban infrastructure, the precariousness of components, such as schools, roads, highways, sanitation, bridges, electric grid, among others, stands out (Lee *et al.*, 2008; Tomitsch *et al.*, 2015). The deterioration is because of the inability to provide infrastructure following the growth rate of the urban population. In this sense, they are directly affected by the lack of adequate infrastructure, mainly to the C and D classes.

The growing concern about the global temperature increase is highlighted, with catastrophic consequences in food production and public health (Bibri, 2018). The expansion of fossil fuels is partly attributed to urban growth because of the use of private vehicles in large centres. Also, urbanization and urban agglomeration have brought new socioeconomic challenges of integrating the population who migrated from rural and peripheral areas to metropolitan areas attracted by opportunities for a better life (Deakin, 2014; Mital *et al.*, 2017; Yigitcanlar *et al.*, 2018).

Integrating everybody in a citizen participatory system is one of the most urgent demands of smart cities (Engelbert *et al.*, 2018; Cardulo *et al.*, 2018). There are several obstacles to greater societal participation in city governance. For instance, technical barriers were identified for using the data available (Zuiderwijk *et al.*, 2012) and the need to strengthen civic engagement (Gagliardi *et al.*, 2017). However, several authors consider living labs a viable alternative to overcome these problems (Deakin, 2014; Vallicelli, 2017; Han & Hawken, 2018; Andreani *et al.*, 2018). Living labs have emerged at *Massachusetts Institute of*

Technology, MIT – as a place for user co-creation of innovations (Burbridge, 2017). The livings labs have become a useful alternative for collaborative development in smart cities, with citizens and other important stakeholders (Gascó, 2017, Canzler *et al.*, 2017).

Because of these issues, it is possible to understand how the urbanisation process has brought complex challenges to be overcome by public management. The design of smart cities is recognised as a potential solution to solve urbanisation problems (Kim, 2015). Sensitive and intelligent technologies have added and interconnected the management of critical aspects of infrastructure and life services in cities, such as management, health, safety, housing, and transportation (Washburn *et al.*, 2010).

In this sense, there is a strong appeal for cities and public managers to insert themselves into the global movement around the transformation of non-smart cities into smart ones. This dissertation explores topics that have not yet been analysed in the literature of smart cities. The first issue is related to the consolidation of an exciting concept for a smart city based on the literature reviews' meta-synthesis carried out until 2020. The second deals with the organisation of approaches for the smart city's assessment, and finally, we will assess the living labs' contribution to smart cities from a quadruple-helix perspective.

1.1. Relevance

Smart city assessment is particularly important because of the relevance to the political and academic guidelines in urban development (Yigitcanlar, 2017; Bibri, 2018; Nilssen, 2018). Despite being a field with almost two decades of existence, there are fundamental points still unresolved, such as defining what would be considered a smart city. In this sense, we have three challenges to overcome throughout this dissertation.

The first challenge concerns the difficulty of understanding what means to be a smart city because this meaning is not yet consolidated in the literature (Caragliu *et al.*, 2011; Chourabi *et al.*, 2012; Marsal-Llacuna *et al.*, 2015; Camboim *et al.*, 2018). Thereby, new aspects are included in the definition throughout the process. An example is the society's inclusion as an inherent part of the smart city concept (Hollands, 2008; Nam & Pardo, 2011, Vanolo, 2014). This view contrasts with the initial definition of smart city, which was circumscribed by a technological phenomenon (Kummitha & Crutzen, 2017). New meanings should be added to the theoretical framework of the subject. This work is a contribution to provide a comprehensive view of the current definitions.

The second challenge concerns the lack of research on the smart cities' assessment approaches (Caird, 2018; Fernandez-Anez *et al.*, 2018). There is a proliferation of academic and non-academic assessment models based strictly on economic point of views. An example of this is the ranking proposed by Forbes magazine in an exclusive editorial published annually since 2014, Cities in Motion, in partnership with the IESE Business School of the University of Navarra (Berrone & Ricart, 2018). The ranking approach for evaluating the best smart cities has contributed to an excessive standardisation, a process criticised in the literature, and called "*smart city in a box*" (Hollands, 2008; Calzada & Cobo, 2015). The wide dissemination and acceptance of ranking-based assessment models is justified by the positive marketing-generated for the city (Larsen, 2015) and has even influenced the development plans of new smart cities, which are shaped to get better results in rankings (Giffinger et al., 2010; Escolar et al., 2018).

Based on the research lines identified in the literature when concluding a conceptual analysis of smart cities, we investigated the development of the knowledge-based economy, addressing a central issue in the relationship between the university, business, and government, known as the triple helix. We describe the functioning of living labs as a new institutional arrangement involving the triple-helix components. Particularly in smart cities, we investigate how living labs can contribute to include one more helix in the innovation process, civil society, and foster the relationship of quadruple-helix networks to generate open innovations aiming smart city's development.

The third challenge is to assess the living labs' contributions to innovation in smart cities. In this study, we propose an evaluation of the contribution of the living labs to the strengthening innovation in smart cities from the quadruple-helix perspective. Several authors point out the living labs could be one of the central elements for the smart cities development (Baccarne *et al.*, 2016; Canzler *et al.*, 2017; Burbridge, 2017; Rodrigues & Franco, 2018; Ballon *et al.*, 2018). In this dissertation, we defend the thesis that living labs are a strategy for promoting co-creation among stakeholders in smart cities. Also, we hope to explain how living labs contribute to smart cities and a description of the roles played by the quadruple-helix components in a living lab.

1.2. Structure

The present dissertation has six parts, including this introduction, which describes a general overview of smart cities' innovation. We present three Chapters each related to a single aspect of of smart cities not previously considered in the increasing literature on the subject. The first chapter addresses the controversy over the definition of a smart city that was the baseline to develop the second on the different approaches to assessing smart cities. Based on these two studies we design and developed the third one exploring the living labs' contributions to smart cities from a quadruple-helix perspective. All the chapters were transformed in articles and the first two were approved to be presented at XLIV Encontro da ANPAD - EnANPAD 2020. The three chapters are been edited to be submitted, respectively, to Journal Technology Analysis & Strategic Management; Journal of Urban Technology and Technological Forecasting and Social Change. We present the research effort as dissertation chapters, in the following order:

Chapter 2 - "A Meta-Synthesis of the Smart City".

In Chapter 2, we look for an equation of systematic literature reviews on smart cities. This systematic review is a necessary initial effort because before knowing how to assess a smart city, it was necessary to understand a smart city's meaning. In this chapter, we answer two questions: How can a smart city be defined? What are the main characteristics of a smart city? Several authors have identified a lack of agreement on smart city definition despite almost two decades of research on smart cities. This chapter explains the smart cities concept, based on studies that have reviewed definitions. Drawing a meta-synthesis study, we found convergences in smart cities' main characteristics and classification systems used to analyse the definitions. The study is a robust effort to understand smart cities and presents a theoretical framework; scholars and governments can use to design coherent public policies accurately.

Chapter 3 - "How do we evaluate smart cities? A review of four approaches".

Chapter 3 delves deeper into analysing smart city appraisal models to prepare for the studies proposed in Chapters 3 and 4. The chapter aims to develop a clearer understanding of possibilities for smart city assessment. This research's methodological approach includes a systematic literature review on smart city assessment models, focusing on those aimed at conceptual development and providing empirical evidence examples. The review identifies four different smart cities assessment approaches - Ranking Approach, Data-driven Management Approach, Innovation Ecosystem Approach, and Maturity Approach. Subsequently, we use the

Delphi method to check the proposed framework's validity with senior scholars researching smart cities. This paper helps to expand our understanding of the different approaches to smart city assessment.

Chapter 4 - "Living labs' contributions to smart cities from a quadruple-helix perspective: experiences in Living Lab Florianópolis, Itaipu Technological Park, and Porto Digital".

We explore the living labs' contributions to smart cities from a quadruple-helix perspective. We conduct exploratory case studies. The selected cases (Living Lab Florianópolis, Living Lab of the Itaipu Technological Park, and Porto Digital) are part of an institutional context characterised by a low interaction between the quadruple-helix components. The data were obtained through documentary analysis and interviews with the organisers and participants of the living labs. The results suggest that living labs can contribute by a) selecting the most promising projects to be promoted; b) connecting quadruple helix components through collaborative practices and events; c) facilitating mediation between participants in living labs and government agencies, universities, and local companies to conduct tests; and d) insertion of the fourth helix as a tester, but not as a co-creator. These results contradict the notion that living labs are predominantly based on user-oriented innovation processes and suggest a producer-oriented trajectory.

In our final chapter 5 we present a brief conclusion considering the three chapters showing their interconnections. After we became aware of the many meanings of the concept of smart city we realize that an investigation into the elusive concept of smart cities through a systematic review and meta-synthesis was necessary. We realize that there was not an encompassing concept in the literature that would be supporting our research effort on living labs' contributions to smart cities from a quadruple-helix perspective. While reviewing the literature on the concepts of smart cities we also became aware that there are multiple approaches to assess them. As we did not kwon which one would be more adequate to our investigation we developed another systematic review on how to assess smart cities.

These two research efforts, even though based on secondary data, were extremely important to have a better delineation of the third research effort, which was based not only in secondary data but also primary one. More important than the data prospected for this particular study is the fact that it was developed in a Brazilian context. Three Brazilian living labs were studied based on the concepts and assessments' of smart cities previously discussed. Having a broad idea of the different concepts and assessment approaches of smart cities it was possible to investigate three different experiences of living labs in the Brazilian context. The findings of the three studies, specially the third one add new knowledge to field and may help public and private managers in their deals with making the nowadays cities smarter.

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2. AN INVESTIGATION INTO THE ELUSIVE CONCEPT OF SMART CITIES: A SYSTEMATIC REVIEW AND META-SYNTHESIS[1]

Abstract: Despite almost two decades of research, authors have disagreed about the concept of smart cities. In this article, we provide a systematic review and a meta-synthesis analysis of smart cities. We find a convergence in the literature on the following primary characteristics of smart cities: a) advanced ICT Technology, b) sustainability, c) innovative and high-skilled society, d) high-tech governance and citizen participation, and e) knowledge-based economy. Based on these findings, we suggest a new notion: A smart city engenders an innovative and qualified society, oriented towards the development of the knowledge economy, which makes advanced ICT technologies aimed at promoting sustainability and participatory urban governance. Our study robustly offers an understanding of smart cities and presents a creative perception encompassing these five principal characteristics worthy of further investigation.
Keywords: smart city, systematic review, meta-synthesis

2.1. Introduction

Many authors have pointed out the potential benefits of information use for city management, especially to heighten efficiency (Bulu, 2014; Albino et al., 2015; Belanche-Garcia et al., 2015). Information technology (IT) has promoted profound social changes, significantly transforming large urban centers (Barns et al., 2017). Urban infrastructure has undergone technology instrumentation delivering and analysing complex real-time data, such as the Internet of Things (IoT), autonomous systems, cloud and cognitive computing (Steele, 2017; Mohamed et al., 2018; Krishna et al., 2019). Some scholars have highlighted the positive results of integrating infrastructure to streamline urban services (Kumar et al., 2018). The modernization of Dubai, in 1999, introduced the smart city (Anthopoulos, 2017). One of the critical milestones propelling this city entailed the Kyoto Protocol in 1997, as it brought innovative perspectives about modern cities, especially concerning sustainability (Cocchia, 2014). In 2010, another critical breakthrough constituted the Europe 2020 Strategy policy, giving prominence to smart cities and growth. Since then, academics have remained interested in the subject, sparking many empirical articles (Dameri & Cocchia, 2013).

[1] Approved at congress XLIV Encontro da ANPAD- EnANPAD 2020 and submitted to journal Technology Analysis & Strategic Management.

Despite two decades of scientific investigation, the controversy over defining a smart city remains heated (Chourabi et al., 2012; Marsal-Llachuna et al., 2015; Schiavone et al., 2019). Several authors have illustrated the complexity of indorsing this idea as a generic solution to urban developmental problems (Caragliu et al., 2011; Datta, 2015). A consensual definition of smart cities does not exist, making the questions of this study relevant. How does one define a smart city? What embodies the primary characteristics of a smart city? Answering these questions represents the core goal of this article. To address them, we developed a meta-synthesis of systematic reviews exploring the smart city topic.

Identifying common aspects in the definitions of smart cities unveils the idea is not as fuzzy as contended. The study clarifies more commonalities than divergences in the purposes of smart cities. In this sense, it disseminates smart cities and develops public policies based on researchers' consensus to guide politicians and decision-makers more precisely.

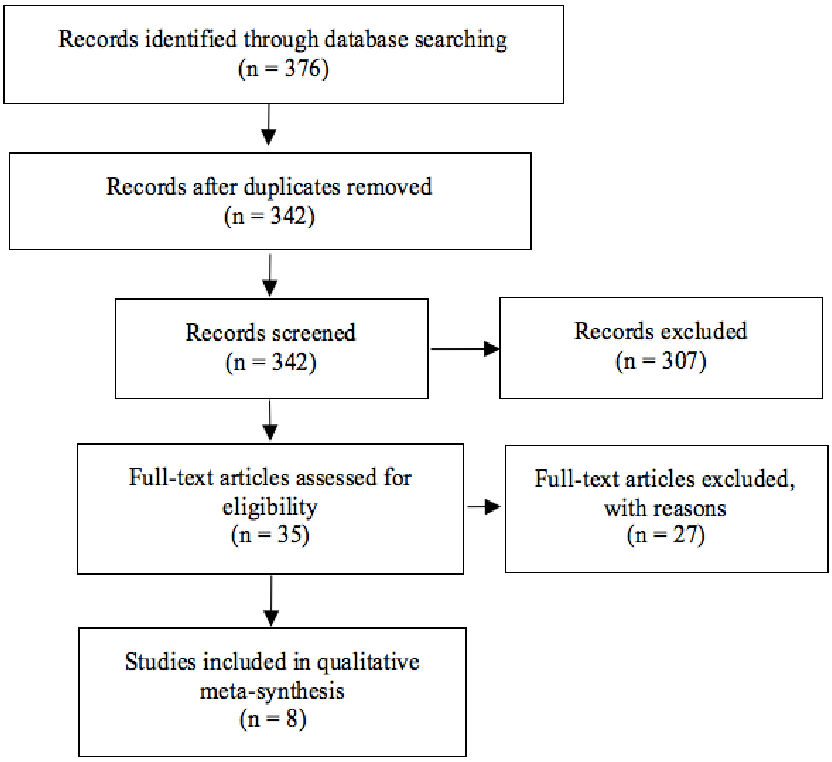
Our investigation comprises five sections, including the introduction. In section 2, we describe the procedures used in the systematic literature review and meta-synthesis. In section 3, we outline the reviewed studies. Section 4 synthesises and discusses the results, while section 5 concludes with the primary findings and the implications for theory and practice.

2.2. Materials and Methods

In this research, we performed a meta-synthesis based on systematic literature reviews investigating the smart city. We used the periodic literature review to select the studies composing the meta-synthesis sample. We elaborate on two research questions: "How does one define a smart city?" and "What embodies the primary characteristics of a smart city?" Our primary goal is to explore the literature to establish an integrated smart city concept based on comparing the systematisations of smart city definitions other well-known, respected researchers have performed. Each study's contribution helped identify subject convergences and divergences.

Based on the research questions, we conducted a systematic literature review using the 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA), ensuring transparent and complete reporting (Liberati et al., 2009; Moher et al., 2009; Wray et al., 2018). Despite the emergence in health studies, it has been widely used in systematic literature reviews in the social sciences (Cucciniello et al., 2016; Voorberg et al., 2017; Mergela et al., 2018; Ianiello et al., 2019). Figure 2.1 shows the research phases of the PRISMA procedure in our study.

Figure 2.1 - Search strategy flow diagram



Source: Authors' elaboration

Our search encompassed the period from 1997 to 2020, including the beginning of the Kyoto Protocol in 1997, one milestone for developing smart cities. Nonetheless, we have identified significant results for meta-synthesis solely from 2015. Through a preliminary literature analysis, discussed among the researchers, we used six expressions normally associated with the subject: “smart cities definition,” “smart cities core components,” “smart cities bibliometric,” “smart cities characteristics” and “smart cities perspectives.”

The keywords were combined to assemble a series of strings, on which to search in the databases. By joining keywords through simple operators and Boolean logic, complex searches were constructed to avoid generic and broad results; "smart city AND definition," "smart cities AND core components," "smart cities AND bibliometric," "smart cities AND characteristics," “smart cities AND systematic literature review," “smart cities AND perspectives," as well as derivatives of these terms.

The articles searched came from various academic databases: Web of Science, Scopus, Elsevier's Science Direct, Oxford Journals, Taylor and Francis, and Springer Link. The databases were selected because they include theoretical studies, and scholars have used them as sources for other systematic literature reviews related to smart cities (Mora et al., 2017; Kummitha & Crutzen, 2017; Camboim et al., 2018; Yigitcanlar et al., 2018).

In the initial search, we found 376 peer-reviewed papers. The exclusion criteria entailed: (1) full-text not available within the selected database, (2) article not written in English and (3) article or review published in a book. Next, we removed duplicate items. Hence, 342 articles remained. Two researchers applied the guidelines of the conventional systematic review, inclusion criteria to the 342 studies. The inclusion standards for our sample consisted of: (1) publication represented a systematic literature review, with defined research questions, search process, data extraction and data presentation, (2) journal reflected an academic and peer-reviewed publications, (3) publication investigated the smart city concept, (4) the study incorporated keywords and Boolean operators used, (5) publication reported the databases used. In case of doubt, the researchers included the paper in the sample of what they would fully read.

After the record screen, the researches selected 35 articles for entire-text assessment. We completely read them to see the detailed procedures and findings, checking the inclusion criteria. Among the 35 items, eight portrayed systematic reviews of the concept of smart cities, and we used them in the meta-synthesis. Markedly, the first criterion (the article must represent a systematic literature review) most affected the sample selection, given researchers use this approach less commonly. The selected sample of the published articles earned an impact factor superior to 2.0, h-index higher than 25 or Scimago Q2 or higher. Table 2.1 displays the journal quality.

Notably, meta-synthesis does not use vast literature (Noblit & Hare, 1999; Clemmens, 2003). In meta-synthesis, pundits observe the source quality rather than the quantity. Exclusively selecting articles published in peer-review journals and the search process transparency generated a rigorous meta-synthesis study (Walsh & Downe, 2005; Hoon, 2013).

Meta-synthesis is defined as a qualitative study using the results of other qualitative studies related to a research topic (Zimmer, 2006). It involves aggregating and interpreting non- quantitative findings (Finfgeld-Connett, 2010). Experts in several fields have employed meta-syntheses, such as social sciences, education and marketing (Siau & Long, 2005; Lee, 2010; Vrontis et al., 2016). Specifically, urban study scholars have used meta-synthesis (Retzlaff, 2010; Karpouzoglou & Zimmer, 2016; Arafah & Winarso, 2017).

Meta-summaries (Sandelowskiet al., 2007), meta-ethnography (Paterson, 2001), and grounded theory (Kearney, 1998) exemplify methods used to develop meta-synthesis. In this study, we employed a meta-ethnographic, following the stages Noblit and Hare (1999) proposed to interpret, translate, and synthesise the literature already systematically reviewed. Our focus is to present existing relationships between studies while preserving and revealing differences between them. Moreover, we used content analysis (Krippendorff, 1980; Elo & Kyngäs, 2008) to look for metaphors, phrases, ideas expressing the smart city topic. Results were crossed among the various studies to understand the smart city holistically.

2.3. Description of Studies Reviewed

In this section, we present the results of the literature selected according to the criteria. The chosen studies represented systematic literature reviews. Therefore, their products synthesized smart city characteristics respected researchers referred to in several studies.

In "Smart Cities: Definitions, dimensions, performance and initiatives," Albino et al. (2015) conducted an extensive literature review and presented definitions of smart cities divided into two domains: hard and soft.

(1) Hard domains represent constructions, energy networks, natural resources, water resource management, urban waste management, mobility, and logistics. In this group, technology plays a vital role in more efficient system operation.

(2) Soft domains consist of education, culture, innovation policies, social inclusion and government. In this cluster, technology is not decisive, but it can contribute as an intermediary for efficient relationships.

In "What makes a city smart? Identifying core components and proposing an integrative and comprehensive conceptualization," Gil-Garcia et al. (2015) identified four essential components in smart city definitions: environmental, societal, governmental and technological/data.

(1) Environmental elements entail natural environment/sustainability and city infrastructure.

(2) Societal components engender a knowledge-based economy and environment favouring business, human capital and creativity, governance, engagement, and collaboration.

(3) Government facets embody institutional arrangements, city management and administration, and public services.

(4) Technological/data items involve communication and information technologies oriented for data and information.

In "Smart, sustainable cities of the future: An extensive interdisciplinary literature review," Bibri and Krogstie (2017) revealed two mainstream approaches to smart cities:

(1) The technology and ICT-oriented approach focus on the efficiency and hard infrastructure and technology advancement (transport, energy, communication, waste and water) through ICT.
(2) The people-oriented approach concentrates on the soft infrastructure and people, especially social and human capital, in terms of knowledge, participation, equity and safety.

In “The first two decades of smart-city research: a bibliometric analysis,” Mora et al. (2017) carried out a bibliometric study and proposed a network analysis. They defined two primary groups: holistic and technocentric.

(1) The holistic group exemplifies a balanced view of human, social, cultural, economic, environmental and technological aspects. Giffinger et al. (2007) and other well-quoted smart city scholars provided the principal link (Hollands, 2008; Caragliu et al., 2011; Schaffers et al., 2011). A network between documents collected evidenced the knowledge exchange among related researchers characterised this collection.
(2) The Technocentric group offers a technological vision of smart cities composed of disconnected documents.

In “How do we understand smart cities? An evolutionary perspective,” Kummitha and Crutzen (2017), based the results of the literature review, proposing a division of studies on smart cities into four schools: restrictive, reflective, rational or pragmatic and critical

(1) The restrictive school maintains high technological relevance and low human aspect. This school primarily focuses on the technology used to operationalize a smart city, chiefly integrating ICT devices, connectivity and data production (Calzada & Cobo, 2015).
(2) The reflective school proposes a more significant interaction between humans and technology in smart cities. For the authors of this school, technology stimulates human capacity and knowledge, contributing to social improvement in a locality. Technology enhances citizens’ ability to innovate and solve the city’s social problems.

Table 2.1 - Eight studies included in our meta-synthesis

ID	Author	Date	Topic Area	Database consulted	Studies reviewed	Citations
S1	Albino et al.	2015	Smart city definition and measurement	Academic databases.	82	1620
S2	Gil-Garcia et al.	2015	Core components	Academic databases and Google Scholar	209	199
S3	Bibri and Krogstie	2017	Sustainability	Academic databases and Google Scholar	187	402
S4	Mora et al.	2017	Bibliometric study of smart cities scientific production	Google Scholar; ISI Web of Science; IEEE Xplore; Scopus; SpringerLink; Engineering Village; ScienceDirect; and Taylor and Francis Online	1067	155
S5	Kummitha and Crutzen	2017	Smart city definition	Wiley online library, the Oxford Journals database, Taylor and Francis, Springer Link, Scopus, Sage, and Elsevier's ScienceDirect	161	191
S6	Camboim et al.	2018	Creativity and innovation	Web of Science and Scopus Elsevier	110	21
S7	Yigitcanlar et al.	2018	Drivers of smart cities	Three hundred ninety-three different databases, including ScienceDirect, Scopus, Web of Science, Wiley online library, a Directory of open access journals.	78	117
S8	Ismagilova et al.	2019	Information System	Journals listed in the 'Information Management' category of the Academic Journal Guide 2018	104	119

Source: Authors' elaboration

(3) The rational or pragmatic school is based on the belief the development of intelligent communities characterises a smart city. Local communities' capabilities drive the smart city. Thus, factors such as education, social learning and human capital depict fundamental aspects of intelligent city characterisation. These capabilities mediate human interactions and technology. Also, it emphasises the role of citizens in the design, construction and maintenance of smart cities. In this light, creating new democratic governance structures and processes empowers citizens and communities to bring intelligence to towns.

(4) The critical school does not indicate a clear smart city definition. Despite this, the authors have pointed out imperfections and gaps in the descriptions and beliefs of other schools. They criticised the imprecision of what embodies a smart city, with several towns worldwide self-proclaiming their intelligence without having human or technological conditions for it (Bunnell, 2015).

In "Driving elements to make cities smarter: Evidence from European projects," Camboim et al. (2018) identified four smart cities dimensions: governance, environmental, socio-institutional and techno-economic.

(1) Governance focuses on collaboration between stakeholders actively participating in a collective decision-making process to make or implement public policy or manage public programs or assets.

(2) The environmental-urban dimension relates to the built infrastructure, mobility, urban design, facilities and amenities, and natural environment.

(3) The socio-institutional element relates to diversity and plurality, civic engagement and social cohesion and normative-legal framework. This dimension encompasses formal (rules, laws and municipal ordinances) and informal institutions (partnerships, negotiations, and networks) arranged to solve problems, enforce rules, or allocate resources.

(4) Techno-economic facets consider knowledge economy dynamics. This dimension comprehends all aspects can foster innovation and entrepreneurship activities in a "glocally."

In "Understanding 'smart cities': Intertwining development drivers with desired outcomes in a multidimensional framework," Yigitcanlar et al. (2018) presented five domain-orientation to deal with the concept of smart cities: technology, economy, society, environment and governance.

(1) Technology, according to this domain, views smart cities predominantly as techno-centric urbanisation. In several studies, it embodies the contribution of technology to improve urban system functioning.
(2) Economy studies examine smart city policies promoting better public economic performance. Besides, highlighting the role of new creatures, not only innovative technologies but also professional knowledge of their development.
(3) Society highlights the need to overcome the risks of social exclusion and gentrification. In this sense, the proposed solution concerns local actors and communities when developing smart cities.
(4) The environment illustrates the negative impacts of developed, intelligent city projects. Little empirical evidence regarding the benefits of smart cities on the environment and sustainability exists. To solve the environmental problems of smart cities, the authors suggested including citizens in urban development to embrace ecological protection.
(5) Governance entails the criticisms of the top-down model prevalent in Asian countries. As a solution, they point to the triple-helix model, showcasing the collaboration between the actors (universities, government and business) promoting participatory governance and expanding new technologies.

In "Smart cities: Advances in research - An information systems perspective," Ismgilova et al. (2019) identified in literature four emphases regarding the definitions of smart cities: technology, citizens, management and operational, well-being and sustainability.

(1) Technology encompasses the technological aspects, including the use of intelligent hardware devices. Technology helps to enable social, environmental, economic and cultural progress.
(2) Citizens engender smart inhabitants, education, social interaction quality, integration with public life and openness to the broader world.
(3) Management and operational definitions focus on the improvement of city management and governance using intelligent technologies.
(4) Well-being and sustainability in these definitions, signify the balance between the economic needs and the quality of life, recognising the sustainable development of the cities remains explicit.

Considering the characteristics identified by these works, we carry out a translation and synthesis process. We discuss these two approaches in the following item.

2.4. Discussion

We divided the discussion into two parts (translation and synthesis), following the framework proposed by Noblit and Hare (1999). Translation comprises comparing the primary characteristics among the studies. In this context, we compared similarities and differences between the key factors identified in the sample, expressed in the matrix presented in Table 2.2. Other meta-syntheses used similar procedures, as in Siau and Long (2005) and Lee (2010). The second part comprises presenting the study's synthesis. In this stage, the translation results were interpreted holistically to constitute a new view on the subject. The results portrayed the smart city characteristics common to the studies and the smart city general definitions based on these consensual characteristics.

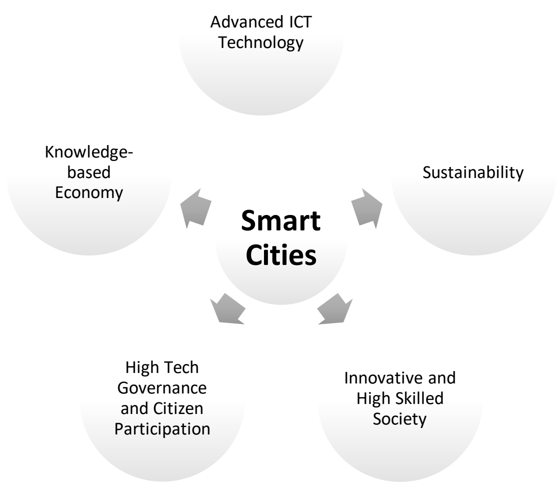
Based on the identified traits, we compared in pairs of correspondence between the results found in the studies. We called studies A, G, B, M, K, C, Y the studies of Albino et al. (2015), Gil-Garcia et al. (2015), Bibri and Krogstie (2017), Mora et al. (2017), Kummitha and Crutzen (2017), Camboim et al. (2018), Yigitcanlar et al. (2018), and Ismgilova et al. (2019), respectively.

The number following the letter (A, G, B, M, K, C, Y, and I) represents a characteristic identified in the concept the authors presented, as summarized in section 1.3. For example, A1 refers to the element "Hard Domain" and "↔" denotes an analogous relationship between the variables. For example, A1↔B1 means the first characteristic Albino et al. (2015) identified corresponds to the first characteristic Bibri and Krogstie (2017) identified. NULL denotes no matching feature in other studies. Table 2 shows the correspondence obtained from the comparison of the systematic literature review studies.

Through the reading of the selected papers, we saw the homogeneity of the studies, indicating the characteristic identification. The matrix reveals an almost full correspondence between the study traits identified. The authors presented the characteristics synthetically (hard and soft domains) and analytically (technology, environment/sustainability and society/citizens, governance, and economy). For this reason, when comparing them pair by pair, we grouped some analytical traits to correspond to a synthetic feature (e.g., B1 ↔G1, G4).

The only divergence refers to what the authors Kummitha and Crutzen (2017) called critical school (K4), which, unlike the other schools investigating new definitions for smart cities, criticised existing ones. We can verify this occurrence in the table by the NULL markers, Despite the critique regarding the lack of consensus on the definition of a smart city or even if it reflects a fuzzy concept, we found a convergence toward five characteristics, as summarised in Figure 2: a) advanced ICT technology, b) sustainability, c) innovative and highly skilled society, d) high tech governance and citizen participation and e) knowledge-based economy. A brief discussion of the five convergent features of the definitions is presented int the Figure 2.2.

Figure 2.2 - Five common characteristics in smart cities definitions



Source: Authors' elaboration

Linking existing urban infrastructure (housing, transport, ports, roads) to new intelligent technologies, such as the Internet of Things (IoT) and 5G networks, enabled the provision of information in real-time and offered more economical and political efficiency (Caragliu et al., 2011; Bibri & Krogstie, 2017; Mora et al., 2017; Yigitcanlar et al., 2018; Ismgilova et al., 2019). A commonly used example to illustrate this feature entails Songdo (South Korea), which has implemented an extensive network of sensors in the infrastructure. Additionally, several urban operating systems manage transportation, buildings, public lighting and other aspects of urban life (Carvalho, 2015).

The characteristic sustainability displayed concern about the balance between conservation and development (Yitigcanlar & Lee, 2014; Camboim et al.,2018; Ismgilova et al., 2019). The central aspects involved an efficient use of energy, new mobility patterns, re-scheduling of spatial scales at the municipal level and establishing environmentally friendly agreements. However, these goals have been criticised for lack of result transparency (Calzada & Cobo, 2015; Yigitcanlar et al., 2018), especially in smart cities created for these purposes, like Masdar in the United Arab Emirates. Yigitcanlar et al. (2018) pointed to the lack of evidence of the smart city contribution to sustainability, an important research agenda related to this dimension.

Concerning innovative and highly skilled society, a city is smart if it hosts a community that has learned to learn, adapt and innovate (Coe et al., 2001; Gil-Garcia et al., 2015; Bibri & Krogstie, 2017). To enjoy technologies, people need to develop the knowledge and expertise necessary to use them. Therefore, the technical absorption capacity determines smart city success (Caragliu et al., 2011). In this sense, more recent researchers have sought to uncover which skills remain essential for smart city citizens (Zait, 2017).

The governance domain in the definitions of smart cities addresses items, such as intelligent technologies (Internet-of-things and artificial intelligence), to improve public management (Camboim et al., 2018; Yigitcanlar et al., 2018; Ismagilova et al., 2019). Moreover, the authors alluding this domain promoted the discussion based on models or perspectives, like the triple-helix fostering collaboration between several stakeholders (Leydesdorff & Deakin, 2011; Gil-Garcia et al., 2015; Meijer & Bolívar, 2016; Camboim et al., 2018; Yigitcanlar et al., 2018).

Finally, smart cities also differentiate by presenting communications infrastructure and a political-economic environment conducive to developing high-value-added businesses (Hollands, 2008; Gil-Garcia et al., 2015; Camboim et al., 2018; Yigitcanlar et al., 2018). An example illustrating this component encompasses the city of Edmonton in Canada, promoting the design of an environment geared to attract new businesses, especially in sectors using or developing advanced technologies, such as the information and biotechnology sectors (Hollands, 2008).

Considering the characteristics identified in the translation phase of the study, we defined which smart city exemplified "an innovative and qualified society, oriented towards the development of the knowledge economy, which makes advanced ICT technologies aimed at promoting sustainability and participatory urban governance".

2.5. Future research studies

The study helped identify the literature gaps future researchers could potentially address. About "advanced ICT technology," the gaps related to the following subjects: improvement of cybersecurity and data privacy, identifying the most effective technologies for smart cities, risks of corporate path dependency and technical aspects related to best practices for data exchange, processing and storage standards (Kummitha & Crutzen, 2017; Yigitcanlar et al., 2018; Ismgilova et al., 2019).

With an "innovative and high skilled society," the contribution of the higher education centers and skilled labor to the smart city's development have presented the greatest challenges. Adopting this perspective helped examine the smart city's implementation based on a bottom-up view (human capital-based) (Albino et al., 2015; Kummitha & Crutzen, 2017). Also, future studies should identify indicators to describe the degree to which a smart city exemplifies this element.

These aspects were also associated with research gaps related to the "knowledge-based economy." The research challenges comprised clarifying the role of intangible capital growth in smart cities (Gil-Garcia et al., 2015; Kummitha & Crutzen, 2017; Yigitcanlar et al., 2018).

Finally, we unmasked research gaps concerning the ethics of data-driven management, user perception evaluation regarding the technologies used in smart cities, citizen engagement in smart city governance, and clarification of open data and open government benefits (Camboim et al., 2018).

2.6. Conclusions

We have developed a systematic literature review on the smart city concept and meta-synthesis. The primary aim was to identify an integrated definition of this construct. The results showed a confluence around two primary categories despite various existing purposes, dealing with technological and human and community aspects. We highlighted no absolute incompatibility existed between these two categories.

Our study examined the results of a systematic literature review on smart city concepts several authors asserted. For instance, some articles in our investigation explored more than a thousand references in their systematic literature review. The sample contemplated the production of smart cities over the last 20 years. In this sense, the meta-synthesis represented a robust effort to understand the smart city precisely.

Our findings indicated the authors who have carried out systematic literature reviews on the subject converged more on the concept than diverged. Moreover, our meta-synthesis attested to the applicability and utility of this analysis to solve problems of conceptual dispersion. The synthesis overlaps in the reviewed studies made it possible to propose a new concept based on five characteristics defining a smart city (advanced ICT technology, sustainability, innovative and highly skilled society, high tech governance and citizen participation and knowledge-based economy).

Formed on the principal traits illuminated in the study, we presented a general concept of a smart city. This premise encompasses previous definitions provided by respected researchers in the field and can be used in future studies. Those five characteristics stemmed from earlier studies related to the descriptions of smart cities, as already pointed out, could be further investigated.

Our findings contributed to the literature on smart cities in the academic as well as in a managerial sense. For the academic community, it presents a new, modern and well-researched smart city concept. In this context, the study provided more security regarding smart city characterisation theoretically, considering we synthesized consensual elements found in robust studies of smart cities. Our evidence highlighted more commonalities in smart city literature than differences. For managers and public policymakers, it systematised primary smart city characteristics, warranting further assessment taking into account the implementation of daily activities of smart cities. For instance, it could help guide the concept of formal documents, such as laws, public policies and government plans.

Table 2.2 - Comparison of systematic literature reviews of smart city's definitions.

	Albino *et al.* (2015)	Gil-Garcia *et al.* (2015)	Bibri and Krogstie (2017)	Mora *et al.* (2017)	Kummitha and Crutzen (2017)	Camboim *et al.* (2018)	Yigitcanlar *et al.* (2018)	Ismgilova *et al.* (2019)
Albino *et al.* (2015)								
Gil-Garcia *et al.* (2015)	G1, G4 ↔ A1 G2, G3 ↔ A2							
Bibri and Krogstie (2017)	B1 ↔ A1 B2 ↔ A2	B1 ↔ G1,G4 B2 ↔ G2, G3						
Mora *et al.* (2017)	M1 ↔ A2 M2 ↔ A1	M1 ↔ G, G3 M2 ↔ G1, G4	M1 ↔ B2 M2 ↔ B1					
Kummitha and Crutzen (2017)	K1 ↔ A1 K2, K3 ↔ A2 K4 ↔ NULL	K1 ↔ G4 K2, K3 ↔ G2, G3 K4 ↔ NULL NULL ↔ G1	K1 ↔ B1 K2, K3 ↔ B2 K4 ↔ NULL	K1 ↔ M1 K2, K3 ↔ M2 K4 ↔ NULL				
Camboim *et al.* (2018)	C1,C3 ↔ A2 C2, C4 ↔ A1	C1 ↔ G3 C2 ↔ G1 C3 ↔ G2 C4 ↔ G4	C1,C3 ↔ B2 C2,C4 ↔ B1	C1,C2,C3 ↔ M1 C4 ↔ M2	C1,C2,C3 ↔ K2,K3 C4 ↔ K1 NULL ↔ K4			
Yigitcanlar *et al.* (2018)	Y1, Y4 ↔ A1 Y2, Y3, Y5 ↔ A2	Y1 ↔ G4 Y2, Y3 ↔ G2 Y4 ↔ G1 Y5 ↔ G3	Y1, Y4 ↔ B1 Y2,Y3,Y4 ↔ B2	Y1 ↔ M2 Y2,Y3,Y4,Y5 ↔ M1	Y1 ↔ K1 Y2,Y3,Y4,Y5↔K2, K3 NULL ↔ K4	Y1, Y2 ↔ C4 Y3 ↔ C3 Y4 ↔ C2 Y5 ↔ C1		
Ismgilova *et al.* (2019)	I1, I4 ↔ A1 I2, I3 ↔ A2	I1 ↔ G4 I2 ↔ G2 I3 ↔G3 I4 ↔ G1	I1 ↔ B1 I2,I3,I4 ↔ B2	I1 ↔ M2 I2,I3,I4 ↔ M1	I1 ↔ K1 I2,I3,I4 ↔ K2,K3 NULL ↔ K4	I1 ↔ C4 I2 ↔ C3 I3 ↔ C1 I4 ↔ C2	I1 ↔ Y1 I2 ↔ Y3 I3 ↔ Y5 I4 ↔ Y4, Y2	

Source: Authors' elaboration

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3. HOW TO ASSESS SMART CITIES? A SYSTEMATIC LITERATURE REVIEW OF FOUR APPROACHES[2]

Abstract: Several criticisms have emerged in the literature on the negative effects and absence of effective results of smart cities. In this study, we review the research directed at assessing the impact of smart cities. We propose that the studies directed at evaluating the effects of smart cities can by separated into four approaches– ranking, data-driven management, innovation ecosystem, and maturity. By systematically reviewing the literature, and the contributions of each of these approaches, our study provides a more general assessment on what each approach reveals about the contributions of smart cities.
Keywords: smart cities evaluation; smart cities assessment; literature review; innovation ecosystems.

3.1. Introduction

The growth of large urban centers has created pressure to offer the best infrastructure, systems, and services to citizens. Cities have sought technological upgrading using new digital technologies, especially the Internet of Things (IoT) and cognitive technologies (Belanche-Gracia et al., 2015). In this context, the smart city concept became one of the most critical urban paradigms (Joss et al., 2017), based on the belief that new digital technologies can solve urban challenges (Tomitsch & Haeusler, 2015).

However, specialized literature presents several criticisms about smart cities. Various authors have postulated that there are unrealistic expectations about the impact of new technologies on the functioning of cities (Rendueles, 2015). For instance, three emblematic smart cities had problems with insufficient results: Songdo (South Korea), PlanIT Valley (Portugal), and Masdar (United Arab Emirates). Songdo and PlanIT Valley had problems related to the original plans, insufficient state support, bureaucracy, the resistance of the interested parties and inability to attract foreign capital investments (Shwayri, 2013; Shelton et al., 2015). Masdar did not contemplate social requirements and the local population expectations (Cugurullo, 2013).

Calzada and Cobo (2015) call these examples as "smart city in-the-box", alluding to the corporate-designed, commercial, and marketing character they own, as showcases for the

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[2] Approved at congress XLIV Encontro da ANPAD- EnANPAD 2020 and submitted to Journal of Urban Technology.

commercialization of intelligent technologies. It is a marketing effort of large corporations without useful results (Söderström et al., 2014). For Krivý (2018), they become a hegemonic notion of urban development and control that supplants planning. This author also summarizes the main criticism against the smart cities, which are their potential to extinguish the informal character of the cities, been subordinated to corporate power and reproducing social and urban inequalities.

These criticisms are relevant given the number of resources invested in the development of smart cities. It is estimated that by 2020, the Smart Cities market will reach US$1.565 trillion (Tanda & Marco, 2018). For instance, the city of Tokyo is investing US$421.2 million to be technologically prepared for the 2020 Olympics (IOC, 2013). The organizers of the mega event are expecting investments in digital technologies to manage the flow of people, monitoring environmental conditions, surveillance and security, and health management (Kassens-Noor & Fukushige, 2018). Although there is uncertainty about the outcome of smart cities, governments everywhere in the world are investing vast amounts of money even though they do not know precisely their practical results.

In this context, reviewing models to assess the development of smart cities become incredibly relevant. These models, assessments, or approaches are indispensable instruments for analysis of the smart cities implementation as well as their continuous development (Albino et al., 2015; Qi and Ba, 2016). Despite the importance of the subject for public policymakers, scholars, and specialized media, few studies have focused on the assessment of smart cities projects (Caird, 2018).

This paper presents clusters of the various views on smart cities assessment found in the systematic review of the literature. The main question answered by this paper is how to assess smart cities? For this purpose, we established three objectives: (1) to review the main models of smart cities assessment considered in the specialized literature published in the last 20 years; (2) to build up a novel framework considering the models identified according to their approaches; (3) to provide a critical analysis of the main approaches to assess smart cities planning and implementation.

We organise the paper into six sections, including the introduction. The second presents a method used to select and review the literature. The third section presents our framework to categorise the models of smart cities assessment, based on four approaches. The fourth section discusses the main results. The fifth section, as a conclusion, reviews the findings and implications for theory and practice.

3.2. Methods

To analyse smart city assessment models and various perspectives drawn from a variety of scholars, we selected the following scientific databases: Web of Science, Wiley online, Oxford Journals, Taylor and Francis, Springer Link, Scopus, Sage, and Elsevier's Science Direct. We used the terms "smart cities assessment", "evaluation of smart city," and "smart city rankings" to identify relevant articles to be reviewed.

We prospected all scientific articles reviewed by peers on smart cities assessment available at the above sources published up to July 2018. We found 199 articles in the initial search and we selected a sample that met the following criteria: (1) single entry, excluding studies found in different databases; (2) publication was academic and peer-reviewed; (3) subject related to the smart city assessment; (4) analysis of smart city assessment models. The result was 26 articles.

The selected articles were analysed using content analysis. Weber (1990, p.9) defines content analysis as "a research method that uses a set of procedures to make a valid inference from the text". We use the conventional content analysis framework (Hsieh & Shannon, 2005) to perform an inductive analysis of the models referenced in the selected articles. The main goal was to identify different approaches to evaluating smart cities implementation. Each author performed a process of reading and categorization to improve reliability and decrease subjectivity (Krippendorff, 1980). Subsequently, the authors unified the categories identified in the individual analyzes. The NVivo software provided operational support to the work of categorizing and comparing results among authors.

We coded the models found based on various indicators. For instance, we registered characteristics as the critical focus, level of analysis, spatial scope, and method, the frequency of analysis, and government feedback. This analysis helped us to design a framework for understanding existing research and perspectives of researchers and experts working in the field. We identified and presented different approaches to solving the problem of smart city assessment in the following sections.

3.3. Smart City Assessment Models

3.3.1. Ranking Approach

The literature related to this approach gives vital importance to the comparison between cities. Most of the models found in the literature are classified in this category. These models are inspired by the traditional and neoclassical theory of urban growth and development

(Caragliu et al., 2011; Lombardi, 2011; Albino et al., 2015). The rankings are operationalized by comparing the performance of cities using a system of indicators as the basis (Lange, 2010). Undoubtedly, in this approach, there is a focus on the use of quantitative methods.

The ranking approach is essential for competition between urban areas (Giffinger et al., 2010). Therefore, it is also a component of the cities' marketing strategy, with rankings used by managers as a benchmark to improve their position in cities competition (Arribas-Bel et al., 2013; Sheng & Tang, 2016). Thus, classifications of the city are tools used to influence national and international political debates (Meijering et al., 2014; Kern, 2009).

The model more influential in this approach is the Ranking of European Medium-Sized Cities (REMSC) proposed by Giffinger et al. (2007). The REMSC influenced other models such as the Smart City Wheel (Cohen, 2015) and the Smart City Index (Lazaroiu & Roscia, 2012). The REMSC aims to establish a benchmarking among medium-sized cities in Europe. Given this context, notwithstanding their importance, it disregards global metropolises. This model analyses six dimensions: smart economy, smart mobility, smart environment, smart governance, smart people, and smart living.

Regardless of the proliferation of the ranking approach in the literature of smart cities, there are several methodological concerns. The first concerns are the selection of indicators that will be part of the indexes, given that the choice of indicators can significantly influence the results (Maretzke, 2006; Wilson et al., 2007). Still, on the selection of indicators, Ahvenniemi et al. (2017) reviewed 16 smart cities assessment models and recommended the inclusion of impact indicators, rather than just including smart solution implementation indicators.

Another concern is the availability and quality of data (Almeida et al., 2001; Ochel & Rohn, 2008), as the lack of updated data from all cities involved makes it difficult to monitor the evolution of cities under analysis periodically. The monitoring is challenging for rankings that have a unique global scope, given the idiosyncrasies of each government. Besides, there are no global standards on how to benchmark indicators, which can also lead to methodological problems.

Finally, rankings are also over-simplifying city performance, and it is necessary to understand that they provide only insights into favorable and unfavorable aspects in cities (Giffinger et al., 2010). Also, managers can manipulate the actual data to get a better qualification (Sheng and Tang, 2016). Manipulations are problematic given the influence of these data on strategic and political decisions (Bulu, 2014). Table 3.1 summarizes the sample of ranking approach models.

Table 3.1 - Sample of Ranking Approach Models

Title	Reference	Spatial Scope
Ranking of European Medium-Sized Cities	Giffinger *et al.* (2007)	Europe
Smart Cities Wheel	Cohen (2015)	World
Ericsson Networked Society City Index	Ericsson (2016)	World
Eurocities CITYKeys Initiatives	Bosch *et al.* (2017); Huovila *et al.* (2017)	Europe
Smart City Index	Lazaroiu and Roscia (2012)	World
Smart City in Europe	Caragliu *et al.* (2011)	Europe
IESE Cities in Motion Index	Berrone *et al.* (2016)	World

Source: Authors' elaboration

3.3.2. Data-Driven Management Approach

The real-time management of cities uses evaluation systems based on big data, city dashboards, and algorithmic governance. This way of managing reflects the advancement of "everyware", to produce a new form of data-rich and data-driven city urbanism (Greenfield, 2006). For many scholars, cities have become "data warehouses" (Kourtit & Nijkamp, 2018) because multiple databases are available on human spatial behavior in real time. For instance, data on volunteered geographic information (VGI), social media, sensors, GSM – global systems for mobil communication data and financial transactions are available. The analysis of this big data, characterised by the volume, variety, and speed, becomes an intelligence source for the management of urban centers (Leszczynski, 2016).

One of the main ways to simplify these large volumes of data is to present them in the form of dashboards. Dashboards are programmed to show at-a-glance view the key performance indicators (KPIs) of any activity been controlled. The city dashboards are auxiliary tools with the capacity of data aggregation and friendly communication of massive information (Balleto et al., 2018). An example of a city dashboard usually mentioned in the literature is the Rio de Janeiro Operations Centre, which gathers information from 30 public service agencies (Kitchin, 2014).

Also, there is an effort in smart cities to automate and predict aspects of smart city management. In this sense, several cities use algorithmic governance — for example, the use of trace analysis to identify patterns of mobility and the prediction of behavior (Pan et al., 2013).

Another application related to mobility is the prediction of park availability by sensor-enabled car parks (Zheng et al., 2015; Vlahogianni et al., 2014).

In the last decade, many researchers developed data-driven management models. There is a remarkable diversity of proposals regarding the models of this approach. Among them we can mention the management and prediction of urban transport (Lv et al., 2015; Zheng et al., 2013), smart grid and energy (Conejo et al., 2010; Halvgaard et al., 2016;) and the prevention of disasters (Horanont et al., 2013, Crooks et al., 2013).

Data-driven management models have several criticisms about their use. A first concern is related to the heterogeneity of data sources, which present different spatial and temporal scales, different levels of aggregation, and precision (Kourtit & Nijkamp, 2018). A second apprehension is data privacy and ethical issues as cities become interfaces for capturing, generating, circulating, and aggregating data (de Waal, 2014). Kitchin (2014) corroborates the view that the ubiquitous collection of data can create "panoptic" cities that directly undermine the right to privacy, confidentiality, and expression. In this context, there is a thin line separating surveillance and service, personal data, and impersonal data (van Zoonen, 2016).

Finally, third distress is related to corporate-oriented efforts (Hollands, 2008; Söderström et al., 2014). This fear is due to the city's dependence on corporations, such as IBM and Cisco, to provide the technology for evaluation of the operation of the system. All these concerns, as well as the main features of our sample of articles classified as being related to the data-driven management approach models, are shown in Table 3.2.

Table 3.2 - Sample of Data-Driven Management Approach Models

Title	Reference	Spatial Scope
Big Data for Social Transportation	Zheng *et al.* (2015)	Beijing
Caltrans Performance Measurement System	Lv *et al.* (2015)	California
Distributed Model Predictive Control (Smart Grid)	Halvgaard *et al.* (2016)	World
Real-Time Demand Response Model (Smart Grid)	Conejo *et al.* (2010)	Spain
Air Pollution Management	Hasenfratz *et al.* (2015)	Zurich
Air Quality Measurement	Zheng *et al.* (2013)	Beijing
Disaster Management	Crooks *et al.* (2013)	Louisiana
Large Scale Auto-GPS	Horanont *et al.* (2013)	Japan

Source: Authors' elaboration

3.3.3. Innovation Ecosystem Approach

The models proposed in this approach derive from the triple-helix model to analyse production and diffusion of knowledge in innovation processes (Etzkowitz & Leydesdorff, 2000). According to this approach, smart cities are networks with at least three critical components: the intellectual capital of universities, the industry of wealth creation and participatory governance of the democratic system (Deakin, 2014). In this sense, the models of this approach focus on the analysis of these components considered essential for regional development (Leydesdorff & Deakin, 2011).

The smart cities literature proposes the expansion of the components presented in the triple helix model. In the quadruple helix, scholars recommend the inclusion of society as users and co-creators of innovation (Carayannis & Rakhmatullin, 2014). Some argue that end-users is an essential stakeholder in co-creating and accepting innovation (Schuurman et al., 2012; Kummitha & Cruzten, 2017).

One of the central points of discussion in the quadruple helix model is how to involve the citizen in this innovation ecosystem. In this sense, public policies have been proposing the introduction of living labs as the best practice to involve this fourth helix. Baccarne et al. (2016) highlight that living labs are ecosystems where end users join other stakeholders to develop new products and services. Living labs involve end-users in the development of innovative solutions and provide tools, information, forums, and development of skills (Schurrman et al., 2012). Therefore, analysing the performance of living labs has become a requirement of quadruple-helix models, and its importance in public policies such as Europe 2020.

Furthermore, some authors point to a fifth helix that would be the natural environment. In this fifth element, they consider aspects of sustainable development and social ecology (Carayannis & Campbell, 2010). The central interest of the quintuple helix model is to demonstrate the natural environment relevance as a component to produce knowledge and innovation (Carayannis et al., 2012).

Other authors sought the combination of the innovation ecosystem with elements of the ranking models approach. Lombardi (2011) have associated the expanded triple helix with civil society to consider the components of the European ranking of medium smart cities. The result was clustered with performance indicators for each of the quadruple helix components.

The main criticism of the models related to the innovation ecosystem approach is their applicability to explain innovation ecosystems in Western developed countries. In this sense, the critique can be unfolded in two points of view: high prevalence of components and absence of components that can better explain regional development.

Concerning the first critique, some authors assert that specific components have more relevance than the others. For example, Yoon (2015) reporting South Korea's late industrialisation development underscores the government's predominance in explaining the innovation ecosystem success. Some argue that triple helix can distort the importance of specific components.

Relating to the second appraisal, we emphasize that the diversity of experiences about the ecosystems of innovation could bring to light other components to explain its success. For instance, Williams and Woodson (2012) stress the importance of Non-Governmental Organisations for innovation in Less Economically Developed Countries. Thus, the composition of the triple, quadruple, quintuple helix models may be different, depending on the context. Table 3.3 shows the sample of articles classified as related to the innovation ecosystem approach models.

Table 3.3 - Sample of Innovation Ecosystem Approach Model

Title	Reference	Spatial Scope
Triple Helix	Leydesdorff and Deakin (2011)	World
	Lombardi *et al.* (2011, 2012)	
Quadruple Helix	Schuurman *et al.* (2012)	World
	Baccarne *et al.* (2016)	
	Van Waart *et al.* (2015)	
Quintuple Helix	Cossetta and Palumbo (2014)	World
	Carayannis *et al.* (2012)	

Source: Authors' elaboration

3.3.4. Maturity Approach

In this approach, the models are used to evaluate the stage of development of a smart city. Therefore, it is the analysis of implementing institutional, technological, and social solutions to transform smart cities. Public managers can use these models as analytical tools to identify complementary policies in the smart city's development plans (Nam & Pardo, 2014). These models help to identify the current level of smart city development.

The models of this approach use predominantly qualitative methodologies to get the results of the smart city performing. For instance, the Smart City Reference Model has six layers that represent stages necessary for the development of a smart city (Zygiaris, 2013). Each layer specifies a need such as hardware (instrumentation layer) or standard definition of data transmitted between intelligent devices (interconnection layer).

However, several authors of this approach establish the use of quantitative parameters and indicators as the next development stage (Lee et al., 2014; Nam & Pardo, 2014). In this sense, the attributes of the assessment models are characteristics of smart cities. Public policies, scientific studies, and best practice models influence these characteristics. The Smart Cities Maturity Model operates an evaluation system based on the British Standards Institution PAS 181 (Urban Tide, 2015).

One of the main concerns regarding this approach is the definition of characteristics and dimensions to consider the city's smartness (Castelnovo et al., 2016). As in the Ranking Approach, the choice of characteristics for the model composition will affect the results. Another aspect of the models that make up this approach is the lack of detailed methodological instructions, which may hinder the effective use of the presented models. Table 3.4 summarizes our sample of maturity approach models.

Table 3.4 - Sample of Maturity Approach Models

Title	Reference	Spatial Scope
Smart City Reference Model	Zygiaris (2013)	World
Framework to Smart Cities Analysis	Lee *et al.* (2014)	World
Smart City Maturity Model	Urban Tide (2015)	World
Smart City's Government Assessment Framework	Castelnovo *et al.* (2016)	World
Smart City Program Model	Nam and Pardo (2014)	World

Source: Authors' elaboration

3.4. Discussion

There have been several criticisms accumulated over the past two decades about smart cities (Hollands, 2008; Caragliu et al., 2011; Komninos et al., 2013; Wiig, 2015; Efthymiopoulos, 2016). Some authors have refuted beliefs that the adoption of new technologies in public transportation has improved citizens' quality of life (Mudler, 2014). Other authors emphasise that existing policies for smart cities, instead of reducing social inequalities, reinforce them through neoliberal orientation (Jazeel, 2015; Datta, 2015; Carvalho, 2015).

The main question that remains unanswered is the actual outcome of smart cities, explaining the benefits to the stakeholders (Wiig, 2015; Beretta, 2018; Bibri, 2018). To contribute to the study of smart cities evaluation, we synthesised assessment models into four distinct approaches. These approaches could aid in understanding the assessment context of smart cities and could assist those working on planning and development of them. Table 3.5 shows a comparison of the four approaches.

As seen in the table, the four different approaches diverge from each other in several attributes identified, especially concerning purpose. However, there are considerable differences in the organizational level, methodology, frequency, and government feedback. The first aspect to emphasise is that approaches are suitable for different purposes.

The ranking approach has an application related to the comparison of cities, which can serve multiple purposes, such as a situational analysis of a region or reports of specialised media (Giffinger et al., 2010). The data-driven management approach meets the immediate needs of management intervention. For instance, Singapore has implemented a real-time data platform to manage various aspects of urban life, such as heat islands and trans-shipment containers (Kloeckl et al., 2012). The models of the innovation ecosystem approach can contribute to the diagnosis of innovation networks that support a smart city (Leydesdorff & Deakin, 2011). Finally, the maturity approach aims to understand the current state of the development of smart cities, providing essential information on the city "smartness" (Zygiaris, 2013).

Table 3.5 - A comparison of the four approaches

Approach	Key focus	Level	Methodology	Frequency	Government Feedback
Ranking approach	Compare the city position with other cities.	Strategic	Quantitative	Annually	Medium/Long-term
Data-driven management	Evaluate management data in real time.	Operational	Quantitative	Real-Time	Short-term
Innovation Ecosystem	Analyze innovation ecosystem.	Strategic	Qualitative	Eventually	Medium/Long-term
Maturity Approach	Analyze a smart city development stage.	Strategic	Qualitative	Eventually	Medium/Long-term

Source: Authors' elaboration

There are differences related to the organizational level impacted by the evaluation results. The models related to the ranking approach, innovation ecosystem and maturity approach have a more direct impact on the strategic level, influencing the formulation of public policies and strategic management decisions (Viale & Pozzali, 2010; Giffinger et al., 2010;

Zygiaris, 2013). Models related to the data-driven management approach impact the operational level, i.e., managers who need to organise the daily operation of cities (Nam & Pardo, 2014; Townsend, 2015).

The approaches also differ from the method used. There is a predominantly quantitative orientation in the models that make up the ranking approach, and the data-driven approach, which uses indicators based on official databases and data got in real time by intelligent devices (Batty et al., 2012; Kitchin, 2014). The models that make up the innovation system approach and maturity approach use a predominantly qualitative orientation to get their results. At this point, case studies evaluate the development stage of the regional innovation network or the stage of maturity of a smart city (Abellá-García et al., 2015).

Concerning the frequency by which the evaluation occurs and the government feedback, the approaches also have divergences. The ranking approach uses annual periodic analyses, following the official statistics, and produces government responses in the medium and long term (Cohen, 2015; Huovila et al., 2017). An analogous response can be observed in the innovation ecosystem approach and maturity approach, which are used to diagnose the current situation of locality and to enable the formulation of public policies. The data-driven management approach evaluates in real-time, allowing immediate management actions and modifications (Lv et al., 2014).

The four summarized approaches are helpful to assess the implementation of smart cities systematically explaining the various perspectives adopted in their evaluation. In this sense, this work presents a contribution to the jigsaw of evaluating the results of a smart city. We have shown that there are several perspectives in the literature on how we evaluate smart cities, and all of them should be taken into consideration when designing and implementing them or just renewing the present ones.

3.5. Conclusion

To bridge the gap on how to access the possible results of a smart city, we have identified the need to review existing models for smart city assessment. After reading selected papers and doing a content analysis, we organized the literature about the evaluation of smart cities into four approaches: ranking approach, data-driven management approach, innovation ecosystem approach, and maturity approach.

The ranking approach is related to competition between smart cities. It seeks visibility and resources through the promotion of the right image at the regional and national levels. It is one of the most cited approaches in scientific works on smart cities. Besides, the ranking approach has the most significant number of models available for the evaluation of smart cities. The principal focus of these models is the comparability between cities.

The data-driven management approach is related to the advance in public management promoted by the adoption of new technologies. Sensors, big data, and artificial intelligence are some technologies of real-time management. The models of this approach depend on technological evolution and are sharply criticized by researchers that see the strong presence of large corporation developing and selling new "solutions" for old problems. As mentioned by some scholars, smart cities became "data warehouses".

The models of the innovative ecosystem approach are based on the triple helix model and its modifications. The triple-helix explains the production of innovation at the local and regional level. The principal focus of these models is the description and analysis of the components essential for local innovation. Extension of this model like the quadruple-helix includes the society as an important stakeholder that must be considered. Based on these models, there is a mushrooming implementation of living labs around the world. The quintuple-helix model considered the environment as another essential component that must be considered in the assessment of smart cities.

The maturity approach is based on models that use features described in the literature on smart cities to assess their implementation and is the one in which there are substantial variations and differences between models due to the diversity of experiences. Cities like persons have their idiosyncrasies. The principal focus of these models is the evaluation of the smart city implementation stage.

Considering all the four approaches, we can visualize a new framework for smart cities assessment. This new framework takes into consideration the following main innovative features: a) the critical variables of the approaches resulted of our analysis of the different models for smart cities assessment; and, b) contrasting the approaches to identify the context in which each one can be applied. Furthermore, the advantages and disadvantages of the different approaches must be taken critically into account.

This new framework was summarized in our previous Table 5. Our research findings contribute to an understanding of possible outcomes and which approaches are most suitable for measuring them. Based on our findings, a researcher or manager interested in analyzing stages of development of smart cities can use models related to the maturity model. If the interest is to evaluate the operation of a specific policy in real time, data-driven approach models can be applied.

For future research, the models of the ranking approach can be investigated regarding comparability and trust in the data and information generated. Data-driven management approach models can follow the development of new technologies to include management of more diverse aspects of urban life. The models of the innovation ecosystem approach can evolve in methodological terms and developing new standards. Finally, the maturity approach models have the demand for a specification of indicators for the characteristics of smart cities.

Although the article represents a step forward in the literature on smart city assessment, there are some limitations in our study. The option to exclude articles without peer review restricts the research; the choice of keywords may have led to the exclusion of articles relevant to the study. However, the study presents an effort to understand the evaluation of smart cities and a theoretical framework that can be used by scholars and researchers and as a reference for public managers.

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4. LIVING LABS CONTRIBUTIONS TO SMART CITIES FROM A QUADRUPLE-HELIX PERSPECTIVE[3]

Abstract: This paper explores living labs' contributions to smart cities from a quadruple-helix perspective. We conduct exploratory case studies. The selected cases (Living Lab Florianópolis, Living Lab of the Itaipu Technological Park and Porto Digital) depict an institutional context characterised by a low interaction between the quadruple-helix components. The data were obtained through document analysis and interviews with living lab organisers and participants. The results suggest living labs can contribute by a) selecting the most promising projects to promote, b) connecting quadruple helix components through collaborative practices and events, c) facilitating mediation between participants in living labs and government agencies, universities and local companies to conduct tests, and d) inserting the fourth helix as a tester but not as a co-creator. These findings contradict the notion living labs remain predominantly based on user-oriented innovation processes, purporting a producer-oriented trajectory.
Keywords: Living Labs; Smart Cities; Quadruple-Helix; Triple-Helix.

4.1. Introduction

A smart city not only has specific information-controlled technology (ICT) but also has positively implemented technology affecting the local community (Caragliu et al., 2011). Despite the recognition of technology as a primary smart city driver, some authors have criticized excessively focusing on digital technologies (Calzada & Cobo, 2015; Jazeel, 2015). Other scholars disapproved of excluding human and democratic aspects from the smart cities (Joss et al., 2017; Engelbert et al., 2019).

New smart cities balance human, technological and participatory governance elements (Meijer and Bolívar, 2015). A central issue of these new projects entails developing innovations with various stakeholders (Deakin, 2014; Leydesdorff & Deakin, 2011). Hence, living labs could accommodate this new smart city, given their ability to aggregate diverse viewpoints, especially citizens (Mora et al., 2018). Living labs broadly cover numerous sectors but notably contribute to open-user innovation (Wersterlund & Leminen, 2011).

Academics and managers have described processes carried out in living labs, asserting their benefits (Ballon et al., 2018; Ståhlbröst, 2013; Evans et al., 2015). However, little is known about their contribution to registered projects (Hossain et al., 2020). Although several ways

[3] Submitted to the journal Technological Forecasting and Social Change.

exist to address this issue, in this article, we apply the quadruple-helix model to unveil answers to our primary goal to gain awareness of how living labs enhance smart cities.

This paper examines how living labs affect smart cities from the quadruple-helix perspective. We investigate the experiences of Living Lab Florianópolis, Itaipu Technological Park and Porto Digital. The article comprises five sections, including the introduction. The second section presents the central theoretical research background. The third describes the case study used and the context. The fourth discusses results scholars have not previously considered. Furthermore, the fifth part concludes, reviewing the main findings, observations, and implications for theory and practice.

4.2. Literature review

4.2.1. Smart Cities

After two decades of research, much controversy about smart cities remains. However, authors evaluating this concept converging on several points. For example, the definitions are situated between two paradigms, technology-driven (Hall et al., 2000) and human-driven (Caragliu et al., 2011).

The first paradigm is based on technological prominence, such as using the most advanced information communication technology. ICT tools provide more data and connectivity to managers and citizens (Calzada & Cobo, 2015). Using the Internet of Things (IoT) to connect offline city components to data networks and big data real-time processes (Silva et al., 2018). The second paradigm is based on communities and citizens developing the smart city. In this case, technology embodies an instrument for increasing citizen capacity to innovate and participate in urban solutions (Angelidou, 2014; Beretta, 2018). In addition to adopting the most advanced ICTs to transition to smart cities, cities should develop citizen skills to create technologies to deal with urban issues (Kummitha & Crutzen, 2017).

Several smart cities have adopted living labs involving the local stakeholder instead of the techno-centric or top-down approach (Mora et al., 2018; Spagnoli et al., 2019). Living labs epitomise an organisation dedicated to developing technological and non-technological solutions for smart cities (Coorevits et al., 2018). Also, embraces stakeholders collaboration and public-private partnerships (Bergvall-Kåreborn & Stahlbrost, 2009; Dell' Era & Landoni, 2014; Herrera, 2017). Finally, these co-creative process incorporates open innovations, including end-user technological solutions (Ballon et al., 2018; Burbridge, 2017).

Living labs offer an alternative promoting entrepreneurship and innovation in cities, contributing to a smart economy, directing people's knowledge, skills and creativity to create new processes, products and services (Perng et al., 2018). Among the living labs in smart cities, some focus on sustainability (Leminen et al., 2012), social activism (Hughes et al., 2017) and entrepreneurship (Rodrigues and Franco, 2018). Public policies have introduced living labs to develop smart cities. The Joint Programming Initiative (JPI) Urban Europe and Horizon 2020 exemplifies such a project (Pallot et al., 2014). This program envisions using living labs in processes where the local population co-creates and test new ideas (Voytenko et al., 2016).

4.2.2. Living labs

William J. Mitchell coined the living lab term when he carried out one of the earliest experiences at Massachusetts Institute of Technology (MIT) in 2003 (Nesterova & Quak, 2016). The initial idea was to promote research and development (R&D) in real situations, making it possible to examine user feedback regarding innovation. Despite almost 20 years, the experts have not reached a consensus on the living lab definition. Some describe it as the innovation arena (Almirall & Wareham, 2011), project (Ståhlbröst, 2012), network (Leminen & Westerlund, 2012; van Geenhuizen, 2016) or methodology (Bergvall-Kåreborn & Stahlbrost, 2009; Dell' Era & Landoni, 2014; Herrera, 2017).

Several authors have highlighted livings labs foment citizen development and experimentation in novel urban technologies (Evans et al., 2015; Ballon, 2015; Veeckman et al., 2015). Others have emphasised the living lab role in smart city innovation and technology (Hielkema & Hongisto, 2013; Letaifa, 2015; Larios et al. 2016). Although several scholars have purported living lab benefits, some stakeholders have professed living labs contribution to collaborative smart city projects remains unclear (Voytenko et al., 2016; Rodrigues & Franco, 2018).

The role of living labs in smart city innovation resembles a boundary spanner or border crosser as an institution understanding various stakeholders (Canzler et al., 2017; Schaffers & Turkama, 2012). Champenois and Etzkowitz (2018) illuminated independent hybrid organizations can form where institutional spheres intersect to overcome innovation barriers. Living labs can portray the intercommunication intermediates of the quadruple-helix (Engelbert et al., 2019; Voytenko et al., 2016). In this sense, they play a role in these hybrid organisations' quadruple-helix.

Følstad (2008) systematically reviewed the literature and identified four common characteristics in living labs studies: 1) discovery of unexpected uses for technologies and services, 2) user solution validation, 3) experimentation or experience in a real context, and 4) conducting medium and long-term studies with users. In another review, Hosain et al. (2019)

highlighted multiple stakeholder interactions and forming networks in living labs, complementing these traits. In summary, living labs are characterised by aspects such as the reciprocity of interests (Nyström et al. 2014), the search for the development of sustainable products and services (Ståhlbröst 2012), the involvement of multiple stakeholders (Rodrigues and Franco 2018) , the testing of innovations in real systems (Mora et al. 2018), and open innovation processes (Nilssen 2018). Based on these ideologies, living labs carry out several tasks, as shown in Table 4.1.

Table 4.1 - Living labs processes

Process	Description	Source
Multiple stakeholder involvement	Living labs are based on the quadruple helix partnership model whereby government, industry, the public and academia work together to generate innovative solutions.	Bergvall-Kåreborn and Stahlbrost, 2009; Nyström et al., 2014; Dell'Era and Landoni, 2014; Ståhlbröst and Holst, 2017; Herrera, 2017; Rodrigues and Franco, 2018
Training and collaborative event promotion	Promoting training courses and events to create the conditions for new solutions, entrepreneurially sharing ideas (hackathons, networking, mentoring, training, workshops, meetings, boot camps, design sprints and design thinking sessions).	Cosgrave et al., 2013; Ståhlbröst, 2013; Perng et al., 2018
Testing inserted in real places	Living labs are geographically embedded in real places, manageably territorialising urban innovation.	Evans and Karvonen, 2011; Voytenko et al., 2016; Mora et al., 2018; Hossain et al., 2019
User-centric development	Users remain involved throughout all the trial process (planning, implementation, evaluation and feedback). The technological solution is revised and continuously improved to meet stakeholder needs.	Bergvall-Kareborn and Stahlbrost, 2009; Almirall and Wareham, 2011; Almirall and Wareham, 2012; Schuurman et al., 2012; Burbridge, 2017; Ballon et al., 2018

Source: Authors' elaboration

Scholars have criticised living labs for their ability to develop end-users-guided innovations. For Kommonen and Botero (2013), confusion exists concerning user involvement and user-driven innovation. The first represents reactivity, while the second depicts active innovation. Vanmeerbeek et al. (2015), when analysing 20 European living labs, uncovered the involvement of end-users demonstrated reactivity in the concluded project feedback. The results also indicated living labs had adopted a producer-oriented perspective rather than an end-user. Other obstacles involved establishing a mutual understanding between stakeholders (Ogonowski et al., 2013). The relationship among them was not always harmonious and functional. Therefore, managing contractual conflicts and various cognitive representations among stakeholders remained common (Zuzul, 2018).

Another concern about living laboratories consists of their long-term sustainability. After the boom of the 2000s, many have ended their activities in the last decade, presenting problems related to the lack of resources to finance their initiatives (Nesti, 2015; 2018). Another aspect entails the perception living lab tests are expensive, which can deter sponsored support (Wilson et al., 2008). Finally, Mastelic et al. (2015), when evaluating the living laboratories comprising the European Network of Living Laboratories (ENoll), identified an absence or underrepresentation of indicators assessing cost structure, customer segmentation and revenue flow of living labs.

4.2.3. Quadruple-helix

The quadruple-helix expands the triple-helix (TH) to appraise knowledge production and diffusion in innovative ecosystems (Etzkowitz & Leydesdorff, 2000). The TH model emerged from the interaction between industry, government and universities as crucial players in explaining groundbreaking conditions in a knowledge-based society (Etzkowitz, 2003). This approach focuses on components considered essential for regional advancement (Jensen & Trägårdh, 2004). In this approach, the industry engenders the production locus, the government represents the contractual source guaranteeing productive relations and the university illustrates the new knowledge and technologies source.

Industry produces new products, services, markets, forming communities and generates new entrepreneurs (Herliana, 2015). The helix industry can facilitate sharing ideas from local companies, mentoring businesses and training new entrepreneurs. Luengo-Valderrey et al. (2020) highlighted businesses have enjoyed the information gathered from the relationship with the other two institutional actors, while Sá et al. (2019) asserted TH networks encourage entrepreneurs to act, garner financial support and establish partnerships.

Government in the TH chiefly acts as a catalyst and, eventually, as an entrepreneur. As a stimulus, it inspires the private sector and universities, favouring financing, offering incentives and protection. In this sense, it can also regulate public policies promoting national and regional innovation (Lee & Kim, 2016) or consuming products and services entrepreneurs have developed (Herliana, 2015). As a businessperson, the government acts directly in technological solutions and new businesses, primarily in market failure (Sarpong et al., 2017).

Universities drive modernisation, edging away from the "ivory tower" (Gunasekara, 2004). As an innovation enabler, higher education is expected to develop its region actively through technology transfer and designing curricula catering to local industry needs (Goddard et al., 2014). Universities provide highly skilled workers, expert advice about local development agencies and firms and attract new enterprises (Cai & Liu, 2015). Despite academia's training role, researchers have pointed to technology centres, public research organisations and consulting agencies as fostering TH networks (Luengo-Valderrey et al., 2020).

Leydesdorff and Deakin (2011) used the TH model to investigate the knowledge-based economy in urban areas. Cities constitute dense networks with THs producing spaces to explore information. Other authors have proposed civil society as a fourth helix, acting as innovation user and co-creator (Carayannis & Rakhmatullin, 2014). End-users embody essential stakeholders in co-creating and accepting revolutions (Schuurman et al., 2012; Kummitha & Cruzten, 2017; Brock et al., 2018). A central issue to the quadruple-helix model in smart cities entails engaging citizens in the groundbreaking processes. Baccarne et al. (2016) recommended using living labs to introduce citizens to these events.

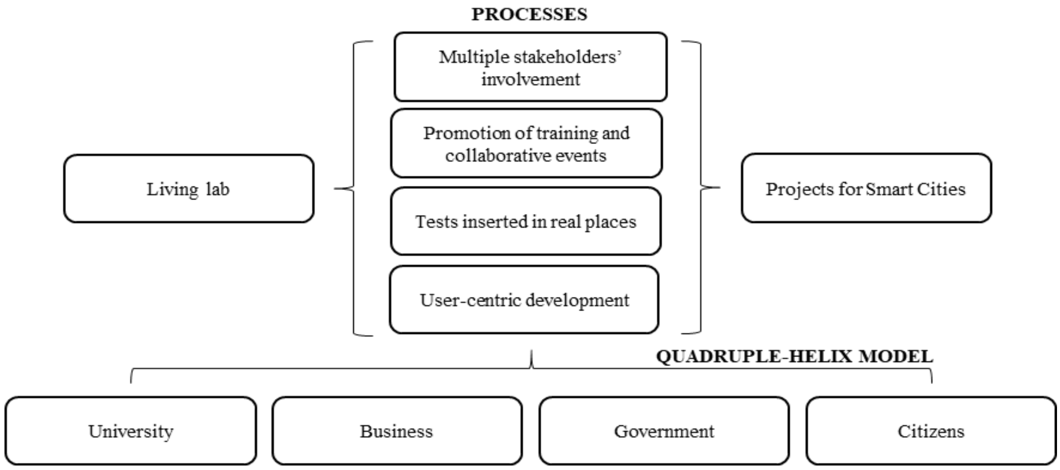
Smart cities, especially from a human perspective, can be seen as open environments oriented towards user-driven innovations (Schaffers et al., 2011). Thus, civil society becomes an essential component of innovation ecosystems, allowing it to provide instant feedback to local governments, businesses and universities (Selada, 2017). Quadruple-helix innovation networks form around smart cities, where citizens aggregate as co-creators of products and services implemented in urban life. Living labs based on quadruple-helix systems may foster the relationship between all constituencies in building new smart cities (Mora et al., 2018). From the quadruple-helix standpoint, living labs can improve smart city efficiency (Nilssen, 2018).

4.3. Methods

4.3.1. Research framework

We conducted exploratory case studies (Eisenhardt, 1989) to investigate the living labs' contributions to smart cities from a quadruple-helix view. The study's primary goal is to discuss how living labs enhance smart cities from a quadruple helix perspective. Figure 4.1 represents the research framework displaying the quadruple-helix supporting the activities living labs execute. They encompass primary stakeholders of our three investigated cases. They engender essential living lab players and quadruple-helix networkers, promoting groundbreaking events in a determined ecosystem producing new smart cities.

Figure 4.1 - Research framework



Source: Authors' elaboration

4.3.2. Context

Smart City Expo, the Knowledge Cities World Summit and the Open and Agile Smart Cities have recognised the selected cases (Living Lab Florianópolis, Living Lab of the Technological Park of Itaipu and Porto Digital) as fostering open innovation and municipal development. The Florianópolis Innovation Network, a partnership between the city hall and the Catarinense Technology Association (ACATE), created the Living Lab Florianópolis in 2018. This living lab implemented new ideas to foster innovative urban growth, using infrastructures to test the feasibility of indorsed solutions. In this first experience, ten projects were generated in the living lab.

The Itaipu Technological Park was created in 2003 to increase tourism, technology and sustainability in Brazil and Paraguay. Since 2018, it has hosted a living lab focused on smart cities, with physical space for test-beds, labs, universities and a business incubator to research renewable energies, IoT, smart buildings, ICT and sustainable urban mobility. The Park living lab has completed 11 projects, and 13 are being developed.

Porto Digital constitutes a technological park hosting more than 300 companies and ICT institutions, Creative Economy and Technologies for Cities. It was created in 2000 as a public policy developing the information technology sector in Pernambuco. Since 2019 it has congregated the Open Innovation Lab, the Connected Urban Objects Laboratory, and the Application Testing Laboratory and incubates many startups to produce new city technologies. Notably, the fledgling institutions can use any structures and laboratories available at Porto Digital. The framework also consists of a multifunctional team, articulating tests and partnerships with local government, other companies and organized civil society. They selected about 15 projects per semester to support. Table 4.2 presents a project sample of the three living labs selected for this study.

Table 4.2 - Sample of living lab projects

Living lab	Project	Description
Living Lab Florianópolis	Mobilis	Electric vehicles for rent and sharing.
	Sigmais	Sensing for monitoring vehicle traffic and managing parking.
	Smart Green	Automation for energy and intelligent public lighting.
Technological Park of Itaipu	NeoAutus	Projects and services in IoT.
	Mobhis - Automação Urbana	Automation technologies.
	AIS Ambientes Virtuais	Immersive experiences (virtual and augmented reality).
Porto Digital	Solis Imperium	Solar energy solutions.
	REPlant	Urban farming app.
	Navegue	Solution for expanding the use of river transport.

Source: Authors' elaboration

4.3.3. Data collection

Secondary dataware was gleaned from sites, news and living labs internal documents. The primary data were collected through 18 semi-structured interviews with living lab organisers and participants, distributed proportionally in the three cases (nine living labs organizers and nine living lab participants). The sample included representatives from government, citizens, businesses and universities. All questions related to the projects, processes and events living labs carry out and their contributions to smart cities. Some interviewees answered in writing, instead of conventional interviews. We transcribed and analysed all the interviews, which lasted from 45 to 60 minutes.

4.3.4. Data analysis

To analyse the collected data, we use the content analysis approach, a method subjectively analysing the contents expressed in the text, operationalised through systematic classification, codification, and identification of themes or patterns (Hsieh & Shannon, 2005). We used an inductive approach to select the categories from the examination of the document and interview content. In the sentences, we identified critical elements for explaining aspects related to the research framework. These excerpts were coded by themes and later grouped into categories presented and discussed in sub-items of the following section. Content analysis involves subjective researcher judgment. Two researchers worked independently on the coding and text classification to avoid reliability problems.

4.4. Results

4.4.1. Multiple stakeholders' involvement.

In the investigated cases, we observed multiple stakeholder involvement in living labs starts with the evaluation committee. According to criteria established in the call for proposals, these committees scrutinised eligible projects. In the three cases, several entrepreneurs participated, teachers, public managers, citizen organisations, investors and members of auxiliary organisations(incubators and accelerators). Similarity in committee composition existed, including all representatives considered in the quadruple helix. In all cases, professionals from the government, industry, universities and society actively partook in the screening and selecting the proposals submitted to each living lab. A comparison of the selection initiatives among the three cases is portrayed in Table 4.3.

Table 4.3 - Selection of initiatives - comparison between cases

Case	Committee	Themes	Selection criteria
Living Lab Florianopolis (excerpt from the Call 1-2018 for Living Lab Florianópolis Program).	"Selection: an Evaluation Committee analyses and evaluates the content of the approved documents and will be composed of actors from the innovation ecosystem (entrepreneurs, teachers, public managers, investors)."	"The themes of solutions, possible demands and opportunities that the program search select are: Water, energy and the environment; Security; Public administration; Tourism, creative economy, culture, entertainment; Transport and mobility; Quality of life and health; Commerce solution."	"The selection criteria are: a) Profile: characteristics of the company/organization and team competence. b) Innovation: the presence of new or distinctive features and comparison with other solutions with similar purposes; c) Adequacy: the solution meets the requirements of the beneficiaries, the rules, and laws necessary for its implementation; d) Usefulness: adding value from the solution to the market/society; e) Market: viability of the solution's commercialization model".
Porto Digital (excerpt from the Call for Porto Digital Entrepreneurship Programs: 2020.1 Incubation).	"An Evaluation Committee will be created to analyse the proposals made up of representatives of the NGPD Business Team, besides partners, investors, researchers, entrepreneurs, and external experts."	"Smart Cities: creating innovation in environmental sustainability, tourism, digital accessibility, urban mobility, citizen empowerment, drinking water, energy, and sanitation."	"Evaluation Criteria: Profile and availability of entrepreneurs; Knowledge of the Problem and Market; Product/Degree of innovation; Impact; Business & Management Model; Business & Capital Opportunity."
Itaipu Technological Park (excerpt from the call for corporate innovation program focusing on developing new companies 001/2020).	"The proposals sent by the entrepreneurs will be evaluated and selected through a panel made up of business specialists to be defined later by the PTI-BR Foundation."	"Thematic lines: Agribusiness; Energy; Tourism and Cities; Critical Infrastructure Security."	"In the selection of proposals for the Incubation phase, three criteria will be considered: a) Technical: [..] will evaluate the proposals under four axes: Market,

Case	Committee	Themes	Selection criteria
			Management, Finance, and Technological. b) Entrepreneur (attendance, commitment, quality of deliveries). c) Solution (potential for scale solution, cost x benefit, MVP quality)”.

Source: Authors' elaboration

Other aspects of committee activities were displayed in the calls: thematic adherence and the project evaluation criteria. The thematic adherence of the project conditions engenders its compatibility with smart city development. Among the themes presented in the cases studied, we found the orientation for developing projects related to sustainability (water, energy, and environment), security, public management, participatory governance, tourism, creative economy, culture and entertainment, mobility and life quality. Notably, themes identified in the three cases remained compatible with those Mora et al. (2018) described regarding the smart city progression.

Regarding the selection criteria, the emphasis remained on examining the participant profile, innovation the project introduced, market potential and social benefits. In the three cases, the solution orientation developed for the market, showing a business concentration on the living labs, as illuminated in Vanmeerbeek et al. (2015). It illustrated a critical process for discussing the contributions living labs offer, selecting the most promising projects favouring resource optimisation. Finally, it should be noted that this rationalisation process contributes to solving the concern with the financial return of living labs, given that it remains an unresolved question in the literature (Nesti, 2018). In this context, we have identified the governmental role as an activator, given their contribution to the financing and organisation of the living lab

Also, several interviewees pointed out the role of universities in the methodology's development and as a strategic partner in providing new information and knowledge during the progression of selected proposals by the living lab. Interviewee # 10 expressed, “at the Living Lab Florianópolis, the Federal University of Santa Catarina, through the research group VIA Estação Conhecimento, specialized in innovation and entrepreneurship habitats, developed the method used in the Program. Also, the university acted as a connector of actions for the viability of solutions.” Respondents mentioned the importance of university for proposals development in the living labs, as voiced from Interviewer # 17: “Many solutions are based on academic research. However, it is necessary to bring this ‘laboratory solution’ to a ‘market solution.”

4.4.2. Training and collaborative events

We identified in the cases the events the living labs organised connecting fledgling projects with other components of the quadruple-helix and fomenting alliances. These practices bond participants to other actors in the innovation ecosystem, who are usually invited to lead workshops during the cultivation. In these activities, several companies, universities, research centres, development agencies, public institutions and private partners participated. Interviewer # 16 articulated, "Our event trail takes place weekly (jam sessions, workshops), to awaken possibilities and connect actors, the place where connections happen." These events align with participant expectations accessing a more extensive business web and discovering future markets (Perng et al., 2018).

The studied cases rely on the living labs as connectors, for the living lab teams seek to reconcile the actual project needs of each with general practices. While a current events agenda meets all project requirements, specific agendas focus on each item. This schema favours projects in more advanced developmental stages, reporting the actions forming new partnerships and increasing visibility. Interviewer # 6 asserted, "No improvement at the product level, but it generated more visibility and strengthened some partnerships." while Interviewer # 7 voiced, "One of the Living Lab's major strengths was establishing partnerships, connecting networks that remained in contact after the laboratory experiment." These statements corroborated living labs can increase project visibility in the media and the community (Ståhlbröst, 2013).

The Itaipu Technological Park depicted a distinct initiative, increasing integrating projects and local institutions. Before the publication, they called public and private organisations in the region to register their technological needs, selected groups can help solve. Therefore, since the beginning, a link existed between the initiatives and the local ecosystem actors. Interviewees emphasised local businesses contributed to the efforts registered in the living labs. Interviewer # 14 mentioned, "In the Program, those who facilitate and mentor are ecosystem companies. We have a significant exchange between entrepreneurs and the ecosystem itself". These companies provide incubated projects with informational, relational, physical and financial resources. As Champenois and Etzkowitz (2018) pointed out, when studying hybrid institutions for innovation, mentors from successful companies helped to develop projects registered in living laboratories, according to the participants' views.

4.4.3. Tests inserted in real places

In the three cases, the interviewees considered the real environments for testing significant, corroborating other investigations (Voytenko et al., 2016; Hossain et al., 2019). At this stage, government participation provides adequate space to carry out experiments, and government representatives in living labs facilitate articulation. Interviewee # 7 exemplified the results of this interaction: “During the Living Lab, the joint work between the living lab team and the city hall was essential to making the tests of the companies feasible, given the variety of products. It was an extremely complex activity, as each company required creating a different testing environment.”

One aspect making testing complex entailed the variety of needs for each project. Interviewee’s # 10 illustrated the need for articulation with government agencies to carry out tests: “One example was the company Sigmais, which, during its participation in the Living Lab, inserted a vehicle counting device at the entrance and exit of Santa Catarina Island. The Florianopolis secretariat of mobility later used these numbers for decision making. Another example was ManejeBem, which used vegetable gardens at health centers to provide remote cultivation advice. The company Wifeed used a busy street in the city center to install its Internet Hotspots with a media platform”. Although the living lab is characterised as a place to test solutions (Evans and Karvonen, 2011; Voytenko et al., 2016; Mora et al., 2018; Hossain et al., 2019), little has been explored about why participants take trial solutions in this context. Living labs simplify interactions with other agents to conduct experiments, especially with the local government.

In the specific case of the Itaipu Technological Park, some spaces allowed prototype installation in the park’s structure, simulating real environments. Interviewee # 17 confirmed the disposition: “The technological park allows the installation of prototypes in the park itself and helps in articulating partners for the prototype installation/validation." Despite the emphasis on government participation as the primary test enabler, we also see contributions from universities and local companies. In these cases, understood as exceptions, colleges and businesses offered physical structures, machines and human resources for more specific tests. These presented situations related to projects depending on the available technology and knowledge in the quadruple-helix.

4.4.4. User-centric development

The living lab promoting a “feedback culture" stood out from the interviewees’ statements. Feedback, an essential part of product development, helps decide whether to continue, pivot, or abandon the project. The excerpt from the interviewee # 7 illustrated, "One of Living Lab's most relevant contributions was the development of a feedback culture, in which customers provide their impressions about the functioning of the products developed [..]. Customer feedback is fourth helix participation, considering that it is a collaboration for product development."

Many interviewees recognised this stage as accelerating technical learning and behavioural issues directly affecting solutions adoption. Interviewee's # 12 professed, "We did a series of tests and surveys with end-users. We face a problem of low engagement. We found that some people did not maintain the app because of the lack of space in the phone's memory, among other hypotheses that we had not tested yet." Most times, this was the first opportunity to test the product or service with the end-users.

Interviewees have reported a short iterative process close to the end-user. They described updates were available for testing as soon as they created the functionalities, allowing for continuous feedback. They also mentioned cycle continuity after the living lab closing, establishing a relationship between customers and suppliers. The excerpt from the interviewee # 4 clarified, "We developed the product with the customer. With each update, the tool received feedback on its functionality, making it better. We used the customer environment as a testing platform, launched the platform, defined the testing time, and met to discuss the results. Even after launch, we train customer employees to understand the tool."

The interaction of the end-user transpired passively. In the primary data as well as in the secondary data analysed, we found no evidence of end-users acting as co-creators in the solution development stages, as most researchers of living labs asserted (Almirall & Wareham, 2011; 2012; Ballon et al., 2018; Bergvall-Kareborn & Stahlbrost, 2009; Hossain et al., 2019; Schuurman et al., 2012).The end-users embodied more a passive tester, distinguished from the expectation of user-driven innovation.

4.5. Conclusions

The paper explored the living lab contribution to smart cities from the quadruple-helix perspective. Three living lab case studies (Living Lab Florianópolis, Porto Digital, and Itaipu Technological Park) revealed four processes living labs contribute for smart cities: a) selecting the most promising projects, b) connecting several agents through collaborative practices and events, c) facilitating mediation between participants and government agencies, universities and local companies and d) incorporating society— the fourth helix, as a tester, but not as a co-creator.

Project selection involved multiple components of the quadruple-helix from the initial stages in the living labs. Particularly, the university focused on technical guidance and methodological definitions used in the living lab. In this sense, the university qualified the project selection within living labs. Additionally, the government, as a living lab financier and promoter, also represented a relevant facet to enact an initiative.

The events virtually connected the participants to the other local actors involved in the innovation. The quadruple-helix led to workshops and lectures, where participants could establish contacts and partnerships to bring efforts to fruition. Local companies found mentors during the living labs.

Also, the living labs mediated testing. The organiser articulation with the local government, universities and local businesses provided access to physical spaces, machines and human resources needed to trial the solutions. The government engaged with the team of living lab organizers, reducing the barriers participants faced.

Finally, it should be noted incorporating civil society in the process did not occur as outlined in the literature. In the three cases studied, end-user participated in the innovation, as testers and providing feedback to the solutions. However, far from being a user-driven innovation procedure. In other words, the end-user played a secondary role during the development, acting more as a tester than a co-creator.

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4.7. Annex I - Interview questionnaire

Research - "Living labs contributions to smart cities from a quadruple-helix perspective".
We intend this questionnaire to assess the effective contribution of living labs to the development of solutions for smart cities. In this sense, we are contacting entrepreneurs and organisers who took part in incubation calls in which there was the support from a living labs. This questionnaire is anonymous and confidential, and we will use only the answers for scientific purposes. This questionnaire is an integral part of a PhD research work in Administration, from the Faculty of Administration, Accounting and Economics of the University of São Paulo, under the guidance of Professor Gilmar Masiero.
We thank you in advance for your availability and collaboration in this study. We are available to answer questions.

1- During the incubation period, were any of these activities offered?
   ( ) Mentoring.
   ( ) Design thinking sessions.
   ( ) Meetups and networking meetings.
   ( ) Hackathons.
   ( ) Workshops.
   ( ) Others.
2- How did the activities mentioned above help entrepreneurs in the development of projects? Could you cite examples of the remarkable experiences you had?
3- Did the incubation experience contribute to the prototyping or improvement of the projects? If so, in what ways could you inform us?
4- During the incubation period, was a structure offered to test the projects in an environment close to reality? If so, could you highlight any experiences?
5- During the incubation period, did the incubated projects receive feedback from the end customers? If so, how did this feedback affect the products / services offered by the projects? Could you give some example (s)?
6- Do you consider that the projects contributed to the development of smart cities in Brazil? if so, in what way?
7- Did the universities play a role or offer contributions to the incubated projects? If so, could you highlight some examples?

8- Has the government, considered in its multiple instances, played any kind of role or offered contributions to the incubated projects? If so, could you highlight some examples?
9- Did local companies and industries play a role or offer contributions to the incubated projects? If so, could you highlight some examples?
10- Did the local citizens play a role or offer contributions to the incubated projects? If so, could you highlight some examples?
11- Did any other institutional actor play a role or offer contributions to the incubated projects? If so, could you detail which actors and their respective contributions?
12- How do you assess the incubation period? What could be improved in the experience?

5. CONCLUSIONS

In this dissertation, we assess the living labs' contributions to smart cities from a quadruple-helix perspective. We divided this principal goal into three specific objectives. The first specific one concerns the consolidation of an operational concept of smart cities from the literature analysis. This clarification was essential to understand the multiple concepts employed by different researchers in the field of knowledge-based economy investigating smart cities. There is no consensus in the literature about what a smart city is or should be. The first concepts took into consideration the technological developments while the later ones consider the citizen´s participatory aspects in designing and implementing new project to improve the quality of life and citizenry in large urban areas.

Our findings of this first research effort show that there is convergence in the literature on the following main characteristics of smart cities: a) Advanced ICT Technology; b) Sustainability; c) Innovative and high-skilled society; d) High-tech governance and citizen participation; and e) Knowledge-based economy. Based on these findings, we suggest a new concept: an innovative and qualified society, oriented towards the development of the knowledge economy, which makes advanced ICT technologies aimed at promoting sustainability and participatory urban governance.

This study is a robust effort to understand smart cities and presents a new concept covering its five key characteristics that should be considered in future investigations. It also contributes to smart cities' management since it provides well-based evidence of characteristics that smart cities must present to fit into an internationally accepted framework. In this way, there is a substantial contribution to overcoming the problem mentioned in the literature of cities tending to congratulate themselves as “smart” without presenting characteristics that allow comparison with national and international peers.

The second specific objective was clarifying the approaches to assessing smart cities' development, corroborating the importance of studying the knowledge-based economy and quadruple helix networks. We reviewed the literature related to the evaluation of smart cities. Based on this review, we proposed four approaches to understand the models related to the smart cities’ assessment: ranking, data-driven management, innovation ecosystem, and maturity. By systematically reviewing the literature and the contributions of each of these approaches, our study provides a more general assessment of what each approach reveals about smart cities' contributions.

Regarding smart cities' management, our research results present unconventional approaches, and managers can use that in the smart city evaluation. Besides ranking models, widely disseminated and accepted in academic and non-academic literature, other types of evaluation models focus less on comparing cities. These other models can facilitate the key aspects monitoring for the development of smart cities, such as their maturity level and the development of their innovation ecosystem.

The third objective was to analyse living labs' contributions to innovative projects developed for smart cities. To our knowledge no previous study on this issue was developed based on the quadruple-helix perspective. Three living lab case studies (Living Lab Florianópolis, Porto Digital, and Itaipu Technological Park) were developed to conclude that living labs contribute for smart cities: a) selecting the most promising projects to be promoted; b) connecting several agents through collaborative practices and events; c) facilitating mediation between participants and government agencies, universities and local companies; and d) incorporating the society - the fourth helix, as a tester, but not as a co-creator.

Using this perspective, we were able to find out these interesting results, specially the last one that contradicts the extant literature. At least in the three Brazilian Living Labs considered in this study the society or citizens are not co-creators of the innovations. Rather, they are just members involved in the experiments to provide feedback without participating in their design or having a voice in the process. As livings labs are institutional solutions to connect quadruple-helix components efficiently the fourth helix must be better included in the projects developed by Brazilian living labs. Brazilian living labs may insert the fourth helix into the innovation process, not relegating it a secondary role. The study presents elements that smart cities managers can use in the articulation of different actors to generate innovation in smart cities.

Considering the issues explored in the second chapter - the evaluation approaches, we would highlight the need for more significant methodological development of data-driven management, innovation ecosystem, and maturity approaches. We realised that they are still in an early stage of evolution, especially when compared to models based on the ranking approach. In turn, the rankings could be explored in specificities or by themes, for example, rankings related to sustainability, mobility, security, economy, innovation, and among other aspects related to smart cities.

Regarding our last research effort described in the chapter 4 there is a strong need to investigate other roles that civil society could play during innovation processes, besides tests and feedback. Our results converge with other research on the producer-oriented perspective adopted more recently by living labs. In this sense, the question of how to implement an innovation model in more user-centric cities remains open. Another issue pointed out by the interviewees' that deserves more attention is the fact that foreign corporations are registered in the living labs. It is noteworthy that many of these corporations also act as sponsors of the initiatives. On the one hand, this corroborates the effectiveness of living labs in developing projects. On the other hand, there is a concern about the country's low technological development.

While developing the research effort to build up the present dissertation, I actively participated in a study on smart cities developed by the Centre for Strategic Studies and Debates (CEDES) at the Brazilian Chamber of Deputies. We heard municipal secretaries for innovation and urban development in Brazilian cities of all sizes, specialists, academics, civil society organizations, control, and inspection bodies. The experience was a counterpoint to the academic theoretical experience because smart cities' literature is basically foreign, especially North American, European, and Asian. This empirical experience highlighted that definitions, evaluation models, and discussing roles and opportunities for civil society participation in living labs may be different for those of developing countries.

For example, developing the basic sanitation system will hardly be reflected in a world smart city ranking. In European and North American cities, these are points that have already been overcome. Another aspect that seems to be a more pressing issue for developing countries is the educational deficit. According to data from the Programme for International Student Assessment - PISA 2018, we live in Brazil with a worrying reality. Part of the population receives education at a level compatible with the best examples globally, considering the average education received in federal public schools and private schools. On the other hand, we also have a significant portion of the population that receives a poor-quality education, considering the state and municipal schools. These examples illustrate that both the conceptual vision of a smart city and the evaluation models must reflect the challenges of overcoming economic and social inequality that plagues developing countries. In particular, thinking about the smart city in Brazil addresses how to overcome the problems experienced by our citizens in our cities.

One aspect that will directly affect our ability to develop smart cities in Brazil is the preparation of mayors, municipal secretaries, and public servants. Throughout all public hearings held, I observed a phenomenon called "blackout of pens" - fear of the public manager to innovate, given the potential sanctions imposed by the control and inspection bodies. In this context, many prefer to continue doing what is already consolidated, avoiding innovative practices and solutions.

Smart solutions in progress in Brazil are not always technological. Many municipal managers are doing fantastic jobs in fields like health and education, basically with restructuring processes aiming to optimize resources. As an example, I would mention the cities of Jundiaí, Joinville, São José dos Campos, Goiânia, Belo Horizonte, and São Paulo. The contact with these ongoing experiences reinforced my view that the human and institutional components are fundamental pieces for developing smart cities.

Another parallel experience that I had during the preparation of this dissertation that strongly impacted my vision on smart cities was to take part in the drafting of the Brazilian Charter of Smart Cities. In this work, three workshops, with over two hundred specialists were developed to establish a smart city concept and the objectives and actions that applied to Brazilian cities. The scenario before the Charter is that municipal governments carry out smart city programs without articulation. Besides, federal programs, such as Digital Cities of the Ministry of Science and Technology, were based on resolving specific problems without a holistic view.

Policies for smart cities should be thought across all sectors. It is not possible to think of an educational policy that does not comprise digital inclusion. It is impossible to develop a knowledge-based economy without structuring the educational system to support knowledge workers. Nevertheless, the Brazilian scene lacks coordination, both horizontally between municipalities and between ministries, and vertical among municipalities and the federal government.

In this dissertation, I proposed the concept of a smart city based on academic literature. However, let us remember cities are organic social phenomena, which adapt and develop according to the current social drives. In this sense, the Brazilian Charter for Smart Cities' is a good example of a marriage between a technical vision of a smart city and a political-social one. Matching academic and technical recommendations with the political imperatives of specific contexts is a promising path for the effectiveness development of smart cities around the world, especially the underdeveloped part of it.