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HOW TO ASSESS SMART CITIES? A SYSTEMATIC LITERATURE REVIEW OF FOUR APPROACHES

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Resumo
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.

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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.

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 and 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 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 and 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 and 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.

2. Method

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 and 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. Smart City Assessment Models

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 and 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 and 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 and 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 1 summarizes the sample of ranking approach models

Table 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

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 and 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 and 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 2.

Table 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

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 and 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 and 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 and Rakhmatullin, 2014). Some argue that end-users is an essential stakeholder in co-creating and accepting innovation (Schuurman et al., 2012; Kummitha and 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 and 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 shows the sample of articles classified as related to the innovation ecosystem approach models.

Table 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)	

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 and 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 and 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 4 summarizes our sample of maturity approach models.

Table 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

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 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 and 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 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	Operational	Quantitative	Real-Time	Short-term

	data in real time.				
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

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 and 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 and 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.

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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