The impacts of open data initiatives on smart cities: a framework for evaluation and monitoring

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A B S T R A C T

As the world's population is becoming progressively urban-dwelling, sustainable development challenges are increasingly concentrated in cities, placing tremendous pressure on society to build more sustainable, innovative, and equitable urban environments. Consequently, today's cities require integrated policies and new innovative ways to manage and improve the complexity of urban living conditions. The growing volume and variety of data produced in the urban ecosystem are crucial for obtaining the city's insights and building knowledge-based solutions for a smarter and more sustainable urban development. In this paper, we look at the open data impacts on these complex ecosystems and its crucial enabler role for the generation and analysis of contextual and actionable data aimed at understanding, managing, and planning the city. Despite the importance of open data, the literature is scarce in systematic and structured research that evaluates its impacts on the smart city context. This paper explores this gap by proposing a theoretical framework, composed of a model and an experiment grounded on the use of Randomized Controlled Trials (RCT), designed to give a more detailed view concerning the context and characteristics of the impacts of open data initiatives on smart cities' sustainable development. This work will contribute to open data management and smart city development, providing boundaries and theoretical insights for further research and experimentation on how open data can be leveraged to develop better smart cities.

Keywords: Open data, Smart cities, Sustainable urban development, Impact evaluation, Randomized controlled trials, Theoretical framework

1. Introduction

Today, 55% of the world's population lives in urban areas, and as the process of urbanization tends to exacerbate with population growth, this number is estimated to climb to 68% by 2050 UNDESA (2018). Although cities occupy only 3% of the total land surface, they are responsible for the production of 80% of global GDP and consume 75% of the natural resources, produce 50% of global waste, and account for 60-80% of Greenhouse Gas Emissions (UNEP-DTIE, 2017). Furthermore, in the current scenario of Industry 4.0—the fourth industrial revolution, as the rapid development of digital technologies and the use of information in productive processes induce structural changes in the economy (production, distribution, and services), new trends in cities are also generated (Lu, 2017; Moustaka, Vakali, & Anthopoulos, 2019; OECD, 2017; Wilson & Chakraborty, 2019).

In this transformative ambiance smart cities arises as a form of interaction among technological, organizational and political innovations to provide an intelligent response to the sustainable urban development challenges, embracing innovative and future-oriented solutions for governance, economy, mobility, environment, living, and people (Abella, Ortiz-De-Urbina-Criado, & De-Pablos-Heredero, 2017; Aguilera, Peña, Belmonte, & López-de-Ipiña, 2017; Bibri & Krogstie, 2017; Khatoun & Zeadally, 2016). Also, by the adoption of future technologies, ubiquitous and data-driven solutions, and their integration in an intelligent system of systems, smart cities constitute urban hyper-connected ecosystems in which a confluence of technologies takes place (Calzada, 2017; Gupta, Panagiotopoulos, & Bowen, 2020; Kummitha & Crutzen, 2017).

The fourth industrial revolution grounds on the data revolution, generating a global trend toward more data-driven decision-making in policymaking. This trend urges governments to promote greater openness and transparency by releasing data in a more accessible way, creating a challenging opportunity to provide a new asset to usher in positive social and economic transformation (Currie, 2020; Kitchin, 2014; Smith, Gerry, & Truswell, 2015; UN-IEAG, 2014; Verhulst & Young, 2017).

Openness and a pathway through a more intelligent openness—supported by descriptive metadata and meeting requirements for interoperability, is paramount to obtaining the promise of the data revolution and the knowledge built on top of that (Boulton et al., 2012). On smart city context, open data initiatives seek to promote better city governance, enhance transparency, analysis, and planning, reinforce citizen engagement and participation, foster co-creation and collective intelligence, and support innovative products and services, while can be useful in providing solutions to many socio-economic and environmental problems (Neto, Rego, Neves, & Cartaxo, 2017; Ubaldi, 2013; Yadav, Hasan, Ojo, & Curry, 2017; Young & Verhulst, 2016).

Although some comparative studies exist (Ojo, Curry, & Zeleti, 2015; Zuiderwijk & Janssen, 2014), and despite the importance of open data initiatives, the literature is scarce in systematic and structured research on the impact evaluation of open data initiatives on smart cities context. The purpose of our study is to address this gap, and we aim at evaluating open data initiatives' impacts to understand further the conception and improvement of open data policies to tackle smart cities' sustainable development.

To achieve this research objective, firstly, we mapped through a systematic literature review methodology issues and characteristics concerning the evaluation and monitoring of the impacts of open data initiatives on smart city context. Secondly, we proposed from the literature review a theoretical framework, consisting of a conceptual model and an experiment grounded on the use of RCTs (Pearce & Raman, 2014; Verhulst, Noveck, Caplan, Brown, & Paz, 2014), which intents to understand the effectiveness of open data policies and to gain insight into the conditions and factors concerning its impacts on smart cities.

The main contributions of this study are twofold. First, notwithstanding some studies to review the literature on the impacts of open data on smart city context have been made in the past, they did not pursue a systematic review approach, were explicitly focused on particular smart city dimension or technology, or missed the opportunity to include the impact evaluation on the analysis. Therefore, by providing a systematic literature review on this topic, we found that this was an appropriate and timely effort: a) no evidence exists of an effective and robust framework for the impact evaluation of open data on the urban context, b) there is a misalignment in corresponding the supply with the demand for open data to keep up with the citizen's expectations, and c) the quality of urban open data provided is not deep enough, and there is a need to enhance it for its effective use. This systematic review of the literature may contribute to the debate on the open data impact assessment in the urban context, aiding in delimiting boundaries, and providing theoretical insights to both research and professional practice. Second, by proposing a theoretical framework that incorporates the previous work and current thinking on open data and smart cities for the evaluation and monitoring of the impacts of open data initiatives, a significant contribution is made. The practical understanding of how open data can be fully realized in smart city environments as been criticized for lacking a theoretical base.

The next section introduces and explores issues and characteristics concerning smart cities and open data. A proposal for a theoretical framework is presented in section 3, consisting of a conceptual model and an RCT as an experimental form of impact evaluation, detailing all the steps, remarks, and options taken to address the research gap. Section 4 discusses the main contributions and the implications for both research and practice. The final section presents the conclusions and the proposals for future work.

2. Theoretical background

2.1. Smart Cities background

The concept of a smart city, although extensively defined, remains ambiguous, and there is no accepted universal definition for it. The reason is that the conceptualization of the smart city varies from city to city and country to country, depending on the specific challenges faced by each city, its level of development, its willingness to innovate, the resources available, and the engagement of its stakeholders (Ghahremanlou et al., 2019; Manville, 2014).

According to the studies of Ahvenniemi et al. (2017) and Mora et al. (2017), there are two main streams in the present smart city discussion. The first is the ICT and modern technologies approach, emphasizing, and promoting the importance or value of technology. The second one is the role of human capital oriented approach—in addition to new technologies, as a holistic perspective of an assembled balance between human, social, cultural, economic, environmental, and technological aspects. Other studies regarding smart cities initiatives suggest a top-down vs. bottom-up approach (Calzada, 2017), and supply vs. demand-driven strategies approach (Angelidou, 2015).

The actual concept of the smart city is broader and takes into account that sustainability is also the engine for innovation (Caragliu & Del Bo, 2018). The fast modifying socio-economic and geostrategic context requires a social change and adaptation to put the capacity innovation at the core of competitiveness and economics while adjusting individual lifestyles that conserve natural resources. Moving toward sustainability is a societal challenge that cities face today by congregating economic development and environmental change. In order to become smarter and more sustainable, cities must embrace the development of sustainable awareness, urban growth, and technological innovations (Bibri & Krogstie, 2017).

By definition, a smart sustainable city *"is an innovative city that uses ICTs and other means to improve the quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects"* (ITU-T, 2016, p. 13). This interpretation based on a human-centric perspective requires to unlock and exploit the potential of ICT for data collection, analysis, and integration on every city domain and system, to develop urban intelligence and gain deep and predictive insights for informed and robust decision making (Mora et al., 2017).

In this data-driven approach to creating innovation in smart cities lies the key and central role that cities play in our efforts to move toward sustainability (Martin, Evans, & Karvonen, 2018). Therefore, smart cities can be described as complex systems and understood using data representation, and as cities that drastically increase the pace of sustainability and resilience, essentially refining the way it:

- encompasses society;
- uses collaborative guidance approaches;
- works crosswise disciplinary areas and city systems; and,
- uses data and technology integration,

with a purpose to transform services and ensure a better quality of life (ISO, 2014; Schindler & Marvin, 2018).

In the literature, several models for understanding and conceptualizing smart cities exist aiming to define smart cities' architecture as a sustainable model for urban development through better city planning and management (Komninos, Kakderi, Panori, & Tsarchopoulos, 2019; Monzon, 2015). These models are focused on different features such as governance, services, environment, facilities, among others (Fernandez-Anez, Fernández-Güell, & Giffinger, 2018).

As stated by Khatoun and Zeadally (2016), the most widely adopted smart city reference model is the one proposed in the influential report by Giffinger et al. (2007) and includes six key dimensions defined by distinct factors, forming a framework for the assessment of a city's performance as a smart city (See Table 1). This report uses a wide range of factors and indicators to measure various aspects of smart cities while ranking medium-sized European cities accordingly.

As a framework for urban transformation, the smart cities initiatives emerge to address the needs of businesses, institutions, and citizens, to enhance quality and performance in all areas, from economy and mobility to environment and energy, increasing security, sustainability and resilience, while promoting competitiveness, attractiveness, and quality of life (Chourabi et al., 2012; Khatoun & Zeadally, 2016; Kumar, Singh, Gupta, & Madaan, 2018; Yigitcanlar et al., 2018).

Table 1
Smart city reference model proposed by Giffinger et al. (2007)

City dimension	Characteristics	Context	Contextual factors
1) Smart Economy	Competitiveness	Economic competitiveness	Innovative spirit, entrepreneurship, economic image and trademarks, productivity, the flexibility of the labor market, international embeddedness, and ability to transform
2) Smart People	Social and human capital	Education and quality of social interaction	Level of qualification, affinity to lifelong learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism/open-mindedness, and participation in public life
3) Smart Governance	Participation	Political participation	Political participation, services for citizens and administration, regarding participation in decision-making, public and social services, transparent governance, and political strategies and perspectives
4) Smart Mobility	Transport and ICT	Accessibility, ICT, and transportation	Local accessibility, (inter)national accessibility, availability of ICT infrastructure, and sustainable, innovative, and safe transport systems
5) Smart Environment	Natural resources	Natural conditions, pollution issues, and environment protection	The attractiveness of natural conditions, pollution, environmental protection, and sustainable resource management
6) Smart Living	Quality of life	Quality of life and wellbeing	Cultural and education facilities, health conditions, individual safety, housing quality, touristic attractiveness, and social cohesion

The study of Ojo et al. (2014) presents the main goals that smart city initiatives aim to achieve, namely:

- carbon emissions reduction and neutrality;
- energy efficiency;
- ICT leverage;
- environment improvement;
- build a greenest city;
- promote access to information;
- endorse economic growth and quality of life;
- develop sustainable communities;
- ensure social harmony; and
- creation of smart city living labs,

by harnessing the use of information technologies and knowledge infrastructure—making sense of vast quantities of data and large volumes of information, to deliver high-quality services and infrastructures, alongside with innovative urban management (Arman, Abbas, & Hurriyati, 2015; Degbelo, 2020; Moustaka et al., 2019; Nam & Pardo, 2011; Ruhlandt, 2018).

2.2. Open data background

Since the last decade, there has been an increasing global trend toward the systematic opening of data. The first countries to open their public data were the United States and the United Kingdom. In 2009, the United States government launched the data.gov portal, one of the largest repositories of open data collected by governments. The United Kingdom launched the data.gov.uk portal in 2010. Washington, New York, Chicago, Helsinki, Amsterdam, Dublin, Manchester, Barcelona, and Berlin were early adopter cities in open data. Since then national, regional, and city governments never cease to endorse open data policies and strategies and create open data initiatives (Khatoun & Zeadally, 2016; Verhulst & Young, 2017; Yadav et al., 2017).

The Open Knowledge Foundation (http://okfn.org/), launched in 2004, is the world's largest open data community, and one of its first projects sought to define digital openness by releasing the Open Knowledge Definition (OKF, 2019). In this paper, we take open data as defined in the Open Knowledge Foundation's Open Data Handbook (Poikola et al., 2010): *"Open data is data that can be freely used, re-used and redistributed by anyone - subject only, at most, to the requirement to attribute and share-alike"* (Poikola et al., 2010, p. n.a.).

In a broader sense, open data can be understood as data that is (Davies & Perini, 2016; OKF, 2019; Verhulst & Young, 2017):

- available as a whole and accessible online;
- machine-readable for use and re-use and redistribution; and,
- for universal participation, by means that everyone must be able to use, re-use and redistribute.

By being available to anyone, open data can be used by policymakers, researchers, entrepreneurs, and citizens in ways that have the potential to foster economic progress and stimulate innovation by enhancing entrepreneurial activity for innovative products and services, and encouraging positive social change by empowering citizens and promoting inclusion (Abella et al., 2017; Berrone, Ricart, & Carrasco, 2016; Davies & Perini, 2016; Smith et al., 2015; Verhulst & Young, 2017).

The majority of open data initiatives are part of governments' efforts to open up data to thoroughly foster greater transparency, improve accountability, generate economic growth, promote innovation, empower citizens, fight corruption, achieve environmental goals, and provide better public services (Berrone et al., 2016; Davies & Perini, 2016; Jaakola, Kekkonen, Lahti, & Manninen, 2015; Ojo et al., 2015; Smith et al., 2015).

A smart city is a natural environment for open data generation due to its inherent capabilities of massive data production (Khatoun & Zeadally, 2016; Moustaka et al., 2019). The plethora of data gathered through the urban data ecosystem—sensors embedded in urban infrastructures, facilities, environments, machines, and devices, which, along with usage of analytics, is helping to obtain predictions and providing useful insights for city development and have opened new paradigms to the sustainable urban development (Aguilera et al., 2017; Calzada, 2017; Meschede & Siebenlist, 2019; Wang, Fang, Liu, & Horn, 2018).

Cities are structured by and pervaded with different types of infrastructures (e.g., ICTs, transport, water, energy, waste networks) that facilitate movement and flows of resources, products, people, and information (Lim, Kim, & Maglio, 2018; Riberto, Govoni, Stefanelli, Suri, & Tortonesi, 2018). Activities in cities allow measurement of transaction, consumption, and communication patterns. These patterns include, in particular (Khatoun & Zeadally, 2016; OECD, 2015):

- citizens' activities;
- interaction and communication between citizens;
- interactions between citizens and the urban environment;
- interactions among components of the urban environment; and,
- interactions and transactions between citizens and businesses with public institutions.

Accordingly, open data is a defining element of smart cities and, as such, can be considered as a smart city initiative in terms of a concept (Ojo et al., 2015; Yadav et al., 2017). Open data initiatives constitute urban innovation precisely because open data can be used freely by anyone, and all sorts of unanticipated ideas and innovations emerge (Ahlgren, Hidell, & Ngai, 2016; Wang et al., 2018). In that sense, open data is one of the most powerful resources that cities can provide to its citizens and the whole community in general, due to its impacts in different cities domains—from the economy, environment, energy, transportation, health, education, to the quality of life, among others (Ojo et al., 2015; Schieferdecker, Tcholtchev, Lämmel, Scholz, & Lapi, 2017)

This intertwining of smart cities and open data initiatives is unfolding at different paces and scales across several cities. The goal is to understand how open data is aligned to a smart city context, and this question is twofold: how do open data initiatives impact the context of smart cities and how do smart city programs shape associated open data initiatives. The study of Ojo et al. (2015) shows that there is clear evidence of alignments of the open data initiatives to their contextual smart city programs, an alignment in which open data initiatives are expecting to impact smart cities' domains directly and at the same time be shaped by the smart city context. This question is of utmost importance to determine the collection of high-value city datasets to release to incentive genuine interest and motivation in using open data (Liu, Jiang, & Li, 2017; OECD, 2015; Prieto, Mazon, & Lozano-Tello, 2019; Yadav et al., 2017; Yarime, 2017).

According to Verhulst and Young (2017), in the context of smart cities, open data initiatives may have four main types of impact and associated outcomes, as described in Table 2.

Table 2
Main types of impacts and outcomes of open data initiatives proposed by Verhulst and Young (2017)

Open data impacts	Outcomes
1) Create economic opportunity	• Enable business creation • Job creation • New forms of innovation • Stimulate economic growth
2) Help to solve complex public problems	• Improve situational awareness and preparedness • Increase knowledge and expertise to bear on public problems • Allow policymakers, civil society, and citizens to target interventions better and track the impact
3) Improve governance	• Enhance transparency and accountability • Improve service delivery • Efficiency gains • Increase information sharing within and outside city domains
4) Empower citizens	• Improve participatory capacity • Act as a catalyst for social mobilization

Despite the recognized potential benefits and significant progress on the realization of open data initiatives, they still represent uncharted territory for many cities (Berrone et al., 2016). Substantial challenges that limit the effective implementation of open data remain to be solved before they can be widely applied to support city development (Lim et al., 2018; Ma & Lam, 2019). From the body of research, several barriers regarding the proper conditions to unleash open data can be identified—they can be political, organizational, legal, technical, and financial (Conradie & Choenni, 2014; Heimstädt, 2017; Ma & Lam, 2019; Verhulst & Young, 2017). Addressing these issues with awareness regarding the availability of open data and the specific needs of users will enable reaching the full range of impacts and outcomes from open data initiatives (M. Janssen, Charalabidis, & Zuiderwijk, 2012; Khatoun & Zeadally, 2016; Ubaldi, 2013).

2.3. Open Data impacts on Smart Cities background

For understanding past research and to represent a logical and comprehensive state of current findings for guiding future research in a given knowledge domain, it is necessary to undertake a literature review (Machi & McEvoy, 2016). In this way, we undertook a systematic

literature review regarding the evaluation and monitoring of the impacts of open data initiatives on smart city context. The rationale for the usage of this type of review is already well established either for the open data domain (Attard, Orlandi, Scerri, & Auer, 2015) or the smart cities domain (Ruhlandt, 2018) and, as such, presenting to be a reasonable and appropriate methodology of achieving a rigorous and theoretically relevant analysis concerning the context of the present work.

We aimed to look for signals or elements of the different types of impacts that open data may produce on a smart city context and by analyzing the defining components of the impacts, how they are measured, which enable and disable factors influence them, what outcomes they produce, and how these domains interconnect and influence each other in this matter. This review also includes the outlining of issues, opportunities, relationships, dependencies, gaps, and trends, to produce new insights and conceptualizations for this topic.

The methodology of the literature search followed the systematic literature review framework presented in Webster and Watson (2002), having their background aligned with the guidelines of the comprehensive and iterative five-stage research method proposed by Wolfswinkel, Furtmueller, and Wilderom (2013), used for the process of reviewing the literature.

In the first stage, we identified the most suitable dataset of the body of literature. First, the appropriate sources to identify relevant studies for both open data and smart cities fields of research hinging on the impact evidence and evaluation were determined. The following databases were accessed: ISI Web of Knowledge, Scopus, Science Direct, IEEE Xplore digital library, ACM Digital Library, and AIS Electronic Library (AISeL). Preliminary analysis has shown that the addition of further databases, such as Google Scholar, would have enlarged the number of duplicate articles significantly, thus making their use redundant. Second, the specific combination of the keywords "open data" and "smart cities" (or "smart city") was selected in order to retrieve the most important studies of the intertwining between both domains. These keywords were kept in a broad sense on purpose, and the term "impact" was not considered as a keyword, as initial searches showed that the combination of the three keywords would drastically reduce the results obtained and. The evidence of the impacts and their evaluation was expected to occur in the full text of the article. Third, the criteria for inclusion/exclusion of studies were defined. Only sources peer-reviewed, journal and conference articles, and book chapters were considered to ensure the quality and significance of the research. The specific combination of the keywords was required to appear in the title, abstract, or author keywords of the article. The literature search was determined to be carried out within the period between 2000 and 2019.

In the second stage, we performed the search on the selected databases having the specific combination of the keywords, the time frame filters, and the inclusion/exclusion criteria defined upfront. As a result, a sample of 667 studies was retrieved.

In the third stage, we refined the sample of studies to be reviewed by excluding 299 duplicate studies that emerged in multiple databases. The remaining sample of 368 studies was further refined during iterative review rounds, first, by screening the abstract, introduction and conclusions of each article, to exclude potential false positives and, second, by reading the full text of the remaining sample, to dismiss studies which did not specifically focus the topic in the review or were not significantly meaningful and pertinent to overall review topic. This procedure resulted in the elimination of a total of 311 articles. Next, on the remaining subset of 57 articles, a forward and backward citation tracing was carried out (Webster & Watson, 2002) to discover further relevant studies to be included in the final sample that were not covered by the previous selection. This procedure included nine additional studies to the sample, and it was executed in order to include seminal literature, mainly because only a minority of studies addressed specifically open data impact assessment and smart city categorization. Finally, we arrived at a final selection of 66 articles.

In the fourth stage, after searching, screening and selecting the final sample fit for analysis, to obtaining a more comprehensive understanding of the subject, we categorized the individual-level studies based on their domain research into three separate groups, as presented in Appendix A: a) the individual relating to open data, b) the individual relating to smart cities, and c) the individual relating to open data and smart cities. All the literature found and selected in the review relates to the precise boundaries setting off for the appraisal of open data impacts on the realm of smart cities' sustainable development, as the topic of study.

Figure 1 contains a graph visually presenting the literature sample quantitatively. It was created using Circos (Krzywinski et al., 2009) to show the relationship between the research domains and the year. In this figure, the elements of the final sample are composited circularly in segments, with ribbons joining segments that are related. Their relationships are quantitatively represented by the thickness of their ribbons, scales, and tick marks. The ribbons are colored based on the elements that they relate to spot patterns easily. The research domains are displayed on the right side of the semicircle, whereas the years are on the left side of the semicircle (counterclockwise, starting at the top). The array of studies span over 13 years, starting in 2007 and the latest having been published in 2019. We excluded the years without studies from the graph to be able to analyze with increasing clarity the rest of the years and see what research domain they are linking to. The scales indicate the total size of each angular segment, which corresponds to the sum of its values. For a particular element, the length of the outer arcs represents the percentage of studies per year/domain in descending order. For example, the year 2017 denote about 86.7% (13 out of 15) of the studies referred to the "open data and smart cities" domain and achieved about 25,5% (13 out of 51) of all studies in that domain. The inner-circle shows the relationships between elements concerning the years and domains.

From the analysis of the figure, the right semicircle shows that the joint domain of "open data and smart cities" outnumbers the other two domains, representing about 77.3% (51 out of 66) of the total amount of the collected studies. This amount was merely obtained in the last five years of the sample, and it is shown in the graph in fairly broad ribbons. A smaller percentage referring to the individual domains of "open data" and "smart cities" represent jointly about 22.7% of the sample. Their occurrences have been balanced across time independently, predominantly in the earliest eight years, when their concepts were introduced in Information Systems literature. Regarding the left side semicircle, it clearly shows that the latest years, from 2015 to 2019, were the most prolific in scientific publication, accounting for more than three-quarters of the sample, with a total of approximately 87.9% of all publications produced.

Although Fig. 1 shows some publication scarcity from 2007 to 2014, it begins with the influential work by Giffinger et al. (2007) on the ranking of medium-sized European cities and follows a dual branch of research on smart cities and open data until 2014. From 2015 onwards, the peer-reviewed research reflects a turning point on the publication output regarding the topic of study, as a clear pattern can be perceived towards the confluence of both domains on the publication contributions to the study of open data impacts on smart cities and its growing importance as a field of research.

In the fifth stage, we draw the findings and insights obtained during the review process. The current academic debate on theory and practice of open data impact focus on whether open data use has led to change (Davies & Perini, 2016; Lim et al., 2018). Several authors

argue that aiming at improving development, open data initiatives' success depends on the premise of corresponding the supply with the demand of open data for its effective use, in order to create added value and innovative services that can accelerate smart city sustainable development (Abella et al., 2017; Kumar et al., 2018; Verhulst & Young, 2017). Also, according to the authors, the factors affecting the success or failure of open data programs are related to the environment and context regarding the existence of specific enabling and disabling conditions that determine if open data usage generates positive, negative or negligible impacts (Dinah, Lefika, & Joseph, 2019; Ghahremanlou et al., 2019; Verhulst & Young, 2017; Zuiderwijk & Janssen, 2014).

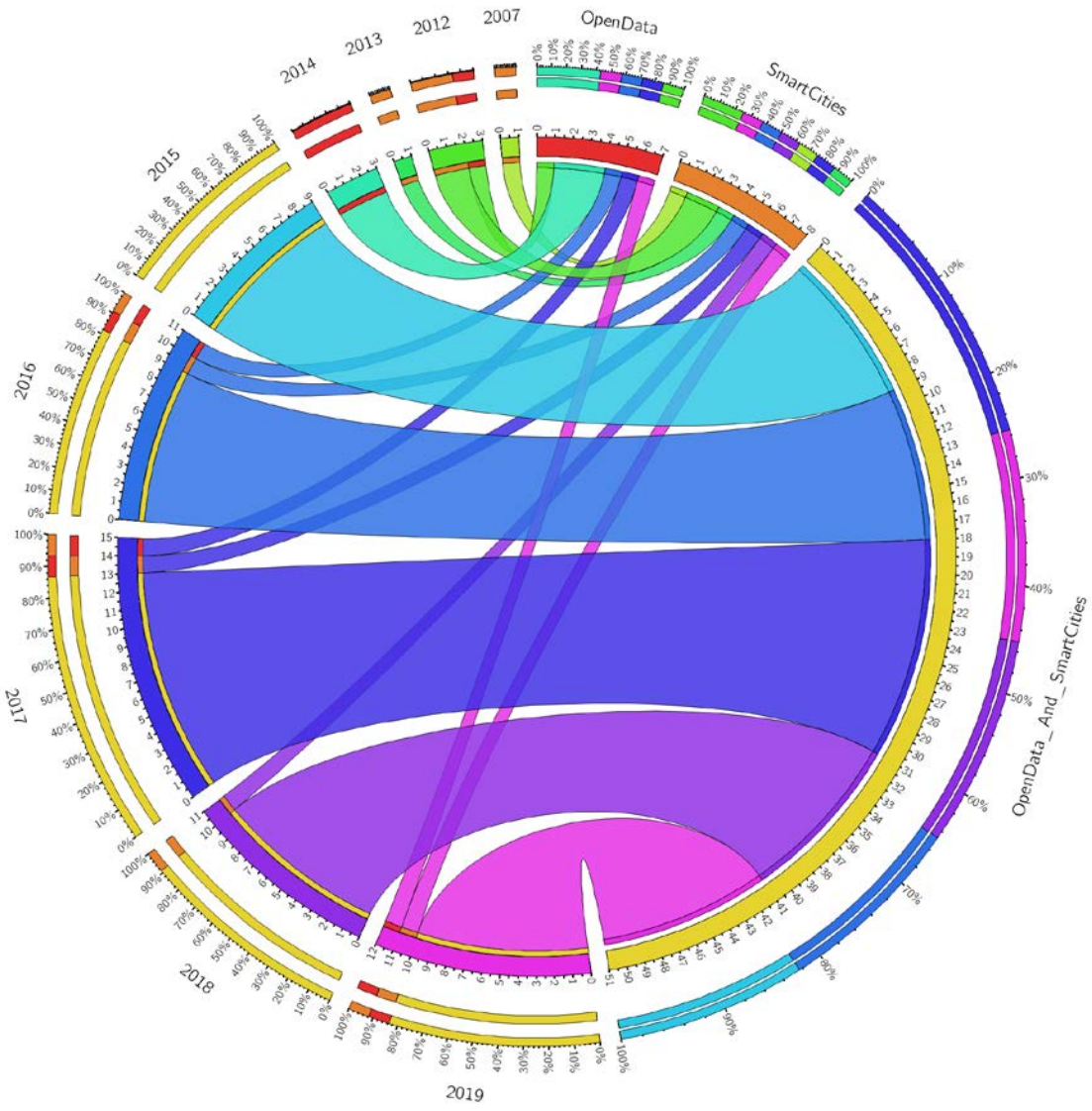

Fig. 1. Representation of the literature sample, by research domain and year

Furthermore, due to the alignment between the open data initiatives and smart cities initiatives (Ojo et al., 2015), these conditions provide a better understanding to unfold the nature of these impacts on both domains. Also, as cities face sustainable urban development challenges, innovative services and analytic capabilities are required for resource optimization and value creation with the reuse of smart cities'data. Therefore, it is likely that the use of open data has impacts on the organizational, political and technical variables of smart cities initiatives, allowing to develop more adjusted urban services for citizen's real demands and expectations (Abella et al., 2017; Chourabi et al., 2012; Giffinger et al., 2007; Kumar et al., 2018; Wilson & Chakraborty, 2019).

However, as stated by Davies and Perini (2016, p. 9), "*There are no large-scale, rigorous studies of open data impacts, and most work remains at the level of ad-hoc and isolated case studies or anecdotes*". Moreover, Lim et al. (2018, p. 86) argue that "*the knowledge and framework for data use for smart cities remain relatively unknown,*" and Liu et al. (2017, p. 133) asserts that "*So far, the evaluation theory and means of quality of urban open data are not deep enough, and the operational capacity is low*". Therefore, the lack of evidence of appropriate frameworks to evaluate the impacts of open data on smart cities emerges from the literature. Indeed, since open data and

smart cities are still relatively new research domains, advanced mechanisms for assessing and monitoring open data use and impact are still scarce, and more scientific and standardized assessment methods to control the quality of open data are need to be developed. To this end, we will elaborate in the following chapter, a framework for evaluating and monitoring the impacts of open data initiatives on smart cities that can be used in practice to adequately support the understanding on the impacts of open data in leveraging smart cities performance and how open data is outlined in return.

3. Methodological approach

In this section, we propose a theoretical framework based on the literature review presented in the previous section. This framework is a combination of a conceptual model and an experiment and underpins which components need to be integrated for the evaluation and monitoring of the impact of open data initiatives in smart cities context concerning their sustainable development.

3.1. Open Data Impact for Smart Cities (ODISC) framework

The data revolution is still in its initial phase, so a full range of impacts and outcomes from open data initiatives in the context of smart cities is yet to be fully realized. The literature is scarce in a systematic and rigorous study in the area of open data in order to support evidence of its impacts in the smart city context. The study presented in this paper addresses this gap. The development of a formal evidence base for open data initiatives' impact in the context of smart cities depends on the availability of open data impact frameworks, such as those described in the studies of Zuiderwijk and Janssen (2014), Davies and Perrini (2016), and Verhulst and Young (2017), as well on the availability of smart cities initiatives frameworks, such as those described in the studies of Giffinger et al. (2007), Chourabi et al. (2012) and Kumar et al. (2018).

Accordingly, based on the systematic literature review presented in the previous section, we propose the Open Data Impact for Smart Cities (ODISC) framework as a solution designed to address the lack of a robust theoretical framework for the impact evaluation and monitoring of open data initiatives in the smart cities context concerning its sustainable development. This theoretical framework aids in making the research findings more meaningful and generalizable (Lee & Baskerville, 2003). It consists of a model and an experiment, specifying major aspects of open data initiatives and how these initiatives can impact smart cities' dimensions to improve government, empower citizens, create economic opportunity, and solve societal problems while promoting smart cities' sustainable development.

The conceptual model in Fig. 2 integrates the various theories and frameworks considered in the literature review from open data and smart cities research domains in one model for evaluating the impact of open data on smart cities. It describes the impact categories and factors of open data affecting the main thematic pillars of smart cities that contribute to the sustainability of resources and resilience against the societal challenges.

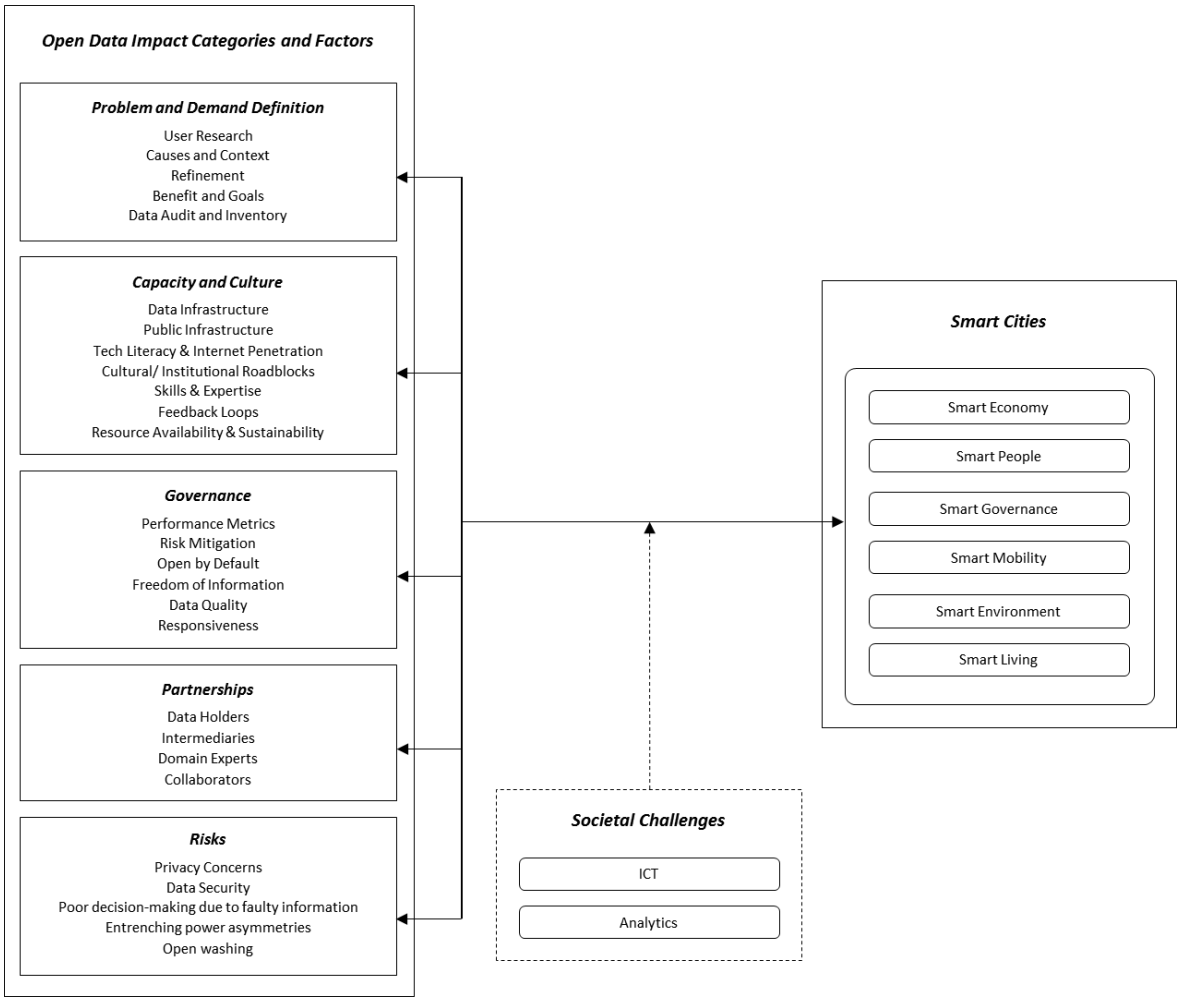

Fig. 2. A conceptual model for the impact of open data on smart cities

The model comprises three components. The first component is a set of 27 open data impact factors distributed into five categories retrieved from the analytical framework proposed by Verhulst and Young (2017). This framework was built upon the analysis of 12 open data case studies and a theory of change to provide the types of impact, the enabling conditions, and disabling factors of open data projects. Table 3 summarizes the open data impact categories and factors proposed by these authors. These impact factors entwine with the second component of the model that involves the six key dimensions of smart cities defined in the city performance framework of Giffinger et al. (2007), as referred to in section 2.1. These authors gave the first operational definition of a city profile throughout a raking-approach study of 70 medium-sized European cities, describing a smart city and its six characteristics in a hierarchic structure: to describe the six characteristics 31 factors were chosen (See Table 1) and to analyze the performance of the 31 factors a catalog of 74 indicators were selected and assigned. The third component adds the role of ICT and analytics as digital enablers into the model, introducing a perspective on how the new and innovative technologies, such as artificial intelligence (AI), Internet of Things (IoT), and big data analytics (BDA) can address smart city challenges. These technologies promote the development of innovative solutions, optimize resource consumption, improve city services, and increase the quality of life, which are crucial to achieving the goals and maximizing the performance of the smart city.

Table 3
Open data impact elements proposed by Verhulst and Young (2017)

Category/Factor	Description
Problem and demand definition:	Understanding and clear definition of the problem and the demand
• User Research	• Optimization purpose for a clear audience
• Causes and Context	• Addressing the causes and context in a direct manner
• Refinement	• Refinement of the understanding of the problem by seeking to understand it
• Benefit and Goals	• Definition of the intended benefits and setting clear goals
• Data Audit and Inventory	• Capability to audit and explore the availability of datasets

Category/Factor	Description
Capacity and Culture: • Data Infrastructure • Public Infrastructure • Tech Literacy & Internet Penetration • Cultural/Institutional Roadblocks • Skills & Expertise • Feedback Loops • Resource Availability & Sustainability	Availability of human capital and technological capabilities • Availability of hardware and software platforms to support data • Availability of data science and statistical knowledge, public services, and users • Awareness about the existence of a digital divide and broadband internet connection • Openness skepticism of the institutional culture and lack of well-trained professionals • Availability of skilled and expert users for sophisticated technical usages • Availability of mechanisms for user feedback and input • Availability of supply and demand, and funding
Governance: • Performance Metrics • Risk Mitigation • Open by Default • Freedom of Information • Data Quality • Responsiveness	Responsive and legitimate decisions regarding the use of open data • Development and monitoring of impact metrics for decision support • Ensuring the data disclosure without infringing citizens' privacy (data anonymization) • Adopting policies and practices to ensure all data is made open • Providing data accessible and usable without restriction for the public • Addressing issues of data credibility (inaccurate/lack of completeness) and trust (out-of-date/corrupted datasets) • Lack of responsiveness and lack of commitment to take up data-driven insights
Partnerships: • Data Holders • Intermediaries • Domain Experts • Collaborators	Collaboration within and across multiple sectors • Endorsing partnerships with private stakeholders to larger the data supply • Using intermediaries to help users reach the open data-driven outputs • Addressing problem areas through domain expertise rather than technology • Extending open data practitioners' capabilities with knowledge transfer
Risks: • Privacy Concerns • Data Security • Poor decision-making due to faulty information • Entrenching power asymmetries • Open washing	Assessment and mitigation of the risks concerning open data • Awareness of the potential for fraudulent and deceptive practices concerning privacy • Striking a balance between data accuracy and privacy violation, or the danger of rights • Recognizing the risks inherent in taking critical decisions based on faulty data • Awareness of the reinforce of existing privileges and authority, or the digital divide • Awareness of the mismatch between the public expectations and the government transparency on data publication

The main reasons why we developed this model using this knowledge base are a) the set of open data impact factors and their categories detail the enabling conditions and disabling factors that determine the impact of open data initiatives in a broad and holistic approach, despite other studies that focus more on specific areas, b) the six key dimensions of smart cities and their distinct factors, as already referred to in section 2.1., constitute the most widely adopted smart city reference model, and c) the digital enabling role of ICT and analytics, as described in section 2.1., are central to improve urban systems by fostering urban innovation and development, making cities smarter and more sustainable in addressing societal challenges.

In summary, this model suggests that open data initiatives, when designed to impact one or more smart city dimensions, can realize the transformation outcomes desired by the smart cities initiative goals. It happens according to certain enabling conditions and disabling factors, to improve government, empower citizens, create economic opportunity, and help to solve public problems, in order to address cities' societal challenges and sustainability.

3.2. An experiment for the impact evaluation and monitoring in the ODISC framework

To address the impact evaluation and outcome monitoring of open data initiatives in smart cities, we operationalize the research framework with an experiment described to answer the cause-and-effect on how open data can be published and efficiently used in the smart cities context in order to tackle cities' societal challenges and sustainability.

According to literature, a randomized controlled trial (RCT) is a research design aimed explicitly at answering questions around causality and attribution, and it is the best way to determine whether a policy is working or not (Haynes, Goldacre, & Torgerson, 2012; Pearce & Raman, 2014). RCTs are an experimental research design form that can be used to evaluate policy. They use random assignment of intervention and are considered the most rigorous compared with other types of evaluation. The RCTs are experiments carried out on two or more groups of participants. The groups are randomly assigned to receive an intervention (the treatment group) or not (the control group). The existence of a randomly assigned control group makes it possible to compare the effectiveness of the intervention. As a result, testing the extent to which specific, planned impacts are being achieved (Banerjee, Duflo, & Kremer, 2016; Gertler, Martinez, Premand, Rawlings, & Vermeersch, 2016; Glennerster & Takavarasha, 2013).

Figure 3 outlines an experiment grounded on the use of RCT for the impact evaluation and monitoring of open data initiatives on smart cities. The experiment contains a process proposed by Haynes et al. (2012) that considers the continual improvement in a nine-step pathway to conducting a complete trial and the conceptual model of the ODISC framework.

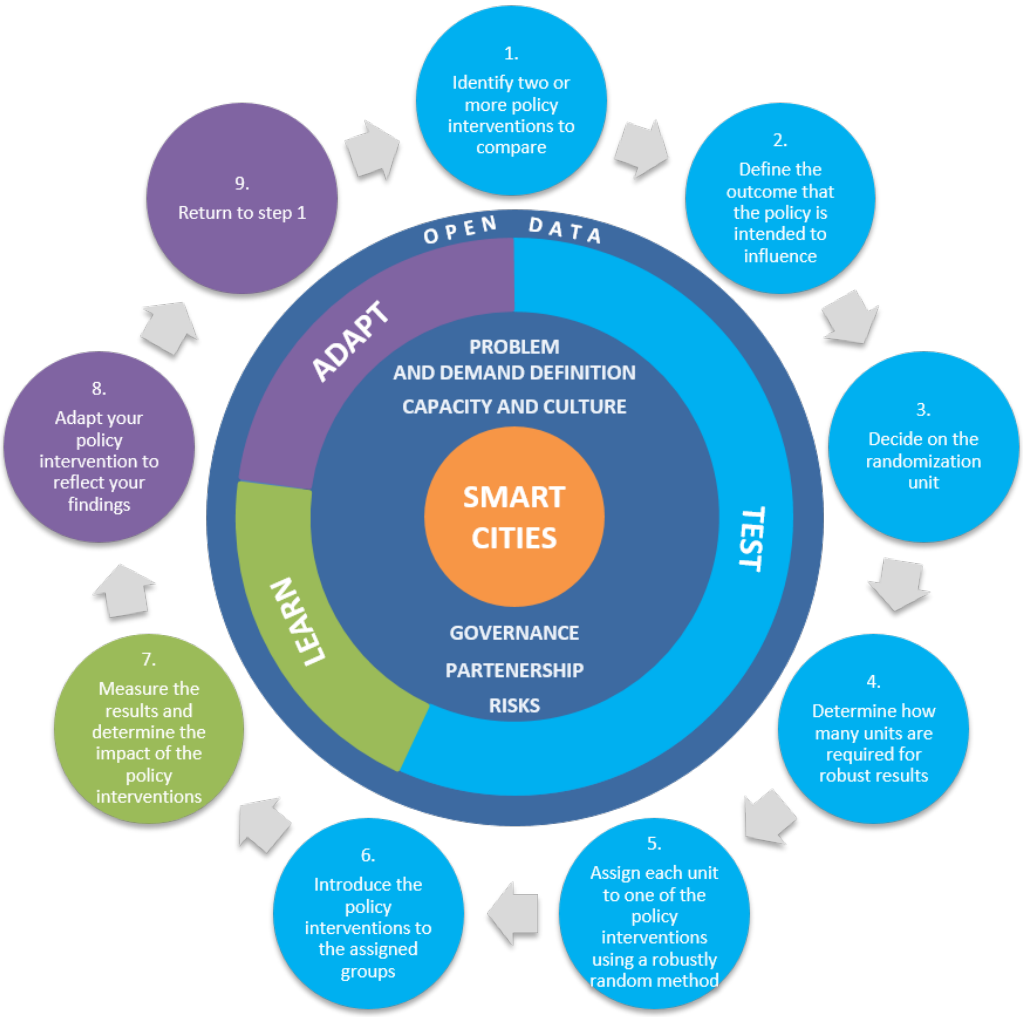

Fig. 3. An experiment for the impact evaluation and monitoring of open data initiatives on smart cities

In Table 4, we describe this method containing the nine-step process divided through three trial stages named: "Test, Learn, Adapt" and the ODISC framework components, addressing the impact evaluation and monitoring of open data initiatives on smart cities, concerning its sustainable development.

The purpose of the RCT described in Table 4 is to answer research questions concerning an open data policy evaluation in the context of smart cities focusing on the impacts by using a random assignment design. It measures the effect of a policy or program intervention on a particular outcome. This design will enable both researchers and practitioners to rigorously answer the research questions related to the project's impacts by analyzing quantitative data on the outcomes.

The RCT should be undertaken following the assumption that it needs to be planned from the beginning of the program implementation. Also, the participation in the program needs to be carefully controlled with the specific experiment in mind. An RTC cannot be undertaken retrospectively, and it is only useful for measuring the impact when a large sample is available. Also, it should only be conducted if it is ethically feasible and economically viable.

Considered together, the model and the experiment build a more complete and detailed view of how and under what conditions open data initiatives impact smart city sustainable development, providing a theoretical framework for further research and experimentation.

Table 4
Steps of the method for the impact evaluation and monitoring of open data initiatives on smart cities. Adapted from Haynes et al. (2012)

TEST	Testing an open data initiative means ensuring having put in place robust measures that enable the evaluation of the effectiveness of the initiative.
Step 1:	Remarks: (i). For example old vs. new open data initiatives; different variations of an open data initiative;

Identify two or more open data initiatives interventions to compare	(ii). Sometimes, trials are conducted to compare a new initiative against current practice. *ODISC Framework Components* - Smart city dimensions: (i). Smart economy; (ii). Smart people; (iii). Smart governance; (iv). Smart mobility; (v). Smart environment, (vi). Smart living.
Step 2: *Define the outcome that the open data initiative is intended to influence and how it will be measured in the trial*	Remarks: (i). An outcome is a change or impact caused by the open data initiative being evaluated; (ii). It is critical in any trial to define at the beginning exactly what outcomes are expected to be achieved and how will they be measured; (iii). Outcomes are determined by the research question; it can often be helpful to develop a logical model or a theory of change, to understand how it is through the initiative will lead to the outcomes, and what assumptions support the logic. *ODISC Framework Components – Conceptual model for the impact of open data on smart cities;* Open data impact categories: (i). Problem and demand definition; (ii). Capacity and Culture; (iii). Governance; (iv). Partnerships: (v). Risks.
Step 3: *Decide on the randomization unit*	Remarks: (i). After deciding what outcome is going to be measured (Step 2), the decision about who or what is going be to randomized is needed (randomization unit); (ii). The decision concerning whether to randomize to intervention and control groups at what level (individuals, institutions, or geographical areas). The question as to whether the randomization unit should be individuals (e.g., student), institutions (e.g., school), or geographical areas (e.g., communities) will usually depend upon practical considerations.
Step 4: *Determine how many units are required for robust results*	Remarks: (i). Units: people, institutions, or areas; (ii). Estimation concerning how many units/participants should be recruited into the intervention to ensure that the research question is assessed. A trial with too few participants is called "underpowered", meaning that it lacks the statistical power to answer the research question; (iii). Some techniques exist to estimate a sufficient sample size. Sample size calculations will help determine how many units (individuals, institutions, or geographical areas) should be included in the intervention and control groups. This technical calculation can be carried out with statistical software, for example, G*Power (www.gpower.hhu.de) or Optimal Design (hlmsoft.net/od/).
Step 5: *Assign each unit to one of the open data initiative interventions, using a robust randomization method*	Remarks: (i). This step depends on the type of trial, the intervention, and the units chosen; (iv). When designing the randomization process, it is important to consider what the allocation concealment mechanism will be and who will implement the allocation sequence in order to prevent selection bias. Typically, this will involve using computer-based randomization for the allocation sequence generation to determine to which group a participant will be allocated and ensuring that until the moment of assignment, the allocation status of any participant is unknown and not predictable. Similarly, in order to ensure that the randomization process is carried out correctly, it is beneficial to separate those who will implement the allocation sequence from those who are involved in the sequence generation process and allocation concealment mechanism. A third party service provided by an independent organization can help to set up a secure randomization service to prevent any potential selection bias and poor allocation concealment situations.
Step 6: *Introduce the open data initiative interventions to the assigned groups*	Remarks: (i). After individuals, institutions, or geographical areas have been randomly assigned to either a treatment group or a control group, the open data initiative intervention follows.
LEARN	Learning is about analyzing the outcome of the open data initiative interventions so that the identification of "what works" and whether or not the effect size is significant enough to offer good value for money.
Step 7: *Measure the results and determine the impact of the open data initiative interventions*	Remarks: (i). Once the intervention has been introduced, measuring outcomes are needed. Before randomization, the timing and method of outcome assessment should have been decided. It will depend upon how quickly the intervention is expected to work, which will differ for each intervention. *ODISC Framework Components* - Open data impacts on smart cities: (i). Create economic opportunity; (ii). Help to solve complex public problems; (iii). Improve governance; (iv). Empower citizens.
ADAPT	Adapting means using this learning to modify the open data initiative intervention (if necessary), so that there is continual refining on the way in which the initiative is designed and implemented.

Step 8: *Adapt the open data initiative intervention to reflect the findings*	Remarks: (i). Any trial that is conducted, completed, and analyzed, should be considered successful; (ii). An RCT that shows the absence of effect or a harmful effect is just as valuable as one that shows a benefit; (iii). Where open data initiative has being shown to be ineffective, then "rational disinvestment" can be considered; (iv). RCT results should also act as catalysts to find other interventions that are effective; (v). When an RCT of a policy is completed, it is good practice to publish the findings. A useful guide for the writing of the RCT report is the CONSORT (CONsolidated Standards of Reporting Trials) statement (Schulz, Altman, & Moher, 2010). *ODISC Framework Components* - Open data impact categories: (i). Problem and demand definition; (ii). Capacity and Culture; (iii). Governance; (iv). Partnerships; (v). Risks.
Step 9: *Return to Step 1 to continually improve the understanding of what works*	Remarks: (i). RCTs should be part of a continual process of policy evaluation and improvement; (ii). If the intervention is to be assigned to a different population segment than the one that was involved in the original RCT, replication of the results of a trial is particularly important; (iii). To build on trial findings is important to identify new ways of improving outcomes. This is particularly pertinent when RCTs are used to identify which aspects of a policy are having the most significant impact.

4. Discussion

Publishing open data is a relatively new city service. When it comes to building and sustaining an open data initiative, many municipalities face significant challenges about their ability to tackle the performance towards the goals, demonstrate the value of the service delivered, and measure the impact of open data programs. These circumstances often occur when these initiatives are implemented without having a performance measurement tool or framework in place. Therefore misalignments between open data and smart cities initiatives may occur, and mismatches between the public expectations and the government transparency on data publication may arise. As to a great amount, open data initiatives are supply-driven when instead they should be demand-driven by citizens, giving rise to open data dump practices of mostly useless datasets and not taking into account insights and user feedbacks (Degbelo et al., 2016; M. Janssen et al., 2012; Ojo et al., 2015; Verhulst & Young, 2017). Consequently, city governments must make an effort to establish a robust, accurate, and meaningful performance measurement tool or framework for their open data initiatives. In seeking to close these gaps, the ODISC framework its a striking solution that can be applied for monitoring and evaluating, helping to leverage maturity in open data to develop better smart cities.

As open data matures, the quality and breadth of datasets accelerate, and cities generate more insightful knowledge concerning the performance measurement and impact of open data. Therefore, the quality of the open data provided and its use are the main success factors for open data initiatives (Belizario & Berardi, 2019). As stated in a report by the World Web Foundation (Montano et al., 2014), "*Opening data will not automatically translate to use*" and cities must look beyond just merely tracking the number of data downloads to determine the impacts of open data. Furthermore, the measurement of open data downloads without a baseline or benchmark does not give a notion if the numbers are noteworthy, neither reports how the data is being used and by whom, and it diverts focus from quality (Liu et al., 2017; Ruijer, Grimmelikhuijsen, & Meijer, 2017; Walker, Frank, & Thompson, 2015). A current appraisal of the quality of open data disclosure is made mostly according to the metrics of the 5-star deployment scheme suggested by Tim Berners Lee (5stardata.info) and technical standards on which the data is released and not grounded on user needs. Although the 5-star system expresses the quality of data through its openness and ease of use for both consumers and publishers, it does not take into account other aspects like accuracy, availability, completeness, credibility, relevancy, timeliness, amongst others. Focusing only on a technical perspective, standardization aim to control the quality levels of datasets published to boost interoperability, consistency, and comparability—see, for example, Open Data Standards Directory (datastandards.directory) for a collection of more than 60 open data standards; the Spanish standardization normative UNE 178301:2015 (AENOR, 2015) for a set of guidelines to evaluate the maturity of urban open data projects; and, the EU Directive 2003/98/EC (PSI Directive) (Cox & Alemanno, 2003) on the re-use of public sector information (Abella et al., 2017; Liu et al., 2017; Vetrò et al., 2016; Walker et al., 2015; Yadav et al., 2017). Therefore, while these approaches provide a valuable description of how data needs to conform to regulations, there is no evidence that they address user's demand for open data, and, as such, they are not deep enough linked to measuring the impacts of open data. This situation provides motivation and input to the ODISC framework in fulfilling the need for more systematic and structured research that evaluates the impacts and reshapes open data programs to effectively promote the development and progress of open data initiatives on smart cities.

In this study, we undertook extensive research comprising a systematic review of existing literature and identification of the most relevant studies to support the evaluation of the impacts of open data initiatives on smart cities, concerning their sustainable development. Furthermore, we built a model upon the analysis of the various elements and practical experiences of several significant studies selected in the literature by their impact appraisal and domain relevance. In order to develop a practical understanding, we proposed an experimental approach in the form of an RCT, which is considered the most rigorous and robust research method for measuring the impact and policy analysis (Haynes et al., 2012; Stoker & John, 2009; Verhulst et al., 2014). The developed model, which is mainly grounded on the elicited research of Verhulst and Young (2017) and Giffinger et al. (2007), and the application method jointly form a framework that connects two theoretical parts: one from the research domain of open data and the other from the research domain of smart cities.

5. Conclusions and future work

In this study, we conducted a systematic literature review on the impacts of open data initiatives on smart cities, and a theoretical framework for the impact evaluation is proposed. The ODISC framework comprehends a model and an experimental method that underpins the knowledge on the topic and may lead to a more comprehensive operationalization of the evaluation and monitoring of open data initiatives in a smart city context. The findings suggest that the impacts of open data initiatives can be evaluated, monitored, and improved. The main advantages of the framework are that it clarifies the discussion about the impact evaluation of urban open data and provides guidance for future research based on a solid theoretical foundation.

The methodological approach of our study contains limitations related to the difficulty to guarantee that we did capture all valuable information concerning the impacts of open data initiatives on smart cities since its development solely relied on the evidence brought by the literature. The primary limitation is the restricted set of keywords used in the search process. Indeed a broader set of words, including, for example, specific open data impact types or particular smart cities contextual factors, would have yielded more concrete and scoped results on which to build our analysis. The second limitation concerns the forward and backward citation tracing used to find additional articles that could be subject to speculation about researcher bias. The third limitation is the level of detail of the framework. When planning and conducting an open data impact assessment, there are many details and complexities that must be foreseen. The ODISC framework having a holistic perspective, can provide only rough guidance in addressing these problems. Also, as our research review revealed, the literature is scarce and with limited guidance on how to measure open data impacts. Quantifying the impact of open data is challenging, and many of its benefits and outcomes are evident to varying degrees among several case studies in the literature. Although these case studies are useful in understanding the potential of open data, their exclusive focus on specific cities or projects is usually intangible and not substantive, which makes the impact of open data hard to quantify through them.

Therefore, as a consequence of the field of open data being relatively new and many of open data policies recently developed, further refinement of our model might need to be performed by including more aspects to evaluate the effects of open data initiatives on smart cities, as the knowledge gap about the impacts of open data policies diminishes. The last limitation is the proposal of the RCT as the experimental method for obtaining high-quality evidence when evaluating the effectiveness and impact of open data initiatives on smart cities. While the theory behind RCT is simple, its implementation can sometimes be challenging. Thus, in situations where the use of an RCT is considered unfeasible, quasi-experimental designs (for example, Difference-in-differences and Propensity Score Matching) can, to some extent, be used as an alternative to undertaking an impact evaluation. These methods are often more practical in application, but not as robust as an RCT.

This study has theoretical implications, as it determines the most relevant issues associated with the significant role of open data initiatives in addressing today's smart cities' societal challenges. As a relevant contribution, it is presented here a new framework and a corresponding method to implement in several studies ahead. This study implies an important development in information systems literature and the theory of information management.

This paper has practical implications for a better understanding of open data initiatives on smart cities, as it provides the themes and trends in contemporary knowledge concerning the impacts and the policy evaluation of open data. Here we also proposed a monitoring and assessment method for open data initiatives that can be further used to extract the potential benefits of open data and attain the initiatives' goals more efficiently. Additionally, this paper can help researchers and practitioners in their studies and support the various stakeholders to find opportunities and the corresponding solutions to their action for addressing smart cities' societal challenges.

The framework could contribute to the design and improvement of open data initiatives in smart cities focusing on the impacts and outcomes. As a result, for future work, it would be important to obtain experimental results by empirically testing the framework and to address the impact of open data initiatives applied to the different stakeholders' scenarios and at different smart city development stages.

Appendix A. Reviewed research studies with relevance for the impact assessment of open data initiatives on smart cities

#	Research Studies	Research Domain	Research Scope
01	Giffinger et al. (2007)	Smart cities	Smart city model for medium-sized cities
02	Andersen and Pold (2012)	Smart cities	Smart city openness
03	Chourabi et al. (2012)	Smart cities	Smart cities initiatives
04	Ren and Glissmann (2012)	Open data	Information assets for open data initiatives
05	Suzuki, Finkelstein, and Gann (2013)	Smart cities	Urban data management
06	Abella et al. (2014)	Open data	Assessment for open data reuse
07	Foulonneau, Martin, and Turki (2014)	Open data	Impact of open data in service creation
08	Zuiderwijk and Janssen (2014)	Open data	Impacts of open data policies
09	Abella-Garcia et al. (2015)	Open data; Smart cities	Smart cities' open data value creation and impact
10	Carrasco and Sobrepere (2015)	Open data; Smart cities	Assessment of open government data at municipality level
11	Janssen, Matheus, and Zuiderwijk (2015)	Open data; Smart cities	Open linked data in smart cities
12	Jorna and Veenstra (2015)	Open data; Smart cities	Open data programs in smart cities ecosystems

#	Research Studies	Research Domain	Research Scope
13	Khan, Anjum, Soomro, and Tahir (2015)	Open data; Smart cities	Open data and big data management in smart cities
14	Lusa, Dos Santos Rabello, and Cervi (2015)	Open data; Smart cities	Open government data architecture for smart cities
15	Mainka et al. (2015)	Open data; Smart cities	Open government urban data initiatives
16	Mulder (2015)	Open data; Smart cities	Co-creation of public services with open data
17	Ojo et al. (2015)	Open data; Smart cities	Impacts of open data innovation in smart cities
18	Ahlgren et al. (2016)	Open data; Smart cities	Open data and Internet of Things (IoT) for smart cities
19	Barns (2016)	Open data; Smart cities	Open data programs in supporting smart cities policies
20	Berrone et al. (2016)	Open data; Smart cities	Framework for open data initiatives in the city context
21	Davies and Perini (2016)	Open data	Open data impacts in developing countries
22	Degbelo et al. (2016)	Open data; Smart cities	Open data support on smart and open cities
23	Feder-Levy et al. (2016)	Open data; Smart cities	Open data support on smart cities value creation
24	Lopez et al. (2016)	Open data; Smart cities	Big and open data value in smart cities
25	McMillan et al. (2016)	Open data; Smart cities	Big and open data value in smart cities
26	Mealha (2016)	Open data; Smart cities	Smart city open data dashboards
27	Salhotra (2016)	Open data; Smart cities	Open data programs and smart cities initiatives
28	Wu, Pan, Ye, and Kong (2016)	Smart cities	Intelligent city evaluation system
29	Abella et al. (2017)	Open data; Smart cities	Data-driven innovation impacts in smart cities
30	Aguilera et al. (2017)	Smart cities	Smart cities citizen-centric platform
31	Consoli et al. (2017)	Open data; Smart cities	Linked open data for smart cities
32	Danneels, Viaene, and Van den Bergh (2017)	Open data; Smart cities	Open government data platforms in smart cities
33	Dong, Singh, Attri, and El Saddik (2017)	Open data; Smart cities	Open data initiatives in smart cities
34	Hivon and Titah (2017)	Open data; Smart cities	Open data use in smart city
35	Liu et al. (2017)	Open data; Smart cities	Evaluation of urban open data
36	Mishra, Misra, Kar, Babbar, and Biswas (2017)	Open data; Smart cities	Open data assessment in smart cities
37	Neto et al. (2017)	Open data; Smart cities	Open data policies evaluation in smart cities
38	Pereira, Macadar, Luciano, and Testa (2017)	Open data; Smart cities	Open data initiatives public value in smart cities
39	Schieferdecker et al. (2017)	Open data; Smart cities	Open data-based ICT reference architecture for smart cities
40	Verhulst and Young (2017)	Open data	Open data impacts in developing economies
41	Yadav et al. (2017)	Open data; Smart cities	Open data initiatives in smart cities
42	Yarime (2017)	Open data; Smart cities	Open data innovation for smart cities sustainability
43	Zotano and Bersini (2017)	Open data; Smart cities	Open data benefits in smart cities initiatives
44	Barns (2018)	Open data; Smart cities	Open data support for smart cities initiatives
45	Diamantini, Potena, and Storti (2018)	Open data; Smart cities	Evaluation of city performance through linked open data
46	Drakopoulou (2018)	Open data; Smart cities	Open data challenges in smart cities
47	Kumar et al. (2018)	Smart cities	Smart city transformation
48	Lim et al. (2018)	Open data; Smart cities	Data-based smart city innovations value
49	Macedo, Cacho, and Lopes (2018)	Open data; Smart cities	Open data publishing tools evaluation for smart cities
50	Mutiara, Yuniarti, and Pratama (2018)	Open data; Smart cities	Open data disclosure for smart city governance
51	Prieto et al. (2018)	Open data; Smart cities	Open data reuse in smart cities
52	Sisto, Lopez, Paez, and Mugica (2018)	Open data; Smart cities	Open data initiatives assessment in smart cities
53	Vasileva et al. (2018)	Open data; Smart cities	Open data benefits in smart cities/smart campus
54	Wang et al. (2018)	Open data; Smart cities	Open data projects evaluation in smart cities
55	Belizario and Berardi (2019)	Open data; Smart cities	Smart and open data in smart cities
56	Burns and Wark (2019)	Open data; Smart cities	Open data database ethnography in smart cities
57	Dinah et al. (2019)	Open data; Smart cities	Open data in smart cities for developing countries
58	Ghahremanlou et al. (2019)	Open data; Smart cities	Open data assessment in smart cities
59	Jeannot (2019)	Smart cities	Urban socio-technical regime within smart cities
60	Jussila et al. (2019)	Open data; Smart cities	Co-creation in the smart city open data initiatives

#	Research Studies	Research Domain	Research Scope
61	Komninos et al. (2019)	Open data; Smart cities	Open data impacts in smart city planning
62	Ma and Lam (2019)	Open data; Smart cities	Open data adoption barriers in smart cities
63	Meschede and Siebenlist (2019)	Open data	Open data in assessing Sustainable Development Goals
64	Moustaka et al. (2019)	Open data; Smart cities	Smart city data analytics
65	Prieto et al. (2019)	Open data; Smart cities	Open data publication prioritization in smart cities
66	Wilson and Chakraborty (2019)	Open data; Smart cities	Open data and civic technology in smart city planning

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