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A FRAMEWORK FOR THE ANALYSIS OF URBAN INNOVATION IN SMART CITIES: LITERATURE REVIEW FINDINGS

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Abstract

The development of a smart city (SC) has always been accompanied by urban innovation (UI). UI mainly refers to the use of smart technology to promote urban development and also as a product of SC development. Smart technology can be used and developed by SC citizens. However, some research on UI in SC is conducted mainly from top-down technocratic perspectives or citizen participation. Therefore, this study proposes that the level of citizen-centric UI can be measured by using the Unified Smart City Model (USCM). With the use of the systematic literature review method, a search was conducted using keywords on three literature databases. Fifty-six indicators of UI were compiled as preliminary findings, with eight of them categorised as USCM indicators—smart architecture, smart governance, smart planning and management, smart data and knowledge, smart facilities, smart services, smart people and smart environment—to develop a citizen-centric framework. This framework will facilitate the analysis of the UI level of SC to enable city comparison and identify areas of weakness to assist in city managers' decision-making.

***Keywords**:* Smart City, urban innovation, citizen-centric, assessment framework, USCM

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INTRODUCTION

According to the 2018 Revision of World Urbanization Prospects, the world's urbanisation level can reach 68.4%, and the world's urban areas will have a population of 6.68 billion in 2050 (UN, 2018). The rapid development of urbanisation has brought urban diseases which may affect city sustainability. Scholars have documented that cities need efficient and advanced smart technology to facilitate the development of urban innovation (UI) (Anthopoulos et al., 2016; Giffinger et al., 2007). With the rise of new technologies such as big data and artificial intelligence, the direction of UI in smart cities (SCs) is increasingly deviating from citizen-centric development.

Humanistic urban researchers have called for attention to the importance of citizen participation in the innovative development of SC (Finger & Portmann, 2016; UNCTAD, 2021). However, the existing UI capacity analysis framework for SC that normally accompanies technology-oriented cognition is not sufficient to analyse the UI capabilities of citizen-centric SC. Previous literature showed the following characteristics: Firstly, scholars generally focus on building a framework from the perspective of technology innovation with the enterprise and on regional innovation (Meijer & Thaens, 2018; Sfez et al., 2017). Secondly, citizens' participation in SC normally focuses on the framework of participation, ignoring that citizens can be included in UI as a large-scale innovation force (Lim et al., 2019; Seng Boon et al., 2020). Thirdly, Nilssen (2019) thought that UI referred to technological, organisational, collaborative and experimental innovation in SC.Putra and van der Knaap (2018) revealed a UI model of mutual innovation between SC participants and organizers. In terms of UI, the synthesis of articles on the development of UI in SC highlights relevant indicators to measure their development direction. However, these indicators are mainly from the macro or technical level and hardly reflect the indicators of citizens as users that prompt UI.

Therefore, the study introduce the Unified Smart City Model (USCM) model[1] to facilitate analysis and understand citizen-centric UI with a more comprehensive perspective. Thus, the guiding research question is, *How do we develop an analytical framework for citizen-centric UI in SC so that the levels of UI may be determined and used for city development strategies?* The research aim is to develop a framework for analysing the citizen-centric UI level in SC. This paper will contribute to our understanding of the areas that have been not well documented in literature, especially in mid-size cities, of UI in SC that have been built for more than 10 years into the maturity phase. The article is structured in two parts. Firstly, the definition of UI in SC and the applicability of the USCM model will be discussed. Secondly, results from a systematic literature review

[1] USCM model is a benchmark SC model that synthetically summarises smart concept models, including SCs' innovation elements.

conducted to outline UI development and the indicators for measuring UI development will be presented according to USCM to construct the framework.

DEFINITION AND ANALYSIS MODEL OF URBAN INNOVATION

Definition of urban innovation

To eliminate the barriers to citizens' participation in UI, citizens are established as the driving force to promote UI (Eskelinen et al., 2015; Wolff et al., 2018). Based on the literature review, a conceptual framework that shows citizen-centric UI in SC was constructed (Figure 1). Figure 1 shows the interactions that exist within the elements of SC, UI and citizens as a two-way relationship between each element. The authors define UI as citizen-centric UI, which is an approach that can facilitate large-scale promotion of citizens' multi-role and multi-dimensional participation, understanding and feedback to the decision-making layer using the SC technology layer. On the basis of iCity (2016), the citizens' willingness to engage in the innovative development of SC is explained by the theory of three-dimensional space coordination in SC, i.e. physical, social and digital space. Citizens' participation may be represented at the personal layer, digital intermediary layer and decision-making layer.

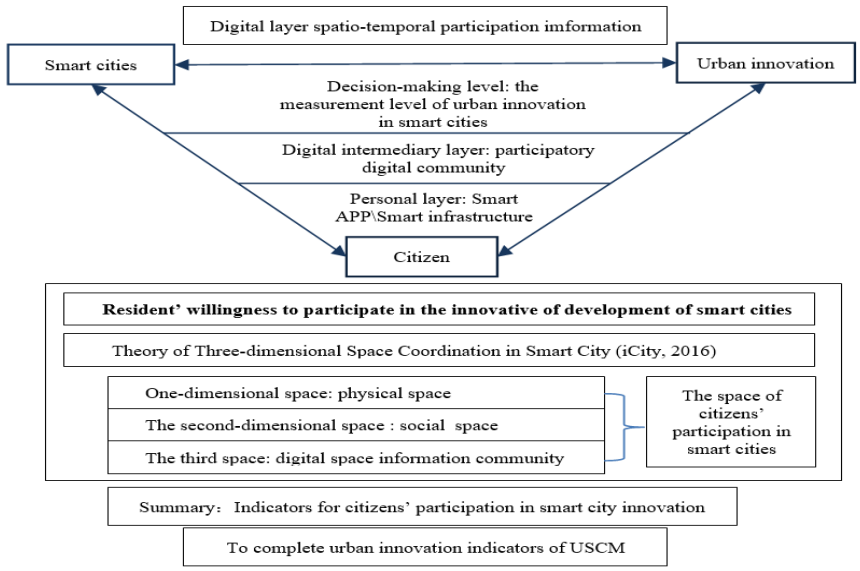

Figure 1: Conceptual framework for citizen-centric UI in the context of SCs
Source: This study

Description of USCM

UI is also the product of smart urban development (Sierpinski & Staniek, 2018). Therefore, this study borrows from the SC analysis framework to help conduct

an analysis of UI in SC (Table 1).

Table 1: **Description of USCM**

Description of USCM	
What is USCM?	USCM is a benchmarking model used to analyse smart cities. It involves smart city architecture, governance, planning and management, data and knowledge, facilities, services, people and environment of SC (Anthopoulos et al., 2016).
Who developed it?	USCM was developed by Anthopoulos et al. (2016) by reviewing many theoretical overviews of various conceptualisations and evaluations of SC from 2009 to 2015.
Who has used it and how has it been used?	USCM has been adopted by many scholars and applied to sustainable urban innovation analysis of smart cities, such as sustainable development capabilities, sustainable development of society, smart governance, urban space innovation, understanding of smart cities and urban innovation (Dalton et al., 2020; Simonofski et al., 2019).

Source: USCM's literature and the use of his literature

For the interpretation of the USCM, smart architecture believes that SC are built with all parts of SC likes an umbrella shape. Smart governance is considered a governance capability that combines urban historical context, resource characteristics, facility layout, city sustainability and service innovation (Baron, 2012). Smart planning and management primarily refer to the published technology roadmap for smart urban development, focusing on SC technology evolution, and models the interconnectedness of services and equipment and technology (Lee et al., 2013). Smart data and knowledge mean that the analysis of new knowledge can be derived from the quantity in SC, such as the access to data sources and the point of interest collection. Smart facilities refer to the use of smart technology to transform into an energy system infrastructure. Smart services requires a vibrant business environment, a stable social environment, urban facilities that bond talent, job growth, a well-educated workforce and a flexible system. Smart people mainly refer to the attractiveness of talents from the city. Smart environment is more specifically the new model of eco-city life and the corresponding sociopolitical relationship.

SYSTEMATIC LITERATURE REVIEW METHODOLOGY

According to Page et al. (2021), a systematic literature review may guide the diagnosis of an accurate systematic review, scope reviews, limitations, context and quality of current research; and search for systematic integration of results (Harari et al., 2020; Siddaway et al., 2019). Some research on SC and UI has adopted the systematic review method, such as social inclusion indicators for building a citizen-centric SC (Malek et al., 2021), sustainability-oriented

innovation in SC (Tura & Ojanen, 2022). Therefore, the review needs to synthesise the existing literature with the conceptual framework (Figure 1). Three steps of the review are as follows:

Firstly, literature collection is limited to three databases, namely, Web of Science, Scopus and Google Scholar, which are the most authoritative, popular and comprehensive databases. The search was mainly restricted to the selected keywords 'smart cities', 'urban innovation' and 'citizen-centric', and alternative keywords. Secondly, a search of the Web of Science database obtained only 1 article by entering the search formula ALL= ('urban innovat*' and 'citizen-centric*'), and 62 articles were obtained by entering the search formula ALL= ('smart cit*' and 'citizen-centric*'). The search formula ALL= ('smart citi*' or 'urban innovat*' and 'citizen-centric*') was used to obtain 680 articles in the Scopus database. A total of 3,250 articles were obtained by entering the search formula smart cit* or urban innovat* and citizen-centric* into the Google Scholar database. In essence, the search formula smart cit* or urban innovat* and citizen-centric* can help obtain more relevant articles. The search period was from 2013 to 2021, and the collection time was in June 2021. This research uses the literature screening flowchart shown in Figure 2.

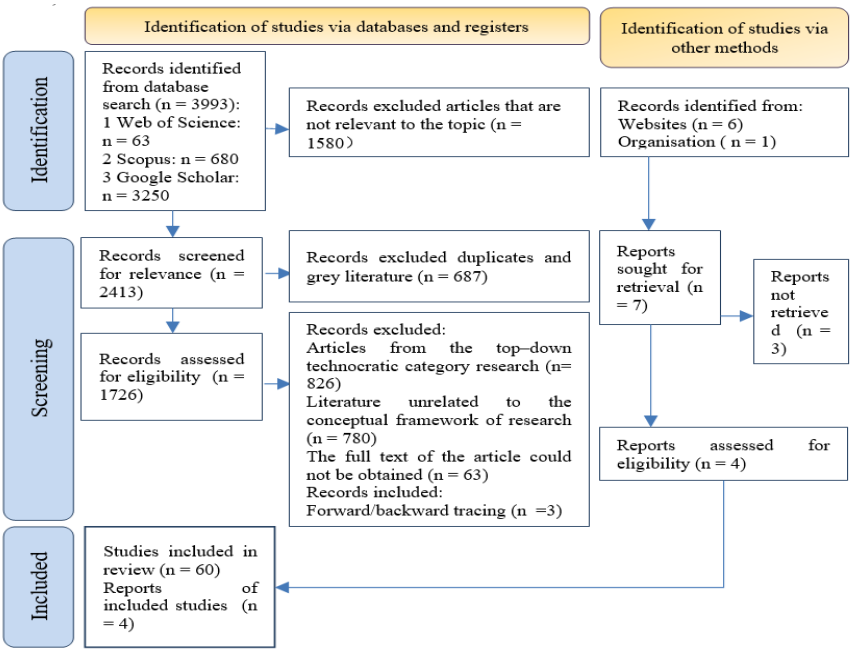

Figure 2. Document screening flowcharts
Source: The author draws according to the requirements of literature screening

Thirdly, the articles were screened to exclude duplicates, grey literature and literature that did not fit the conceptual framework. The review removed topics that are not closely related to the definition of UI, such as SC community governance and SC national mentality. The literature review mainly extracted the quantitative indicators from the selected literature. The other literature without quantitative indicators is summarised to have the same meaning basis of the conceptual framework. The review adds potential indicators' considering from the innovation organisation such as European Commission and Cornell University. A total of 64 data sources of information related to the study were derived.

RESULTS AND FINDINGS

Existing indicators of urban innovation

This research is based on the conceptual framework model constructed in this study, which is divided into the three-dimensional space environment of citizens' participation in SC, citizens' willingness to participate in SC, the participation digital layer and the communication decision layer. The three-dimensional space environment layer of citizens' participation in SC refers to the spatial and temporal and digital environment of citizens' participation in SC. Citizens' willingness to participate in SC mainly refers to their understanding of and role in the innovation of SC. The digital layer indicators have the characteristics with receiving and processing of information using IoT, such as apps, webpage and smart virtual community. The decision layer includes the level of government and macro-level measurement of SC innovation. Table 2 is a collection of 56 indicators and bibliography from the 64 collected studies.

Table 2: Fifty-six urban innovation indicators

Author	Indicator	Number
2.1 Three-dimensional space (physical, social, digital)		1
(Kim et al., 2021; Przeybilovicz et al., 2020)	Role and identity of residents participating in a smart city	
2.2 Citizens' willingness to participate layer		1
(Peng et al., 2017; Vakali et al., 2013)	Awareness	
2.3 Digital layer		7
(Reddick et al., 2020)	Virtual community platform	
(Grigg, 2020; Reddick et al., 2020)	Affordability	
(Khan et al., 2017; White et al., 2021)	Virtual feedback platform	
(Lee et al., 2013; Lytras & Visvizi, 2018; Yu et al., 2019)	Ability to use effectively	

(de Oliveira Neto & Kofuji, 2016; Panta et al., 2019; Prandi et al., 2017)	Accessibility	
(Parusheva & Hadzhikolev, 2020; Van Audenhove et al., 2007)	Electronic participation	
(Lee et al., 2013; Lytras & Visvizi, 2018; Simonofski et al., 2019; Yu et al., 2019)	Availability of basic and standard skills	
2.4 Decision-making level (Urban innovation indicators available at the government level)		4 7
(Commission, 2019)	Average carbon oxide (CO_2) emissions per km by new passenger cars in a given year	
(Cornell University, 2019)	Policymakers actively pay attention to the use of local wealth, crafts and skills to promote local, frugal and inclusive innovation	
(Liu, 2015)	Urban innovation activities and measures in smart cities	
(Karvonen et al., 2018)	Innovative talents (innovators) and the proportion of innovative talents in the population	
(Commission, 2019)	Corporate R&D intensity as a percentage of GDP	
(Achmad et al., 2018; Dewalska–Opitek, 2014)	Cultural base, earthly facilities for integrating talents and promoting employment growth and quality of life	
(Commission, 2019; Kwon et al., 2012)	Local financial investment in science and technology and the proportion of GDP	
(Cornell University, 2019)	Promote the shift of science and R&D expenditure to efforts to create and maintain a sound and dynamic innovation ecosystem	
(Khan et al., 2017; Sierpinski & Staniek, 2018)	Efficient for collecting community information	
(Nam & Pardo, 2011)	Convenience of ICT E-government affairs and residents' cognition	
(Commission, 2019)	Proportion of population aged 25–34 who have completed higher education	
(Commission, 2019)	Emission intensity of particular matter (PM2.5) from the manufacturing sector	
(Caragliu & Del Bo, 2019; Commission, 2019)	At the national level, employment in technologically advanced and knowledge-intensive sectors	
(Commission, 2019)	Total domestic R&D expenditure as a percentage of GDP	
(Sinaeepourfard et al., 2020)	Information and communications technology	
(Lu et al., 2015)	Local education investment and GDP proportion	
(Ricciardi & Za, 2015)	Published volume of papers	
(Yu et al., 2019)	Virtual network platform	
(Commission, 2019)	Number of Internet users per 10,000 people	

(Park et al., 2020; Yu et al., 2019)	Accessibility and convenience of information education
(Kwon et al., 2012)	A well-educated workforce and flexible system
(Commission, 2019)	Broadband Internet users per 100 inhabitants
(Mboup, 2017)	Prosperity of the urban business environment
(Ingrams, 2019)	Use of public data by residents
(Lombardi et al., 2012)	University rankings
(iCity, 2016)	Support the experience of citizens' space
(Grupp & Schubert, 2010); Li et al. (2015)	Annual number of patents granted per million residents
(Heitlinger et al., 2019)	Smart property rights
(Li et al., 2015)	Science and technology progress award at or above the provincial level
(Rodríguez-Pose et al., 2014)	R&D investment
(Anttiroiko, 2015; Komninos, 2009)	Internationalisation of inventions
(Wesseling et al., 2019)	Smart data and implementation of the platform
(Commission, 2019)	Number of elite science and technology human resources
(Lee et al., 2013)	Citizen -centric elements of the data roadmap
(Nugent & Suhail, 2021)	Stability of the urban social environment
(Gössling & Rutten, 2007; Matuzeviciute et al., 2017)	Researchers per million inhabitants
(Clohessy et al., 2014)	Online services
(Farmanbar & Rong, 2020)	Interactive use of smart cities
(Liu, 2015)	Indicator mobile app creation
(Caragliu & Del Bo, 2019)	Published volume of patent
(Cornell University, 2019)	Research input
(Picatoste et al., 2018)	Employment growth
(Commission, 2019)	Elite number
(Commission, 2019)	Global R&D company
(Karima & Peter, 2012)	Knowledge-intensive employment
(Caragliu & Del Bo, 2019; Richter et al., 2015)	Availability
(Caragliu & Del Bo, 2019)	High-tech situation
Total	5 6

Source: various sources

Table 2 shows that the indicators that measure the innovation capacity of cities from the macro or government level are relatively mature. The literature also shows that the indicators in terms of patents and technologies may be quantified according to the inhabitants as unit subjects. However, these indicators are relatively single, scattered and fragmented. Citizens' participation in the environment, citizens' understanding of SCs and citizens' awareness of the digital dimension are currently mainly qualitative indicators and underdeveloped. This study explains and illustrates the eight categories of the USCM model,

which can help the compilation of citizen-centric UI indicators and their integration with existing indicators.

Urban innovation indicators under the 8 USCM indicators

The above indicators are not listed in particular order (Table 2). Therefore, this study uses the eight categories of the USCM to sort the citizen-centric UI indicators. The resultant 56 UI indicators under the 8 USCM indicators are shown in Table 3.

Table 3: UI indicators under the 8 USCM indicators

Dimension	Category	Urban innovation indicator (56)
Smart architecture	Citizens' understanding of smart architecture	
sa2	Citizens' participation in smart cities	Are you involved in the architecture of smart cities? (role or identity)
		Is there a suitable virtual platform to provide the government with feedback on opinions on smart city architecture?
		Interactive use of smart cities
		Support the experience of citizens' space
sa3	Citizens' acquisition of technological innovation	Availability
		Accessibility
		Affordability
		Awareness
		Ability to use effectively
sa4	Citizens' acquisition of open innovation in cities	Start data and implementation of the platform
		Use of public data by residents
sa5	Citizens' acquisition of urban sustainable innovation	Is there a better and more efficient platform for collecting feedback from the residential community?
		At the national level, employment in technologically advanced and knowledge-intensive sectors
		Promote the shift of science and R&D expenditure to efforts to create and maintain a sound and dynamic innovation ecosystem
		High-tech situation
Smart governance	Citizens' understanding of smart governance	
sg1	Efficiency of public policy governance	Convenience of ICT E-government affairs and citizens' cognition
		Government online services
		Electronic participation
sg2	Local investment in education and technology	Local education investment and GDP proportion
		Local financial investment in science and technology and the proportion of GDP

Smart planning and management	Citizen-centric technology roadmap	
spm1	Technology roadmap for smart city development	Citizen-centric elements of the data roadmap
Smart data and knowledge	Citizens' understanding of smart data and knowledge	
sdk1	Data and knowledge innovation	Published volume of papers
		Researchers per million inhabitants
		Elite number
		Total domestic R&D expenditure as a percentage of GDP
		Research and Development (R&D) investment
		Annual number of patents granted per million residents
		Internationalisation of inventions
		Science and technology progress award at or above the provincial level
		Information and communications technology
		Corporate R&D intensity as a percentage of GDP
		Global R&D company
sdk2	Knowledge innovation	Smart property rights
		University rankings
		Published volume of papers
		Number of elite science and technology human resources
		Research input
		Proportion of the population aged 25–34 who have completed higher education
		Availability of basic and standard skills
Smart facilities	Citizens' understanding of smart facilities	
sf1	Smart facilities	Number of Internet users per 10,000 people
		Broadband Internet users per 100 inhabitants
		Virtual community platform
		Virtual network platform
		Indicator mobile app creation
Smart services		
ss1	Smart services	Prosperity of the urban business environment
		Stability of urban social environment
		Cultural base, earthly facilities for integrating talents and promoting employment growth, quality of life
		A well-educated workforce and flexible system
Smart people	Citizens' understanding of smart people	
sp1	Human capital	Employment growth
		Innovative talents (innovators) and the proportion of innovative talents in the population
sp2	Employment environment	Knowledge-intensive employment

Smart environment	Citizens' understanding of smart environment	
se1 Inclusiveness of urban innovation environment	Social inclusion	Policymakers actively pay attention to the use of local wealth, crafts and skills to promote local, frugal and inclusive innovation
	Information education	Accessibility and convenience of information education
	Innovation ability	Urban innovation activities and measures in smart cities
se2 The dynamic model of the eco-city system		Average carbon oxide (CO_2) emissions per km by new passenger cars in a given year
		Emission intensity of particular matter (PM2.5) from the manufacturing sector

Source: various sources indicators list based on USCM

DISCUSSION

This review focuses on the extraction of citizen-centric indicators involved at the level of the four segments of UI. Only a few articles focus on citizen-centric UI in SC, such as ones on removing barriers to innovation (Wolff et al., 2018). Limited articles are available on citizen-centric UI in terms of willingness, engagement, feedback and the multiple elements that influence SC as a whole to assess the elements. More articles delve into the independent component (Kim et al., 2021; Przeybilovicz et al., 2020; Simonofski et al., 2017). One possible explanation is that the evaluation of these combined dimensions makes the study complex and neglects integration in the analysis of citizen-centric UI in SC.

According to the review results, these diverse indicators can be comprehensively evaluated in urban areas by using representative indicators of many SCs in eight dimensions of the USCM model. Future studies can conduct empirical research by using the framework, which can help better identify the innovation capabilities of SC integrated with citizens or the macro achievements and the differences between citizens and SC innovation. The framework can also be used to help identify the innovation ability in various dimensions of SC, such as smart environment and smart people. The dimensions or single indicators in the framework can be used to assess the potential of the development of SC, and for single comparison of dimensions and indicators of different SC, such as those that aim to understand citizens' interaction link to SC through technological innovation at the citizen participation level, digital level and decision-making level.

CONCLUSION

With the recent surge in research on citizen-centric SC, the authors acknowledge the limitations of this literature review. The three selected databases may not be comprehensive, especially because of the possible interdisciplinarity involving

management and economics, among other issues. The method of searching the literature may have resulted in missing literature.. However, the preliminary results of a citizen-centric framework for assessing UI in SC are complete. It facilitate to cogitate UI development driection in smart cities and identify the factors that are conducive to effective communication of innovative ideas.

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