

A SYSTEMATIC LITERATURE REVIEW ON SMART CITIES: INDICATORS, METHODS, AND CASE STUDIES

FREDY PURNOMO¹, FORD LUMBAN GAOL², HARJANTO PRABOWO²
SUHONO H SUPANGKAT³ AND MEYLIANA²

¹Computer Science Department, School of Computer Science

²Doctoral of Computer Science, BINUS Graduate Program
Bina Nusantara University

Jl. K. H. Syahdan No. 9, Kemanggisian, Palmerah, Jakarta 11480, Indonesia
{ fpurnomo; fgaol; harprabowo; meyliana }@binus.edu

³School of Electrical Engineering and Informatics
Bandung Institute of Technology
Jl. Ganesha No. 10, Bandung 40132, Indonesia
suhono@stei.itb.ac.id

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ABSTRACT. *Nowadays, the term of Smart City has been a hot topic in the table. However, there are still limited survey papers that provide the indicators, methods, and the examples of the Smart City cases. This research aims to provide a systematic and comprehensive survey using a systematic literature review method, on indicators, methods, and the examples of the Smart City cases. This literature review contributes to the foundation of the research in the area of Smart City. The method used in this paper is a systematic and comprehensive literature review proposed by Ridley and Okoli & Schabram. The results show that Smart Environment is the most paramount indicator used in the literature. Moreover, some characteristics generally appear in the studies such as: small scale implementation, the readiness of the laws & regulations as well as the technology.*

Keywords: Smart City, Systematic literature review, Indicators, Case, Implementation

1. Introduction. The advancement of technology has helped organization to reshape their cultures and provide more positive experiences to their customers and stakeholders. Technologies like artificial intelligence, big data, machine learning, and IoT are poised to have transformational impact to the organization. In the level of city and government, the topic of Smart City technology has become a subject undergoing intense study in many areas. However, the implementation and research in this area are still a blue-sky area and still in the phase of infancy. There are several definitions of a Smart City coined by the researchers. In general, the term of Smart City is where the governance of the government (i.e., a city) invests an integrated system where human, ICT, city infrastructure interact with each other and provide a sustainable economic growth for the city and improve its citizens quality of life [1]. Several researches have been done in this area; however, there are still limited survey papers that provide the indicators, methods, and the examples of the Smart City cases. In order to evaluate if the Smart City implementation is successful for a city or not, the researchers have to determine several success indicators to the system. Priano and Guerra [2] indicate six characteristics of a success indicator on well performing city, “*built on the smart combination of endowments and activities of self-decisive, independent and aware citizens*” [2]. According to the Smart City framework, proposed by Priano and Guerra [2] and Colldahl et al. [3], there are six characteristics in a Smart City model. The six characteristics that encompass the Smart

City model are: Smart Economy, Smart People, Smart Government, Smart Mobility, Smart Environment, and Smart Living [2,3]. The contribution of this paper is to provide a systematic and comprehensive survey using a systematic literature review method, on indicators, methods, and the examples of the Smart City cases. This literature review contributes to the foundation of the research in the area of Smart City. The methods and examples of Smart City cases in this paper are limited to computer science, information technology, and information system only. The results show the paramount indicators of success to implement Smart City framework.

2. Theoretical Foundations.

2.1. Smart City. The word Smart City has become a popular term in all across the world. A city as the centre of the civilization cannot be separated from the social and economic problems such as crowdedness, and security. A lot of villagers are considering moving to the city for a better life and job. Hence, city needs to change their governance, policy, as well as their infrastructure to support their citizens. A Smart City potentially provides a good framework to support the governance of a city. Certainly, there are several indicators needed to evaluate the effectiveness of the implementation of a Smart City framework. There are several definitions of Smart City across the literature found. There is still not a clear, universal, consistent, and consensus agreement on the understanding of a Smart City [4]. To compile all the definitions, a Smart City is a city that invests in the development of the city to provide a high quality of life, “*with a wise management of natural resources.*” [1] in monitoring and integrating conditions of all of its critical infrastructures [5]. There are several characteristics that describe the distinctive features of a Smart City, which are: Smart Economy, Smart People, Smart Government, Smart Mobility, Smart Environment, and Smart Living [2,3].

2.2. Smart City framework. The scope of the implementation of a Smart City can be extremely wide. The implementation would affect the whole city (e.g., policy, and infrastructure). A framework would help to frame and provide boundaries for the Smart City development or implementation in a city. A model can be the themes of the implementation of the Smart City. There are several well-known Smart City frameworks and models. However, the main themes of the frameworks and models are relatively similar one to another. The ITB Garuda framework consists of three layers: the resources, the enablers, and the services layer. The resources as the core layer can be processed and enhanced to become the enablers. The enablers layer will enable the outer layer of services [7]. Another Smart City framework that is well-known is proposed by IBM [6]. The IBM framework also consists of three layers: planning & management layer, human layer, and infrastructure layer. All the layers are simultaneously connected one to the others creating the Smart City ecosystem [6].

3. Methodology. This research implements a systematic and comprehensive literature review proposed by Ridley [8] and Okoli and Schabram [9]. The steps proposed in this paper to systematically review the literature are: defining the purpose and scope; searching for literature review; defining the inclusion and exclusion criteria with practical screen and quality appraisal; data extraction; and finally, the synthesis of studies [8,9]. The purpose of this study is to understand the paramount success indicators for a Smart City model. Moreover, this paper also analyzes and comprehensively describes the methods as well as the case studies of the implementation of a Smart City. The methods and case studies analyzed and described in this paper are limited to computer science, information technology, or information system area. This paper contributes and serves as the foundation of the research in the area of Smart City specifically in the area of ICT. To summarize, the research questions of this paper are: **[RQ-1]** What are the paramount

indicators of success in the implementation of a Smart City? And [RQ-2] What are the methods used to successfully implement a Smart City framework, particularly in the area of ICT? Finally, [RQ-3] What are the real case studies (i.e., the progress and limitation of current research) of a Smart City?

Next step is to search the existing papers in this area. The database used in this research mostly contains papers in ICT area. They are Science Direct (www.sciencedirect.com), ACM Digital Library (dl.acm.org), and IEEE Xplore (ieeexplore.ieee.org). In addition, Google Scholar (scholar.google.com) was also used to cover more wide papers which might not be indexed by those three databases. The keywords used to search the paper are “Smart City”, “model”, “indicator”, “method”, “case” with the synonyms. The combinations of searching queries are: [Query-1] (“index” OR “indicator”) AND (“plan” OR “design” OR “model” OR “framework”) AND (“Smart City” OR “Smarter City” OR “ubiquitous city”); [Query-2] (“index” OR “indicator”) AND (“Smart City” OR “Smarter City” OR “ubiquitous city”); And [Query-3] (“case” OR “implementation” OR “case study”) AND (“Smart City” OR “Smarter City” OR “ubiquitous city”). Next step is to define the inclusion and exclusion criteria with practical screen and quality appraisal. The inclusion criteria for this study are: [C-1] The title and abstract of the paper contain contents that might help to answer the research questions raised in this research; [C-2] The keywords of the paper contain the keywords used to search the literature. Moreover, there are also some exclusion criteria to limit the literature that is not too relevant to the scope of this research, and they are not a paper that is: [C-3] published before 2004; [C-4] duplicated; [C-5] too technical, that only address one technology aspect; [C-6] focusing on the issues of government regulation; [C-7] focusing on the issues of energy. All the papers matched with the criteria (i.e., the candidate studies) were downloaded to be extracted and analyzed. The candidate studies that strongly provide information to help to answer the research questions raised in this research (i.e., the selected studies) were further analyzed and synthesized.

4. Results and Discussion. The process data extraction was started in 2015 and gathered around 367 papers with the keywords [Query-1], [Query-2], and [Query-3] and also matched with all the criteria [C1] to [C7]. All those papers are potentially providing information that help to answer the research questions [RQ-1], [RQ-2], and [RQ-3] (i.e., the candidate studies, 198 papers). After the papers were thoroughly extracted and analyzed, there were only 34 papers that strongly provide information to help to answer the research questions raised in this research (i.e., the selected studies).

4.1. Demographic analysis. The number of researches those have been done in this area has been significantly increasing for past this decade. The number of papers published in the area of Smart City is significantly increasing from 2004. This research demonstrates 65% selected studies from journal, and the rest were from conference paper/proceeding. Total of 102 authors were contributed to 34 selected studies with Dr. Alberto De Marco (Italy) and Dr. Mei-Chih Hu (Taiwan) as the top contributors (with two papers each contributor). There are 25 countries which contributed to the research with Italy as the top contributor (23 contributions in the selected studies), followed by China (8 contributions). The implementation of Smart City framework is mostly done in European/UK region (16 implementation papers, 47% of selected studies) with Italy as the top city that implemented Smart City framework (5 implementation papers, 14.7% of selected studies). The second top region that implemented Smart City framework is Asia (total of 12 implementation papers, 35.3% of selected studies) with China as the top city (total of 4 implementation papers, 11.8% of selected studies). Moreover, USA also has the same number of implementation papers with China. All the selected studies implemented the Smart City framework in a large scale in a city level.

4.2. Smart City indicators and implementation. This research categorizes the Smart City indicators into six categories based on [2,3]. The indicators proposed in the selected studies were analyzed and mapped to the six categories. Figure 1 illustrates the indicators implemented in the 34 selected studies mapped to the six categories. The 34 papers were selected because those papers are potentially providing insights to answer research questions posed in this study (i.e., [RQ-1], [RQ-2], and [RQ-3]). For each paper, we analyzed the content and spotted some keywords related to the six indicators of a Smart City proposed by [2,3]. In the original paper, each indicator has more specific sub-indicators (see [2,3]). For example, [40] proposed an evidence of the implementation of a Smart City framework from China. The authors discussed several aspects such as Smart Transportation, Smart Energy, and Smart Government. Hence, the mapping goes Smart Transportation is part of Smart Mobility, Smart Energy is part of Smart Environment, and Smart Government. All the keywords in the paper are mapped into six categories and then aggregated. The total number of indicators counted (not distinct) is presented in Figure 1. The data distribution of each indicator is fairly normal across all the databases or search engines (i.e., paper sources). The most mentioned and used indicator is the Smart Environment with total of 89 mentions (19.5%), and Smart Mobility with total of 89 mentions (19.5%), followed by Smart Living with total of 75 mentions (16.5%). In contrast, Smart Economy is the least mentioned and used indicator in the selected studies with total of 57 mentions (12.9%).

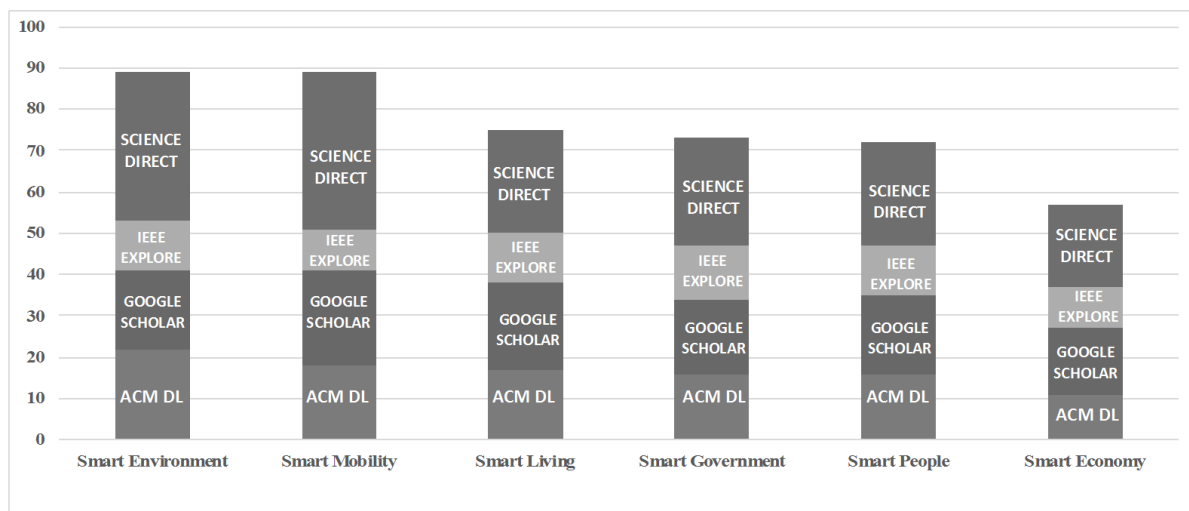


FIGURE 1. Indicator data distribution in the selected studies

According to [2,3] the six indicators can be broken down into several sub-indicators. Albeit the Smart Environment indicator was the most mentioned and implemented in the selected papers, there were some limitations to implement the indicator in a city level. Law, regulation, and social aspects influence the implementation of the indicator in a city level. Moreover, some of technologies are still not ready to be implemented in a real world. The highest number of implementations in the selected studies mostly shares similar characteristics, such as: implemented in a small scale, the regulators are ready to design the laws and regulations related to the smart technology, and the technologies are ready to be implemented in the real world (not only works in the lab environment). The most sub-indicator implemented in the selected studies is Public Transportation System (35) under Smart Mobility indicator, followed by Environmental Sustainability (29) under Smart Environment indicator. The indicators can also indicate the area of implementation of a Smart City framework, for example: implementation in the healthcare services [15,18], implementation in the public transportation system [42], implementation

in the education system [21,22]. Hence, the most area implemented with a Smart City framework is in the public transportation system [42]. To summarize, the sub-indicators which are regularly mentioned and implemented in the selected studies can be listed and sorted as: Public Transportation System (35), Environmental Sustainability (29), ICT Infrastructure (21), Healthcare Services (21), Social Security and safety (18), Social and Cultural Plurality (17), Entrepreneurship and Innovation (16), Housing Quality (15), ICT and E-Government (15), Economic Vitality and Planning (15), Transparent Governance & Open Data (14), Education System and Facilities (13), Monitoring Pollution Degree (10), Energy Management (10), Participation in Decision Making (8), Creativity (8), Productivity (8), (Inter)-National Accessibility (7).

Table 1 demonstrates the mapping of the six indicators proposed by [2,3] with the selected studies. The papers are listed in the row in accordance with the bibliography

TABLE 1. Indicators mapping per selected study

| Papers | Indicators | | | | | |
|--------|-------------------|----------------|--------------|------------------|--------------|---------------|
| | Smart Environment | Smart Mobility | Smart Living | Smart Government | Smart People | Smart Economy |
| [10] | X | | | X | | |
| [11] | | | | | | X |
| [12] | X | X | | X | X | X |
| [13] | X | | | X | | |
| [14] | X | X | | | | |
| [15] | X | X | X | X | X | X |
| [16] | X | | | X | | |
| [17] | X | | | | | X |
| [18] | X | X | X | | X | |
| [19] | X | X | X | X | X | X |
| [20] | | | X | X | X | |
| [21] | X | X | X | X | X | X |
| [22] | X | | X | X | X | X |
| [23] | X | X | | X | | |
| [24] | X | | | X | | |
| [25] | X | | | X | | |
| [26] | X | X | X | X | X | X |
| [27] | X | | | | | X |
| [28] | X | | | X | | |
| [29] | X | | | X | | X |
| [30] | X | X | X | X | X | X |
| [31] | X | | | | | |
| [32] | X | | | X | | |
| [33] | X | X | | X | X | X |
| [34] | X | X | X | X | X | X |
| [35] | X | X | | X | | |
| [36] | X | X | | | X | |
| [37] | X | X | X | X | X | X |
| [38] | X | X | X | X | X | X |
| [39] | X | X | X | X | X | X |
| [40] | X | X | | X | | X |
| [41] | X | X | X | X | X | X |
| [42] | | X | | | | |

numbering and mapped with the six indicators shown in the column of the table. The mark “X” indicates that the paper implemented or mentioned the indicators. To map the paper into the six indicators, the paper was analyzed based on the contribution and area of research. Some of keywords also mapped to the six indicators based on either the synonym or the sub-category or sub-indicators. For example, [13] discusses a topic that is related to Organization, Policy, and Environment in a Smart City. Hence, the paper is mapped with Smart Environment and Smart Government.

5. Conclusions. This research contributes to the exploration of three research questions stipulated in this study. **[RQ-1]** What are the paramount indicators of success in the implementation of a Smart City? The results indicate that the paramount indicators for a Smart City implementation in general are Smart Environment and Smart Mobility. Both indicators (i.e., Smart Environment and Smart Mobility) are the most indicators used or mentioned in the 34 selected studies with 89 mentions, followed by Smart Living with 75 mentions across the selected studies. Moreover, in the level of implementation the top three indicators are Public Transportation System (35), Environmental Sustainability (29), ICT Infrastructure (21). **[RQ-2]** What are the methods used to successfully implement a Smart City framework, particularly in the area of ICT? **[RQ-3]** What are the real case studies (i.e., the progress and limitation of current research) of a Smart City? The results show that most of the implementation still limited in a relatively small project. There are several similar characteristics of the implementation of Smart City framework, which are: implemented in a small scale, the regulators are ready to design the laws and regulations related to the smart technology, and the technologies are ready to be implemented in the real world (not only works in the lab environment). Most of the Smart City framework implementations in the selected studies are in the area of Public Transportation System (35) followed by Environmental Sustainability (29). The synthesis of this research hopefully can serve as a foundation to the researchers that are working in this area. Finally, as the future work, the exploration of Smart City framework based on indicators other than 6 mentioned in the paper will be conducted to have a holistic review on the Smart City framework all over the world.

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