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著者	Xiaolong Zou, Shihan Ma, Sihan Xin
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An Analytical Hierarchy Process Approach for Smart City Assessment in Japan:
From Concept to Indicators

Xiaolong Zou[1,2*], Shihan Ma[1] and Sihan Xin[1]

1 School of International & Public Affairs, Jilin University.
2 Institute of National Development & Security Studies, Jilin University.
** Corresponding Author, Email: zou_xl@jlu.edu.cn*

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Abstract: The smart city (SC) has become the new megatrend in sustainable urban development and enjoys worldwide popularity. After thoroughly reviewing the relevant literature, two clusters of smart city concepts/notions are observed. One cluster focuses on information and communication technologies (ITCs) and their application, while the other focuses on improving quality of life via ITCs. To better assess SCs in a regional context, we have summarised the key features and components of SC and proposed a comprehensive SC framework comprising two objectives, six domains and two means of implementation. Moreover, we selected and compiled specific indicators under each SC domain and applied an analytical hierarchy process for indicator weighting in the case of Kitakyushu City, Japan. The outcomes of this paper provide several insights into the methodological approaches for developing and evaluating SC projects for stakeholders such as urban planners, scholars, community developers and policymakers.

1. INTRODUCTION

The trend towards the concept of ‘smart cities’ (SCs) is gaining rapid momentum across the globe. There seems to be international recognition that the ‘business as usual’ model of development is essentially unsustainable and that the need for sustainable modes is becoming increasingly pressing. In the history of urban development, several major trends have emerged—typified by the ‘garden city’, ‘eco-city’ and ‘low-carbon city’ concepts—which address urban development needs and pursuits in a contextually appropriate manner (Zou & Li, 2015). Among them, the ‘smart city’ is the latest to emerge and has been welcomed by city planners and community developers worldwide (Khoir & Davison, 2019).

Just as similar as the ‘eco-city’ and ‘low-carbon city’ concepts lack universal definitions (Zou & Li, 2014), there is no internationally standardised universal definition for an SC. After reviewing the existing literature on SCs, including some of the frequently cited grey literature (i.e., conference papers, reports from international organisations, etc.), two broad streams of SC definitions can be identified. One stream focuses on the development of the SC concept to cover a broader scope and multiple domains (e.g., economic growth, social life, infrastructure, energy, urban governance, etc.) (Angelidou, 2014; Lazaroiu & Roscia, 2012; Perboli et al., 2014). The other stream relates to specific aspects of SC development through the implementation of information and communication technologies (ICTs) in all aspects of daily life to improve the quality of life (QoL) of a population (Chourabi et al., 2012; Cosgrave, Arbuthnot, & Tryfonas, 2013; Schuurman et al., 2012). Notably, each approach has its proponents, and proponents among different stakeholder groups.

The 'digital city' is one of the early origins of the SC concept, which refers to the use of cities for various digital endeavours. Similar examples can be found in Amsterdam (Digital City Amsterdam), Helsinki (Virtual Helsinki) and Kyoto (Digital City Kyoto) (Ishida & Isbister, 2000; Schuurman et al., 2012). Beyond this umbrella terminology, which includes the terms 'wired city' and 'smart city', all of these concepts address technology-oriented SC initiatives and each one has its own focus (Paskaleva, 2011). The 'ubiquitous city' is another concept similar to the SC, also known as the 'U-city'. Scholars believe that the U-city will be an alternative model for future urban development that blends the physical and virtual spaces of a city and aims to promote urban innovation and improve QoL, with an emphasis on input from end users (Kwon & Kim, 2007). However, this concept has faced criticism for preferentially focusing on specific end-user groups (e.g., young people) rather than all age groups (Choi, 2010; Schuurman et al., 2012).

The early idea of a 'smart city' was coined by Mahizhnan (1999), which primarily aimed to promote Singapore as a resource-poor 'intelligent island' striving to embrace new information technology (IT) to boost its economy and improve the QoL of its people. In the ensuing years, the SC concept gained progressive momentum. Despite this, SC continues to lack a precise definition and some criticism has emerged as to whether a valid SC actually exists(Shelton, Zook, & Wiig, 2014). Additionally, some have critically questioned whether these SC 'city labelling' phenomena are just another variant of the 'entrepreneurial city' advocated by Hollands (2008).

Most of the more straightforward interpretations of SC have focused on the application of smart sensors embedded in smart devices in ICT scenarios, where the Internet of Things connects several sensors to manage cities with greater efficiency and effectiveness since it is assumed that sensors play a role in making cities 'smarter' (Mitton et al., 2012). In this regard, there seems to be a consensus among many in the academic IT field that the primary goal of creating an SC is to improve the QoL of its inhabitants, and that one of the main tools used to achieve this goal is the implementation of 'smart technology' (mainly ICTs).

In this paper, we will attempt to collate and summarise the two identified mainstream concepts of SC in order to systematically understand precisely what SCs and their defining characteristics are. Based on the literature reviewed, the authors attempt to propose an encompassing working definition of SC and use this to propose a smart city framework with specific indicators for a better and more systematic assessment of SCs. Using the city of Kitakyushu, Japan—an internationally renowned city for innovation in urban sustainability—as a case study, the authors have tailored a system of indicators based on our proposed SC framework.

2. SMART CITIES: ORIGIN, CONCEPT AND INDICATORS

In this section, the authors review and collate the existing literature on the origins of SCs. They conclude that SCs originated from the 'smart growth' movement in urban areas of the Global North. Additionally, the authors summarise the main SC concepts and their other indicators.

2.1 Smart City Origins

The notion of an SC is not new (Shelton, Zook, & Wiig, 2014). The history of the SC concept dates back to the 'new urbanism' that developed in North America during the 1980s, which aimed to 'improve the urban environment and quality of life by promoting the idea of community and limiting urban sprawl...' (Vanolo, 2013). During the emergence of the SC movement in the 1990s, the US government funded a 'smart growth' network that encompassed the interests of a wide range of stakeholders, such as the Environmental Protection Agency (EPA), NGOs, environmental organisations, professional associations and institutions, and real estate developers to revitalise US cities while benefiting the environment as a whole (Bronstein, 2009). Notably, the term 'intelligent city' tends to describe a new urban model that combines the urban sphere and technological sphere to foster innovation, transition to e-government and provide ICT infrastructure (Bronstein, 2009; Komninos, 2009). The term 'intelligent city' has since been subsumed as the term 'smart city', with the two terms being used interchangeably in subsequent years.

2.2 Smart City Concept

To date, academic interpretations of 'smart' cities have varied, with definitions of SC tending to focus on two domains: 1) 'soft domains' (e.g., education, culture, policy innovation, social inclusion and governance); and 2) 'hard domains' (e.g., infrastructure (buildings, energy grids, etc.), natural resources, water and waste management, mobility and logistics) (Albino, Berardi, & Dangelico, 2015). Albino, Berardi, and Dangelico (2015) developed a comprehensive list of SC definitions that provides a detailed collation of the literature since 2000. Here, we have added revised definitions of SC based on the existing literature and grouped these definitions according to their core meaning to obtain a compressed view (refer to the Appendix for details). By examining the established SC concepts longitudinally, we summarised the two main components of a smart city: the goals of a smart city and the means to achieve them. Moreover, two main goals can be identified from the listed concepts, which encompass a dual and parallel pursuit: improving QoL and pursuing sustainable urban development. The implementation of 'smart' technologies is the means to achieve these goals, mainly in the form of (but not limited to) ICTs (Kumar et al., 2020).

The industrial sector has also responded positively to being at the forefront of the SC wave. International consortia such as IBM, Cisco Systems, Siemens AG and Hitachi Group have all offered their 'services' to help their clients develop SC projects, from providing specific technical products to producing complete solutions for smart communities.

With regard to what constitutes an SC, (Giffinger, Rudolph et al., 2007) first identified four SC characteristics (i.e., 'industry', 'education', 'participation' and 'technical infrastructure') and then further expanded them into six components (i.e., 'smart people', 'smart living', 'smart economy', 'smart mobility', 'smart environment' and 'smart governance') (Giffinger, Rudolf & Gudrun, 2010). Lombardi et al. (2012) delineated a series of components that have aspects of urban life that can be related to the aforementioned industry of a smart economy, education of smart people, e-democracy of smart governance, logistics and infrastructure for smart mobility, efficiency and sustainability for a smart environment, as well as security and quality for smart living. Other specific SC dimensions have been identified in the literature (e.g.Barrionuevo, Berrone, & Ricart, 2012; Chourabi et al., 2012; Giffinger, Rudolph et al., 2007; Kourtit & Nijkamp, 2012; Mahizhnan, 1999; Nam & Pardo, 2011a, 2011b; Eger, 2009). As noted by Albino, Berardi, and Dangelico (2015), the commonalities of these dimensions can be summarised as follows:

- *Networked infrastructure that provides the impetus for political, social and cultural development*
- *Business-led urban development for sustainable growth*
- *Urban stakeholder engagement to develop social capital*
- *Protection of the natural environment for the future*

The 'eco-city' and 'low-carbon city' concepts have become major trends in development. Currently, there are some 143 designated or self-named SC projects around the world, primarily in Asia and Europe (50 and 47 projects,s respectively), followed by North America (35 projects), South America (10 projects) and Africa (10 projects) (Lee, Hancock, & Hu, 2014). However, there is some overlap in the names of some of these projects. For example, the city of Masdar in the Unites Arab Emirates, a world-renowned example, is referred to as an 'eco', 'low-carbon' and 'smart' city. Other notable SCs around the world include Songdo smart city in South Korea, Barcelona, Amsterdam, Berlin in Europe, Manchester, Edinburgh and Bath in the UK, California, San Diego and San Francisco in the US, Ottawa and Quebec in Canada, and so on (Albino, Berardi, & Dangelico, 2015).

2.3 Smart City Indicator Systems

Many methods, approaches, indices and indicators have been proposed in the academic community for the measurement and evaluation of SCs. Setting the scope at medium-sized European cities, Giffinger, Rudolph et al. (2007) conducted a comprehensive ranking of SCs using six indices of SC characteristics, 31 factors and a total of 74 follow-up indicators. Notably, their framework provided useful insights for subsequent SC development. Additionally, Lazaroiu and Roscia (2012) proposed another SC model with four criteria: economy, environment, energy and mobility, and governance. Moreover, fuzzy logic was applied to measure the listed indicators as a complement to the indicator system applied in their 'smart city ranking'. Their results indicate that SCs are most significantly influenced by sustainable, innovative and safe public transport (Lazaroiu & Roscia, 2012). Other major rankings include (but are not limited to) the Smart City Rankings conducted by the NRDC, the Global Power City Index created by the Urban Strategy Institute in Japan, institutions such as the Smart City Council and the World Resources Institute, business groups (e.g., IBM, Siemens, Cisco, Hitachi, etc.) and other individual scholars, who have proposed various specific measures or means of evaluating SC objectives and instruments. For example, Idowu and Bari (2012) proposed a general framework to facilitate the development and deployment of SC services. Furthermore, Barranco et al. (2015) were commissioned by the EU to propose a framework to evaluate and assess urban development in terms of the time series and geographical characteristics of urban areas. Lombardi et al. (2012) applied an analytical model to measure the performance of SCs, which provided good inputs for policy development and also identified potential indicators.

Having reviewed this literature, we believe that it is not currently feasible to develop overarching indicators or indicator systems for SC measurement at this early stage of SC development. In contrast, it would be more sensible to conduct an assessment or evaluation within a specific system boundary to establish the correct concepts, development goals and methods. A policy or framework to develop tailor-made mechanisms would better facilitate the smart development of regional cities.

2.4 Proposed Smart City Framework Based on the Literature Review

Following a thorough compilation of SC concepts, dimensions, frameworks and indicator systems, two objectives were found to be embodied in most articles: 1) improving the QoL of local citizens; 2) pursuing sustainable urban growth and development. The primary means of achieving these goals is through the innovation and implementation of 'smart' technologies such as ICT and sensor networks, as well as the involvement of key stakeholders from industry, academia and government (triple helix model). The main components of SCs include both ‘soft’ and ‘hard’ domains. Soft domains include (but are not limited to) ‘economy’, ‘governance’ and ‘people and living’, while hard domains include (but are not limited to) ‘infrastructure’, ‘energy & mobility’ and ‘environment’ (see *Figure 1*).

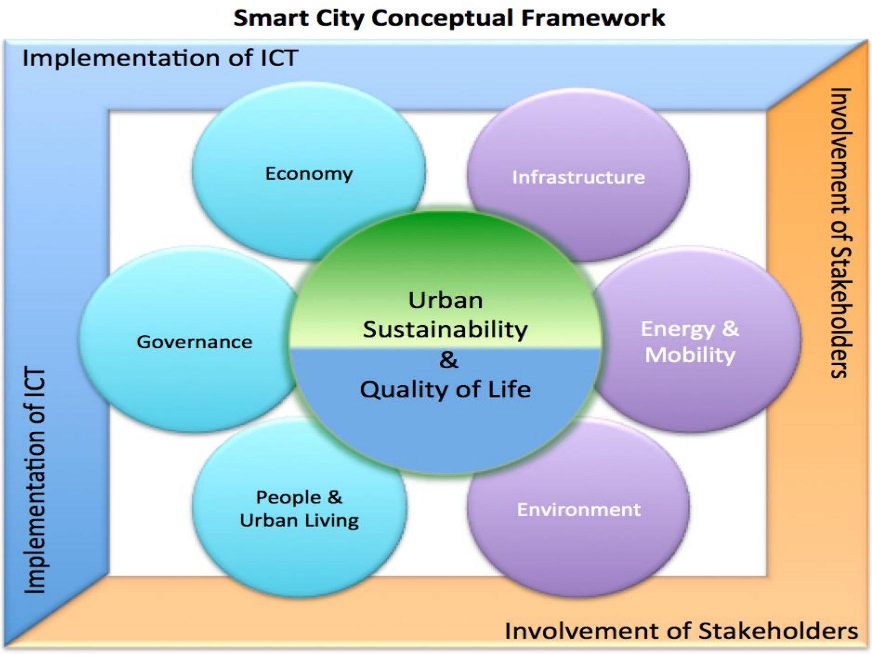


Figure 1. Conceptual framework of smart cities

We have attempted to understand the aims and objectives of SC and the tools for their implementation—with an additional analysis of their main elements and areas of development—to obtain a more in-depth elaboration of SCs in this paper. The proposed framework is used as the theoretical basis for the later presentation of a system of indicators for measuring SCs in Japan, as described in the following sections.

3. MEASYRINF THE 'SMARTNESS' OF KITAKYUSHU CITY, JAPAN

3.1 General Overview of Smart Cities in Japan

In the Japanese Smart City Portal, an SC refers to 'a new type of city that provides sustainable growth, with the aim of encouraging healthy economic activity and providing a guarantee for reducing the burden on the environment while improving the quality of life of its residents'[1]. The initiative was initiated by the Ministry of Economy, Trade and Industry (METI) of Japan and has been run by the New Energy Promotion Committee since 2010. The project has a total of four main sites: Toyota City, Yokohama City, Keihanna Science City and Kitakyushu City, to test energy distribution and innovative social systems related to smart grids and SCs.

On 11 March 2011, the Great East Japan Earthquake erupted and the nuclear power plant crisis triggered by the earthquake and tsunami sounded alarm bells worldwide. As a highly urbanised country, Japan is inevitably showing the limitations of traditional ways of doing business if it wants to improve QoL. To address these issues, the active implementation of ICT technologies will enable a new generation of SC initiatives. For example, electric vehicles can be charged by individual smart houses whose batteries can also be used to power the house in case of emergency. Currently, these four project sites serve as cutting-edge testbeds for numerous other experiments that will be implemented on a large scale in future SCs. Additionally, the Japanese government is actively promoting the participation of various stakeholders (especially the general public) by providing more channels to share their ideas and suggestion, which will help translate SCs into reality.

3.2 Kitakyushu City and its Smart City Project

Kitakyushu City is situated on the northern part of the Japanese island of Kyushu, has a population of approximately 957,600 and a territory of over 491 square kilometres. From the 1950s to the 1970s, under the influence of heavy industrialisation such as iron manufacturing, the air and water in Kitakyushu were heavily polluted and the city's Dokai Bay was even referred to as the 'Sea of Death'. Under this influence, public health was seriously threatened. In contrast, most of the pollution has been successfully remedied in recent decades due to the efforts of the local government towards environmental protection and sustainable development. Kitakyushu has been awarded national and international honours, including the 'Japan's

1） http://jscp.nepc.or.jp/en/index.shtml

Eco-model City Award', 'United Nations Global 500 Role of Honor Award', 'Earth Summit: UN Local Government Honors', etc. (Maeda, 2010).

Regarding the SC (Eco-Town) project in Kitakyushu, its scope covers the entire eastern section of the Hibiki Landfill area. This project was approved by Japan's then Ministry of Industry, Trade and Industry (MITI) in 1997 (replaced by the METI in 2001). The METI provided strong support for the project by providing resources such as subsidies for infrastructure development and marketing. The overall objective of the project was to contribute to the development of a 3R (reduce, reuse, recycle) society in Japan by reusing waste from local industry and promoting zero emissions. Overall, the project was divided into two phases: the first phase (1997–2002) was focused on 'recycling', while the second phase (2002–2010) was focused on 'reuse'. The overall strategy was to link work with academic research, demonstration, applied research and the private sector of local industry. The city of Kitakyushu's project to develop SC has achieved world-renowned results and has also demonstrated the profitability and financial benefits of SC development. For this project, a total of ¥50.2 billion was initially invested, of which 7% came from the private sector to create over 1,000 local jobs. From 1998 to 2003, a cumulative total of ¥109.3 billion was invested in this SC project (Zou & Li, 2015).

3.3 Proposed Framework with an Indicator System for Kitakyushu City

In the previous section, we mentioned that over the past few decades, the city of Kitakyushu has made continuous efforts to pursue urban sustainability through various forms of government initiatives, citizen participation, technological innovation and implementation. However, in general, Japan lacks a universal metric for comprehensive SC development. To fill this gap, we have attempted to propose a set of indicators for the comprehensive measurement and evaluation of such SC projects based on the framework presented in Section 2.3, which we also hope will bring greater clarity to policymakers, urban planners, and scholars in relevant fields of research. Under the framework we summarise, we advocate finding a way to select the most appropriate and manageable indicators from the existing pool of indicators. Notably, these are considered to summarise the main characteristics of what constitutes an SC, as proposed in the literature and case studies around the world.

In pursuit of the twin goals of sustainable urban development and improved QoL, six dimensions are included in our indicator system: 'Governance', 'Economy', 'People & urban living', 'Infrastructure', 'Energy & mobility' and 'Environment' (see *Figure 1*). We selected each dimension based on the relevance, applicability and usability of the indicators. The indicators currently include the Sustainability Indicators Index proposed by Dhakal (2002) of the Institute for Global Environmental Strategies (IGES), a public policy research institute initiated by the Japanese government. The indicators also include the Asian Green Cities Index proposed by Economist Intelligence Unit (2011) and the Smart Cities Index established by Giffinger, Rudolph et al. (2007). We argue that sustainable cities and green cities are also SCs. Based on this, we mainly favour the first two indices in our choice of indicators. We have summarised 18 aspects under six dimensions, with a total of 36 indicators. Detailed descriptions of each dimension and its subsidiary indicators are shown in *Table 1*.

However, within this framework, not all indicators from IGES were matched appropriately. We have made a refined selection based on the indicators mentioned in the previous section by combining the relevance of content, suitability and data availability.

Table 1. Proposed smart city indicator system for Kitakyushu City

Dimensions	Aspects	Indicators
Governance	***Transparency & Management***	Perception of transparency of bureaucracy Perception of fight against corruption Monitor its environmental performances
	Civil participation	City representatives per resident Female city representatives Public participation in environmental decision-making
Economy	***Innovation***	% of budget of local government allocated for environment R&D expenditure in % of GDP
	Sustainable development	Use of electricity per GDP Use of water per GDP
	Labor & Capital	Gross city product per capita Households below poverty line
People & Urban living	***Human health***	Number of doctors per 1000 population Number of hospitals per 1000 population
	Institutional & Social capacity	Number of environmental staffs in city government per 100 thousand population % of industries complied with emission control regulations % of vehicles compliant with emission control regulations Adult literacy rate
Infrastructure	***Buildings***	Energy consumption of residential buildings Energy-efficient building standards
	Land use	Green spaces per capita
	Smart grid	Accessibility of smart grid
Energy & Mobility	***Renewable energy***	Share of renewable energy in total energy use
	Energy efficiency	CO2 per capita from energy use
	Sustainable transportation	Green mobility share E-vehicle in commercial vehicle shares
Environment	***Air quality***	SO2 concentration TSP concentration
	Water availability	% of population with access to adequate and clean water Water renewable rate of the source
	Water quality	BOD concentration of inland water bodies COD concentration of the coastal water % of green area in the total land use
	Urban green	% of green area in the total land use
	Waste & Waste water	Per capital waste generation % of total solid waste collected % of total waste water treated

Admittedly, there are some limitations to this study and the proposed index. Since this study used an indicator weighting approach, we decided to keep the size of the indicators within a manageable range of 2–5 per aspect and 2–5 aspects per dimension.

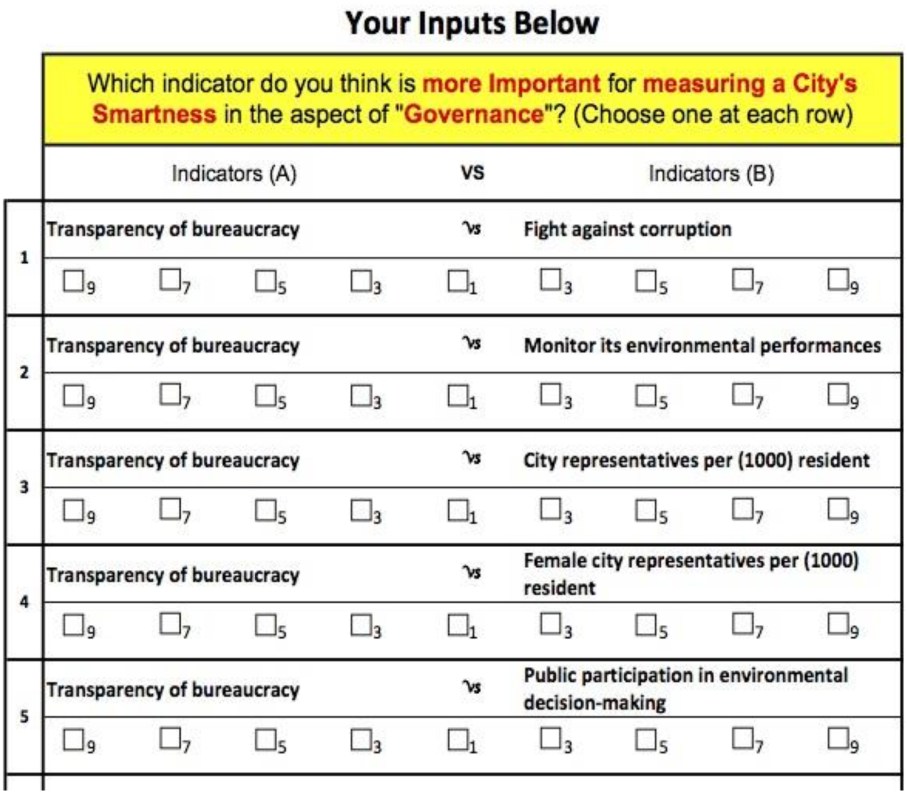
3.4 Weighting of the Proposed Smart City in Indicators

To weight the indicators of the proposed SC index, we applied the analytical hierarchy process (AHP) method by surveying experts' opinions. Expert selections were cross-referred by their research fields in terms of the subject matter and years of practical working experience. All of the surveyed experts were affiliated with partner universities in the region, such as Ritsumeikan University, Ritsumeikan Asia Pacific University, Kyushu University and Kitakyushu University, which offered familiarity with and expertise on the local context of Kitakyushu City.

According to the AHP methodology (Saaty, 1980), the decision-making process consists of a total of three levels: objectives at the first level; criteria at the second level; alternatives at the third level. In this study, the alternatives do not appear to be important since only the evaluation of the SC indicators was required. Therefore, under these conditions, we re-integrated and utilised the AHP hierarchy by customising it to a three-level, two-tier structure, with the overall objective being the 'weight of the SC index' and the goal being to assess the importance of the indicators under each domain, with the criteria under each objective being the individual indicators.

We then prepared paper-based questionnaires to survey the available experts in person. For experts that were not immediately available, we sent the questionnaires to them via email within the course of 1 month. We sent the survey out to a total of 60 experts, with each SC domain being weighted by 10 experts. During this process, we collected a total of 48 valid responses, which allowed for a follow-up analysis.

Thereafter, to clarify the importance of the indicators, we asked respondents to assess each indicator via a paired comparison using a scale of 1 to 9. In this scale, '1' indicates equal importance, '3' denotes a slightly higher significance, '5' denotes a moderately higher significance, '7' denotes a considerably more significant level and '9' denotes the highest possible significance. *Figure 2* provides an example of what we included in our survey for the respondents.


Your Inputs Below

Which indicator do you think is **more Important** for **measuring a City's Smartness** in the aspect of "**Governance**"? (Choose one at each row)

	Indicators (A)				VS	Indicators (B)			
1	Transparency of bureaucracy				vs	Fight against corruption			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
2	Transparency of bureaucracy				vs	Monitor its environmental performances			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
3	Transparency of bureaucracy				vs	City representatives per (1000) resident			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
4	Transparency of bureaucracy				vs	Female city representatives per (1000) resident			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9
5	Transparency of bureaucracy				vs	Public participation in environmental decision-making			
	☐9	☐7	☐5	☐3	☐1	☐3	☐5	☐7	☐9

Figure 2. Survey example for AHP scales

After collecting all the data, we used the AHP calculator developed by Goepel (2013a) for analysis, wherein key parameters were calculated and key indicators were displayed. Four key AHP indicators for our SC index ranking—i.e., weights for indicators based on the raw geometric mean method, the consistency ratio (CR), the aggregated weights (AWs) for indicators, and the group consensus ratio—were selected to conduct the analysis.

After checking the CRs of the survey results for each participant, we removed four respondents out of the 48 collected because their CRs exceeded the 20% threshold (excessive rates indicate invalidity). Notably, a CR within the range of 10 to 20% is deemed consistent for judgements (Goepel, 2013b).

3.5 Indicator Weighting Results

After conducting the AHP analysis of the survey results and removing those deemed not consistent enough for further analysis (CR>10%), we obtained the following results (see *Table 2*). Detailed results for all indicators are listed in the Appendix.

For the 'Governance' domain of the proposed SC index, the two most important indicators are 'Monitoring environmental performance' and 'Perception of the transparency of bureaucracy', which together account for 56.5% (24.2% + 32.3%). In this area, 'female urban representation per (1000) inhabitants' has the lowest weight (5.5%), which might be explained by the working status and cultural background of Japanese society in general.

For the 'SC Economy' domain, 'R&D expenditure in % GDP' and 'Use of electricity per GDP' with 22.8 and 20.4%, respectively, ranked in the top two. The indicator with the lowest weight is 'Household below poverty line', which accounts for 11.4%. A possible explanation might be that most of the surveyed experts were currently working in Japanese institutes or universities, where poverty is no longer a major concern. Additionally, each indicator showed less deviation in AW (approximately 11.4 to 22.8%). This illustrates the similarity in the values of these highly quantifiable indicators in terms of prioritisation.

Regarding the 'SC People & Urban Living' domain, the second-highest group consensus rate (GSR) of 74% was obtained (see the Appendix). This indicates that the group is more likely to agree on what people and urban life mean for SCs. The two highest weighted indicators are 'Number of doctors per 1000 population' and 'Adult literacy rate'. Notably, the 'Number of hospitals' resembles the 'Number of doctors per unit', which received the lowest AW of 8.8%. This might be caused by the similar nature of the two indicators. However, it could also reveal the notion that people such as doctors play a more important role than physical infrastructure such as hospitals. While medical personnel would contribute to the overall quality of living, the literacy rate would benefit the residents' overall level of development, as dictated by common sense.

In contrast, there are only four indicators in each of the 'SC Infrastructure' and 'SC Energy & Mobility' domains. This leads to a greater concentration of AW values for each indicator, as dictated by common sense. However, to our surprise, the majority of experts reached a consensus by weighting 'Green spaces per capita' at 38.3%—a value nearly three times higher than the lowest weighted indicator in the group, 'Energy-efficient building standards' (14.7%). A similar phenomenon was observed in the energy and mobility area, where 'Share of renewable energy in total energy use' and 'CO_2 per capita from energy use' account for the main AW rates of 46.8 and 24.9%, respectively. In contrast, 'Accessibility to sustainable grid' and 'E-vehicle in commercial vehicle shares'—both of which have a weight of 14.1%—are the lowest weighted indicators in these two domains.

Table 2. Smart city indicator weightings for each domain

SC Governance	AW	Rankings
Perception of transparency of bureaucracy	32.3%	1
Monitoring environmental performance	24.2%	2
Public participation in environmental decision-making	19.2%	3
Perception of fight against corruption	13.0%	4
City representatives per (1000) resident	6.4%	5
Female city representatives per (1000) residents	5.5%	6
SC Economy	**AW**	**Rankings**
R&D expenditure in % of GDP	21.8%	1
Use of electricity per GDP	20.4%	2
% of budget of local government allocated for environment	19.6%	3
Gross city product per capita	13.5%	4
Use of water per GDP	13.3%	5
Household below poverty line	11.4%	6
SC People &Urban Living	**AW**	**Rankings**
Number of doctors per 1000 population	25.8%	1
Adult literacy rate	25.5%	2
% of industries compliant with emission control regulations	17.0%	3
% of vehicles compliant with emission control regulations	13.3%	4
Number of environmental staffs in city government per 1000 population	9.3%	5
Number of hospitals per 1000 population	8.8%	6
SC Infrastructure	**AW**	**Rankings**
Green spaces per capita	38.3%	1
Accessibility of sustainable grid	26.3%	2
Energy consumption of residential buildings	20.7%	3
Energy-efficient building standards	14.7%	4
SC Energy & Mobility	**AW**	**Rankings**
Share of renewable energy in total energy use	46.8%	1
CO2 per capita from energy use	24.9%	2
Green mobility share	14.1%	3
E-vehicle in commercial vehicle shares	14.1%	3
SC Environment	**AW**	**Rankings**
% of population with access to adequate and clean water	25.5%	1
Air quality (indicated by SO2, Total Suspended Particles etc.)	19.4%	2
% of total waste water treated or recycled	17.8%	3
Water quality (measured by BOD, COD contents etc.)	15.8%	4
Per capital waste generation	11.1%	5
% of total municipal solid waste (MSW) collected & treated	10.5%	6

Note: AW means 'aggregated weight'

This could be explained by our proposed SC conceptual framework, whose overall objective was to pursue urban sustainability and the implementation of ICT as a major instrument.

In terms of the 'SC Environment' domain, we originally proposed 10 indicators under the five themes within this domain. Given the consideration of comparison confinement, we combined them into six indicators after consulting with experts in the field. Two indicators—'air quality' (indicated by SO2, TSP) and 'percentage of population with access to adequate and clean water'—gained more AW shares, totalling 45.3% (19.4% + 25.5%), while other indicators regarding waste generation and treatment received lower AWs.

The indicator weighting results reflect the physical and environmental situation in Japan, where most of the surveyed experts are stationed. Japan is known for its good ambient environment quality and rigorous effort in environmental protection amongst Asian countries. Notably, Japan has already established a sound and effective waste separation and collection system from waste generation to final treatment. Therefore, the rather low assignment of AWs for waste-related indicators are understandable given the already solid solutions in practice.

Although the study provides important findings, it does have certain limitations. First, the proposed SC index should have considered the opinions of both policymakers and key stakeholders in the local setting. However, in this paper, we focused more on the academic interpretation of what constitutes an SC in our review of previous work and publications instead of surveying local stakeholders on a large scale. Second, the indicator selection may only reflect the geopolitical and social settings and features of Japanese cities. Further upscaling of the proposed index would require further efforts in adjusting to the designated area, which is why localisation and customisation are required for adaptability elsewhere. Third, in terms of indicator weighting, feedback from the surveyed experts indicated that misinterpretations are likely to occur given their lack of specific knowledge of AHP. Therefore, a more simple and traditional scoring of 1–9 or a Likert scale of 5 options was preferred by some respondents.

4. CONCLUSION

The world is currently in the midst of a rapid and continual trend towards urbanisation. Since the end of the 19th century, large-scale urban movements such as the 'garden city', 'green city', 'eco-city' and 'low-carbon city' concepts have emerged frequently as 'prescriptions for development' in response to various 'urban diseases', with the SC concept being the latest. However, among all of these megatrends, none have formed a universal paradigm or model that can be applied without localisation or customisation to regional characteristics or local circumstances.

As the latest megatrend for urban development, SCs can become a pivotal paradigm for urban transformation towards sustainability in the information era. Determining how to develop tailor-made SC projects for local people and communities has become a practical agenda for urban planners, community developers, policymakers, scholars and other stakeholders.

By thoroughly reviewing the current major SC concepts, we have concluded a conceptual framework that recapitulates the common features that SCs should have (as shown in *Figure 1*):

Dual objectives of improving the QoL while also pursuing urban sustainability.

Major contents of six dimensions, including the hard domains of ‘Infrastructure’, ‘Energy & Mobility’ and ‘Environment’ as well as the soft domains of ‘Governance’, ‘People and Urban Living’ and ‘Economy’.

The two major instruments for realising objectives are the application of ICT and the involvement of stakeholders.

Furthermore, to demonstrate the application of our proposed framework, we have enlisted and involved the local communities of the City of Kitakyushu in Japan as a case study in order to customise an SC project index for better evaluation and implementation. Based on our proposed SC framework, this index consists of six dimensions with 18 aspects and a total of 36 quantitative indicators. The 18 aspects showcase our topics of concern within Kitakyushu’s SC development, while the 36 indicators offer specific guidance and measurements for translating policies and concepts into reality.

However, we wish to reiterate that our goal was not to prove that our concluded SC framework or proposed SC index for Kitakyushu City should become the ‘new norm’ for smart city development. Rather, we argue that local inputs and contexts should be fully considered and integrated into translating SC concepts into real-life implementation.

Sometimes, in terms of practicality, new frameworks or new indicators may not be as effective as assessment tools that are customised for specific SCs in different places. While the SC concept lacks a common definition, we can identify common objectives and characteristics that contribute to its achievement. For policymakers, urban planners and stakeholders pursuing this model of urban development, this research can provide clear insights or references.

We focus on the implementation of ICTs or ‘smart’ technologies, and even more so on attempts to understand SCs as a new approach to resolving the tension between existing urban problems, improving the quality of human life and sustainable development. Ultimately, we believe that all eco-cities and low-carbon cities that contribute to sustainable urban development are inherently 'smart' to some extent. Therefore, a holistic view of developing or measuring new SC projects should include features from previous paradigms and experiences in local contexts.

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