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A Systematic Review of Performance Measurement Models for Smart Cities

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Abstract

Performance of a Smart City (SC) can be measured in terms of the smartness which in turn is defined by means of smart characteristics. However, the lack of a proper benchmark itself is a limitation in designing and Performance Measurement (PM) of SCs. While there are no well-accepted definitions for the smartness of a SC, literature seems to adopt a common set of smart characteristics while defining the term. This paper comprehends a systematic literature review on eight PM Models, which cover a multidimensional span of SC characteristics, to derive a fitting set of PM Models for SCs with PM indicators. As the major finding of this study a summary model is produced representing all the smart characteristics. Findings revealed the importance of determining indicators through the identification of themes and subthemes of PM frameworks. Therefore, as a way forward, a fitting PM framework with indicators will be produced as part of an ongoing research project aiming to enhance the SC development in Sri Lanka through PM.

Keywords
Performance Measurement, Smart Cities, Smart Characteristics.

1. Introduction

Measurement of the performance of smart cities was first considered important while implementing smart city solutions in Europe (Huovila et al., 2017). According to Landy et al. (2017), performance and the measurement of performance, is a situational expectation that differs with various occasions in conducting human affairs. While this situational expectation turns out to be a "superior expectation", in other words, the common expression "success" measuring performance is problematic as the definition of success is changing (Landy et al., 2017). Consequently, when such occasions happen to be "smart cities", a vision with regards to the aforementioned situational superior expectation is indubitably even more convoluted, as the superior expectation has not reached a consensus yet (Gil-

Garcia et al., 2015). In fact, due to the complications of interests gravitated around public administration in smart cities, as a result of the wide variety of work performed and their complex interconnection, the concept of Performance Measurement (PM) needs to appreciate the multi-dimensionally (Bouckaert and Halligan, 2008). Moreover, determining the depth of performance of smart cities' administration at different levels such as local government, organisations, and individuals and the span in classified content dimensions is rather comprehensive (Merli and Bonollo, 2014). Therefore, a number of authors have come up with different PM models addressing a broad span (Lombardi et al., 2012; Komninos, 2008; Merli and Bonollo, 2014; Shen et al., 2018; Australian Government, 2017; Ambrosetti, 2012). Meanwhile, some have distinguished between the depth over span to a given content dimension, e.g., Garau et al. (2015) benchmark only the Smart Urban Mobility. Whatsoever, these models witness the need of PM in smart cities (Albino et al., 2015). Alternatively, to fulfil the requirements of a smart city it is important to benchmark appropriate smart city "characteristics" and that again implies the need of accurate benchmarks; which can be used in setting city goals and determining priorities (Harms, 2016).

Therefore, to answer the research question; "what are the dimensions of a smart city's characteristics that can establish indicators in a PM system for a smart city", this paper aims to analyse the smart city characteristics multi-dimensionally by reviewing a selected set of PM frameworks for smart cities. The objectives are to identify the importance of PM for smart cities and different PM systems/ Performance Assessment Systems/ Models for smart cities.

2. Research Method

Research method is certainly is the most important selection in the process of answering a research question. In seeking for different PM Models in smart cities, this paper undertakes a systematic literature review. One of the major advantages in carrying out a systematic review of literature over other traditional literature reviews is that; it requires a comprehensive and holistic review followed by a series of steps which allows unbiased obtaining of only the most relevant information for the focused area (Choong, 2014). While the search terms "Performance Measurement in smart cities" and "Performance Measurement frameworks for smart cities" found an exhaustive list of publications in research databases (namely Science Direct, Emerald Insight, and Scopus); however, none of them did specify PM frameworks for smart cities. The initial selection of papers to read further was not limited to a year range, yet, they were based on the title and abstract. Likewise, some directly related articles which are written as part of the CITYkeys project (Huovila et al., 2016; Huovila et al., 2017) were found in Research Gate. Therefore, as the next step, the search terms were also used in Google Scholar. Thereafter with the use of snowballing technique eight frameworks were selected followed by a cross-checking done with Google Scholar again. Selection of the eight papers is majorly based on the wide span of the content dimensioned covered from the framework, availability of indicators/subthemes and clear and comprehensive interpretations done without being limited to a selected context/scenario.

3. Need of Performance Measurement IN Smart Cities

PM in smart cities is being looked at through several lenses while the smart city requirements are also discussed in a great variety (Szendi, 2019). Benchmarking would provide a clear basis for the famous maxim, "whatever is measured will only get done" (Behn, 2003) and lack of this would give negative impacts on determining city goals and requirements (Brorström et al., 2018). In fact, as per Fredrick W. Taylor's management by exception principle, attempts to control every aspect resulting in controlling of nothing; remarks one of the most popular aphorisms in PM (Shafritz et al., 2016). Therefore, planning, controlling, and decision making regarding defining and redefining of the priorities and solutions in a smart city and resource allocation, assigning responsibilities, etc., can be achieved with a proper PM system (Merli and Bonollo, 2014). Consequently, by developing a PM system, not only goal benchmarking but also goal alignment with improved accountability in complex and large city projects is assured (Brorström et al., 2018). Benchmarking together with ranking allows identifying and comparing strengths and weaknesses in a smart city (Carli et al., 2013). Furthermore, modifications to the development in smart programmes to enhance smartness can be done through PM (Afonso et al., 2015). In addition to that, a transparent and common PM system is important in creating trust in solutions and also to monitor their progress (Huovila et al., 2017). Additionally, possible problems and their causes can be predetermined with an established PM system (Harbour, 2009). All in all, public managers of public agencies including cities use PM for performance evaluation, to control the behaviour in civic engagement, for budgeting, promoting, motivating, celebrating success, learning, and improving (Behn, 2003).

While the concept of a smart city and its requirements are difficult to delineate (Orlowski and Romanowska, 2019), definitional elements that are spotlighted by different authors can be identified as the themes with which they exhibit smart cities concept as an approach to overcome the problems occurred in basic cities (Yigitcanlar et al., 2018). In line with such smart cities definitional elements, researchers and industry players together with government and central agencies have come up with different models that invoke the aspects of urban life which are to be upgraded through smart cities (Bifulco et al., 2016). Consequently, PM systems / Performance Assessment Systems were constructed emanated from smart city requirement which are also known as smart characteristics (Lombardi et al., 2012; Komninos, 2008; Merli and Bonollo, 2014; Shen et al., 2018; Australian Government, 2017; Ambrosetti, 2012).

4. Performance Measurement Models for Smart Cities

Smart cities inherit an interdisciplinary character and therefore integrate city technologies, marketing, knowledge economy, economic geography along with spatial planning (Richter et al., 2015) the same which have become the basis in determining the city performance. Thereby various PM methods and indices have been developed throughout the evolvement of the concept smart cities and its definitional elements (Albino et al., 2015). The actual measurement objectives in measuring the performance of smart cities were categorized with content dimensions of a smart city as observed by different institutes (Merli and Bonollo, 2014). They are the same aspects in which smart cities mostly require indicators to measure their performance (Huovila et al., 2017). In other words, it is these aspects which different authors term as themes/sub-themes (Bosch et al., 2016); characteristics/factors (Giffinger et al., 2007); clusters (Lombardi et al., 2012); blocks (Komninos, 2008); dimensions (Merli and Bonollo ,2014); categories (Shen et al., 2018); and layers (Zygiaris, 2013) measure the performance of a smart city in terms of smartness of those each aspect.

The progression of PM models in smart cities can be traced back to 2007, with the formation of Giffinger et al.'s (2007) framework to assess the performance of smart cities (Merli and Bonollo, 2014). despite the application of the framework has meant to be decisive for cities, it is the most cited and widely used due to its comprehensive nature (Bifulco et al., 2016). Therefore, the characteristics of this very framework is used as a base in combining all the aspects of a PM model in this study as well.

However, the interpretation of a particular theme may not be compatible with the meaning a similar theme from another framework hence subthemes becomes informative Airaksinen et al. (2017). Therefore, in this study, the themes/classifications of eight smart city PM frameworks are compared intending to form a constructive set of themes and subthemes that can lead to producing comprehensive indicators under each of such themes/sub-themes. Table 1 depicts each of the selected smart city PM framework's themes and sub-themes (if available).

Table 1: Content Dimensions in Performance Measurement Systems for Smart Cities

No	Content Dimensions	Source
1	• People – Health, Safety, Access to (other) services, Education, Diversity and social cohesion, Quality of housing, Built environment • Planet – Energy and mitigation, Materials, water, land, Climate resilience, Pollution and waste, Ecosystem • Prosperity – Employment, Equity, Green economy, Economic performance, Innovation, Attractiveness, Competitiveness • Governance – Organisation, Community involvement, Multi-level governance • Propagation – Replicability and scalability, Factors of success	(Bosch et al., 2016)
2	• Smart Economy – Innovative spirit, Entrepreneurship, Economic image and trademarks, Productivity, Flexibility of labour market, International embeddedness • Smart People – Level of qualification, Affinity to lifelong learning, Social and ethnic plurality, Flexibility, Creativity, Cosmopolitanism/ Open-mindedness, Knowledge about the EU (Country or Region where they live)	(Giffinger et al., 2007)

	• Smart Governance – Participation in decision-making, Public and social services, Transparent governance • Smart Mobility – Local accessibility, (Inter-)national accessibility, Availability ICT infrastructure, Sustainable, Innovative and safe transport systems • Smart Environment – Attractivity of natural conditions, Pollution, Environmental protection, Sustainable resource management • Smart Living – Cultural facilities, Health conditions, Individual safety, Housing quality, Education facilities, Touristic attractivity, Social cohesion	
3	• Smart Economy • Smart People • Smart Governance • Smart Mobility • Smart Environment • Smart Living University Government Civil society Industry	(Lombardi et al., 2012)
4	• Education and skills of the population • Knowledge and innovation institutions • Digital infrastructure and e-services • Innovation performance	(Komninos, 2008)
5	• Production • Technological innovation • Quality of life of the community • Eco-sustainability	(Merli and Bonollo, 2014)
6	• Smart Infrastructure • Smart Governance • Smart Economy • Smart People • Smart Environment	(Shen et al., 2018)
7	• Jobs and Skills • Infrastructure and Investment • Liveability and Sustainability • Innovation and Digital Opportunities • Governance, Planning, and Regulation • Housing	(Australian Government, 2017)
8	• Mobility management • Resource management • Quality of life for citizens	(Ambrosetti, 2012)

According to Table 1, the indicator system produced by Komninos (2008) was originally named as Metrics for "intelligent cities". However, the author did not provide a clear-cut difference between the intelligent cities and smart cities; in fact, by referring the terms as of having similar meanings (Komninos, 2008), it was implied that metrics for intelligent cities can be applicable to smart cities as well. Given that smart cities look beyond intelligent cities, the indicator system may have issues in its scope as well. However, Merli and Bonollo (2014) in their research have identified the four blocks that measure fundamental dimensions of the intelligent city and their indicators which were presented in Komninos (2008) study as also applicable as a PM model for smart cities. Consequently, Merli and Bonollo's (2014) PM model was inspired by the aforementioned two models along with The European House Ambrosetti's model. Similarly, Lombardi et al.'s (2012) model was inspired by Giffinger et al. (2007)'s framework with particular reference to the (revised) triple helix.

Similarly, the PM model developed by Bosch et al. (2016) covered similar content dimensions which were also identified in Giffinger et al.'s (2007) framework while emphasizing some aspects like Prosperity and Propagation through theming. Whereas Shen et al.'s (2018) framework, which aimed the Chinese context, replaced the themes Smart Living and Smart Mobility with Smart Infrastructure. Meanwhile, the framework constructed for the Australian context by Australian Government (2017) took a completely different form of theming.

The Most Significant Themes/ Dimensions in a PM Model for a smart city

Given the significance of Giffinger et al.'s (2007) framework, it was used as the basis to understand the most significant themes. The sole purpose of signifying themes is to incorporate every possibility of the indicators so as to form the comprehensive summary PM model for smart cities. Although the themes Smart People and Smart Living are usually considered separate two themes, the compared frameworks convince that both can be considered as a single theme when amalgamating the frameworks/themes. Moreover, the applicability of the theme Propagation is arguable as the replicability of smart features are said to be unique to the context where they are applied. Therewith it can be observed the following as the most significant themes.

4.1 Smart Economy

Bosch et al.'s (2016) content dimensions "Prosperity" refers to the "economic viability" and "project value" to users, stakeholders, neighbourhood, and indirectly affected entities. Authors also consider the subtheme "Economic Performance", which provides a compatible definition to the focus area of Smart Economy introduced by Giffinger et al. (2007). Similarly, in Komninos's (2008) framework, "innovation performance" covers aspects of Giffinger et al.'s (2007) Smart Economy in general. However, Giffinger et al. (2007) emphasized much on the economic competitiveness and therefore the factors around that. Although this is the case, the other frameworks specify the economic outcomes of smart city initiatives as per Chourabi et al. (2015) such as business/job creation, development of the workforce, and improved productivity as their content dimensions. For example, Production - Merli and Bonollo (2014), Jobs and Skills and Innovation and Digital Opportunities (Australian Government, 2017).

4.2 Smart People and Smart Living

According to Giffinger et al.'s (2007) classification smartness of people refers not only to the level of education/qualification but also to their open-mindedness, social interactions, public life, and other aspects like flexibility and creativity while the classification of smart living encompasses the aspects of quality of life of citizens with regards to housing, health and safety, education, cultural facilities, social cohesion, and touristic attractivity. These similar aspects under smart living are mentioned under the people factor in Bosch et al.'s (2016) classification. Importance is given to the "education and skills of the population" and "knowledge and innovation institutions" in Komninos (2008)'s classification as well. Similarly, in Merli and Bonollo's (2014) classification the quality of life of the community factor is highlighted. In the Australian Government's (2017) PM framework relatable content dimensions are mentioned. For instance, "Jobs and Skills", which was aforementioned under smart economy has additions like educational attainment which comes under the smart people classification as per Giffinger et al. (2007). In addition to that the two policy priorities in Australian Government (2017)'s Performance Measurement framework; "Liveability and Sustainability" which represent indicators purely based on the quality of life factor of citizens and "Housing" come under Giffinger, et al. (2007)'s Smart Living classification.

4.3 Smart Governance

Giffinger et al. (2007) emphasized governance as a key factor that requires attention in three main areas; the political participation, public administration, and services for citizens. Governance is classified with a similar interpretation by Bosch et al. (2016). In fact, both the classifications highlight the transparency of governance together with community involvement in decision making. In the Australian Government's (2017) framework Governance together with Planning and Regulation are discussed with regards to governance fragmentation. Similarly, in Shen et al.'s (2018) framework, although the classification termed as Smart Governance, new aspects like e-Government availability, participation by social media, and trading platforms for public resources have raised the concerns. Having

users of e-gov as an indicator under digital infrastructure and e-services, Komninos (2008) has also paid attention on this regard.

4.4 Smart Environment

Giffinger et al. (2007) described Smart Environment mainly in terms of the attractivity of natural conditions such as green spaces, and climate the efforts taken towards resources and pollution management and environmental protection. The areas such as resource management, pollution and waste management, and attractivity and conservation of ecosystem which Giffinger et al. (2007) considered as important are also emphasized by Bosch et al. (2016) as well. They further added the focus areas like energy and mitigation, as well as climate resilience under Smart Environment/planet classification. Similarly, Merli and Bonollo (2014), Australian Government (2017), and Ambrosetti (2012) too have themed Eco-sustainability and Resource management respectively under their classifications.

4.5 Smart Mobility

While Giffinger et al. (2007), Lombardi et al. (2012), and Ambrosetti (2012) refer smart mobility under transport and ICT infrastructure authors like Komninos (2008), Merli and Bonollo (2014), and Shen et al. (2018) rather highlighted the importance of the ICT infrastructure. Alternatively, the Australian Government, (2017) has considered mobility under the two classifications, namely "Infrastructure and Investment" and "Innovation and Digital Opportunities". Under "Infrastructure and Investment" they referred to transportation where they have specified the indicators such as Jobs accessibility (in 30 minutes), work trips by the public, and active transport and peak travel delay. Under "Innovation and Digital Opportunities" they have discussed the indicator Broadband connections which is one of the indicators used by Komninos (2008) under his Digital infrastructure and e-services classification. Shen, et al. (2018) have also specified a similar set of indicators in elaborating their classification of smart infrastructure.

4.6 Propagation

This theme is classified under the Bosch et al.'s (2016) framework where propagation is referred to as the potential of a smart city solution(s) to replicate and scale to other locations/contexts/cities depending on the smart city project's inherent characteristics. However, this theme should be construed in a way that it does not show any intention to compromise the identity of an existing context to where the smart city is designed, as ideally the whole smart city concept should be understood without disturbing the existing conditions (Tomar and Gupta, 2019).
The importance of layer wise classification (University, Government, Civil society, and Industry) of each theme can be considered as the most vital lesson to be obtained from Lombardi et al.'s (2012) framework. Therefore, identification of indicators under each layer of themes/subthemes is the ideal way to form a summary PM model.

5. Conclusions and Future Work

PM in smart cities has raised its concerns in an established market where the notion has not yet reached a consensus. Subsequently, the content dimensions of the PM frameworks always took the form of Smart Characteristics which in other words refers to the requirements that can measure the smartness of a smart city. While different authors/organizations investigated different focus areas, the foremost framework presented by Giffinger et al. (2007) could be accepted as the most constructive, comprehensive, and the most cited framework. Therefore, this study also considered Giffinger et al.'s (2007) framework to be the basis to compare with other frameworks/classifications and amalgamate to summarise the themes. The content dimensions of each framework are termed as themes. Under the themes some frameworks listed out sub-themes and thereafter indicators while some frameworks only have indicators. Whatsoever, in situations where the elaborating of theming is vague, immediately the sub-themes and indicators should be referred. Moreover, the most ideal way to determine indicators is to identify them under the layers, namely University, Government, Civil society, and Industry. Likewise, the outcome of the reviewing of themes resulted in briefing of the themes to six, namely Smart Economy, Smart People and Smart Living, Smart Governance, Smart Environment, Smart Mobility, and Propagation. Figure 1 depicts sub-themes that have been identified under each of the themes.

SMART ECONOMY

- Innovation, Innovative spirit, and Innovation performance
- Entrepreneurship
- Economic image & trademarks; Production and Productivity
- Employment, Flexibility of labour market, and Jobs and Skills
- International embeddedness
- Equity
- Green economy
- Attractiveness & competitiveness

SMART GOVERNANCE

- Organisation composition, process, leadership, and transparency
- Community involvement in decision-making
- Multi-level governance
- Governance fragmentation
- Public and social services
- Transparent governance
- Planning and Regulation

SMART ENVIRONMENT

- Attractivity of natural conditions
- Pollution & waste
- Environmental protection
- Sustainable resource management
- Energy & mitigation
- Materials, water, land, Ecosystem
- Climate resilience
- Eco-sustainability

SMART PEOPLE

- Level of qualification, Education and skills of the population
- Affinity to lifelong learning
- Social and ethnic plurality
- Flexibility
- Creativity
- Cosmopolitanism and open-mindedness
- Knowledge about the region/ country
- Knowledge and innovation institutions

SMART LIVING

- Cultural facilities
- Health conditions
- Individual safety
- Education facilities
- Touristic attractivity
- Access to (other) services
- Diversity and social cohesion
- Quality of housing and the built environment
- Quality of life of the community
- Liveability
- Sustainability

SMART MOBILITY

- Local accessibility
- (Inter-)national accessibility
- Availability ICT infrastructure
- Sustainable, innovative, and safe transport system

Figure 1: Themes and sub-themes for performance measurement in Smart Cities

This study is a part of a research project, of which one of the broader scopes is to form a PM framework for Sri Lanka with a comprehensive set of indicators. In the process of forming a PM framework to Sri Lanka, a summary model with indicators will be prepared based on themes, subthemes, and indicators as specified in the literature. This paper presents the work up to summarising the themes and subthemes from literature. Therefore, the next step in the proceeding of this study until creating a summary PM model for smart cities would be to follow this same process to determine the indicators. Employing a top-down approach, the selected summary of the themes and afterwards the sub-themes will be used as a guide under which the indicators are to be recognized.

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