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FROM SMART CITY RHETORIC TO MEASUREMENT: VALIDATING CITIZEN-CENTRIC URBAN INNOVATION (CCUI) INDICATORS IN CHINA

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ABSTRACT

Smart city research has produced numerous evaluation frameworks, yet most remain technology-led and offer limited means to assess whether smart city strategies enable citizens as active innovation actors. Although "citizen-centricity" is frequently promoted in policy discourse, it is rarely operationalised into measurable indicators suitable for city-scale benchmarking and governance improvement. This study addresses this gap by developing and validating a Citizen-Centric Urban Innovation (CCUI) indicator framework for Chinese smart cities. Drawing on the Unified Smart City Model (USCM) and a structured literature synthesis, an initial indicator set was refined through a two-round expert judgement process using median-based discriminant evaluation. The study confirms a final CCUI framework comprising 58 validated indicators across eight dimensions: smart architecture, governance, planning and management, data and knowledge, facilities, services, people, and environment. The validation results highlight that CCUI measurement should prioritise city-scale enabling conditions—service accessibility, usable digital infrastructure, urban data systems, citizen digital capability, and institutional responsiveness—rather than macro-level innovation prestige proxies. The framework provides a practical tool for assessing and guiding more inclusive and innovation-capable smart city development in China and beyond.

Keywords: Smart Cities (SC), Citizen-centric urban innovation assessment, Expert judgement, Indicators, China.

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1. INTRODUCTION

Contemporary urban development necessitates innovative technologies and integrated solutions to foster livable, synergistic, and innovative cities (United Nations, 2023). Smart cities (SCs) have garnered global attention as an innovative approach, advancing urban safety, sustainability, transportation, energy, and social development (Jang & Gim, 2022; Tura & Ojanen, 2022). With this context, Urban Innovation (UI) is operationally defined as the development of novel and practical ideas, products, services, processes, or paradigms that improve urban quality of life, enhance municipal efficiency, and address complex urban challenges through the collaborative efforts of diverse stakeholders. As hubs for UI, SCs provide platforms for deep citizen-city interaction, facilitating resident engagement in development through ubiquitous technologies (Mueller et al., 2018; Zakzak, 2019).

In many countries pioneering SC development, the urban population is widely recognised as the essential driver where large-scale citizen involvement is crucial (Dowling et al., 2019; Lim, Malek, et al., 2021; Vidiasova et al., 2017), such as Malaysia and Singapore, recognize the urban population as an essential driver, emphasizing the role of "smart citizens" in shaping society and well-being (Lim, Abdul Malek, et al., 2021; Shamsuzzoha et al., 2021). Consequently, positioning citizens as a powerful engine underscores the critical importance of their participation in driving economic and infrastructural progress (Kumar et al., 2020; Zhang, 2016).

Theoretically, citizens are positioned at the core of SC development and are seamlessly integrated into various aspects of urban life through advanced technologies. However, the potential of citizen participation within SCs to catalyze UI has, to a significant extent, been neglected (Kim et al., 2021; Sameer et al., 2022). Crucially, realising this potential requires SCs to establish specific enabling conditions that cultivate civic capacity, thereby allowing for broad and active engagement in UI development. The current literature highlights such a disconnect in citizen participation, characterized by limited engagement, a diminished sense of agency, and technological dissonance (Myeong et al., 2021; Przeybilovicz et al., 2020; UNCTAD, 2021). To address this, SCs worldwide are transitioning from merely serving digital platforms for broad citizen participation toward facilitating a citizen-digital-government feedback loop, forming an interactive cycle that promotes continuous innovation (Kusumastuti & Rouli, 2021; Sengboon et al., 2018; White et al., 2021).

In China, despite the initiation of over 500 SC projects and the establishment of assessment standards like GB/T 33356-2016, existing evaluation frameworks frequently overlook the citizen-centric approach (IResearch, 2019; Shen et al., 2018). Specifically, current studies tend to neglect the role of civic engagement in SC assessment within the Chinese context, particularly in promoting UI. This critical deficit of citizen-centric operational indicators fails to capture resident subjectivity, thereby marginalising the citizens' role in unlocking UI potentials (Huang et al., 2021; Ruhlandt, 2018; White et al., 2021).

Motivated by this theoretical gap, this study poses this research question: What citizen-centric indicators do experts deem relevant for assessing UI within the SC context? Therefore, the study aims to determine the relevant Citizen-Centric Urban Innovation (CCUI) indicators for China by extracting, evaluating, and validating CCUI from the literature. The paper is organised as follows: the introduction, followed by a literature review of SC evaluation, and the Chinese experience. Subsequently, the methodology of expert judgment of relevant CCUI indicators for China is provided, followed by data analysis, the results, discussion, and conclusions in subsequent sections.

2. LITERATURE REVIEW

2.1 Smart City Evaluation Indicators

SCs' evaluation indicators are essential for evaluating the efficacy and performance outcomes of SC initiatives (Kubina et al., 2021; Liu et al., 2022; Purnomo & Prabowo, 2016). Existing evaluations of SCs can be divided into three distinct categories. The first category encompasses single perspectives, for instance, assessing government performance, technical infrastructure, maturity, and SC accomplishments (Ayyoob, 2020; Benites & Simoes, 2021; Liu et al., 2022). The second type focuses on multi-dimensions with comprehensive perspectives of SC (Purnomo & Prabowo, 2016), by using multiple-dimension models as a basis of evaluation, as shown in Table 1. The third category is dedicated to evaluating the synergistic development between citizens and SCs. Scholars investigating citizen participation in SC development have conducted an analytical framework focusing specifically on citizen participation within SCs (Ju et al., 2018; Simonofski et al., 2017; Xu & Zhu, 2020). Table 1 summarises the common SCs evaluation indicator sets.

Table 1: The International Comprehensive SC Evaluation Dimensions and Indicators

Indicators set	Number of indicators	Included dimensions								References
		Smart architecture	Smart governance	Smart planning and management	Smart data and knowledge	Smart facilities	Smart services	Smart people	Smart environment	
Smart city research										
Smart cities Ranking of European medium-sized cities	74	√	√			√	√	√	√	(Giffinger et al., 2007)
Smart Cities Wheel	62	√	√			√	√	√	√	(Cohen, 2015)
Smart Cities benchmark model (USCM)	52	√	√	√	√	√	√	√	√	(Anthopoulos et al., 2016)
Smart city assessment tools and indicators	98	√	√		√	√		√	√	(Sharifi, 2020)
International organization indicators										
IESE Cities in Motion Index 2019	106	√	√	√		√		√	√	(Berrone et al., 2019)
ISO 37122 model indicators for smart cities	90	√	√		√	√		√	√	(Organisation, 2018)
ITU International Telecommunications Union	37	√				√		√	√	(Union, 2014)

Source: Adapted from smart city journal papers and an international organization practice

2.2 Evaluation Indicators for CCUI in SCs

The consolidation and refinement of SC strategies have traditionally relied on the performance or outcomes of assessment indicators (Albino et al., 2015; Angelakoglou et al., 2020; Petrova-Antonova & Ilieva, 2018). Simonofski et al. (2019) extended their framework to include democratic participants, co-participants, and ICT user-participants. Singh and Singla (2021) propose a framework that centers on citizen participation and responsibility, incorporating dimensions like types, processes, roles, and

personalities of participation. However, these frameworks lack integration of interaction and feedback dimensions with the SCs, failing to theoretically articulate how smart governance acts as an institutional and technological enabler that transforms bottom-up citizen participation into continuous urban innovation.

2.3 Identifying the gap: Citizen-Centric Urban Innovation (CCUI) Framework

The above review of SC evaluation literature reflected how the assessment indicators are mainly oriented toward technological development or holistic SC integration, inherently reflecting a top-down paradigm of urban governance (Caragliu & Del Bo, 2019; Wang & Deng, 2022). Existing assessments of UI tend to be sector-specific or focused on particular facets, lacking a comprehensive citizen-centric approach within the broader SCs dimension (Li et al., 2015; Putra & van der Knaap, 2018). Thus, the CCUI framework proposed in this study contributes to the smart city literature by theoretically bridging the triad of citizen participation, urban innovation, and smart governance. The framework operationalizes a citizen-centered perspective into a structured evaluation system to assess how urban innovation capacity develops from the agency, participation, and innovation practices of citizens themselves, repositioning them as subjective innovators within a responsive smart governance ecosystem.

3. RESEARCH METHODOLOGY

To achieve the aim of this study, three research phases were undertaken as depicted in Figure 1.

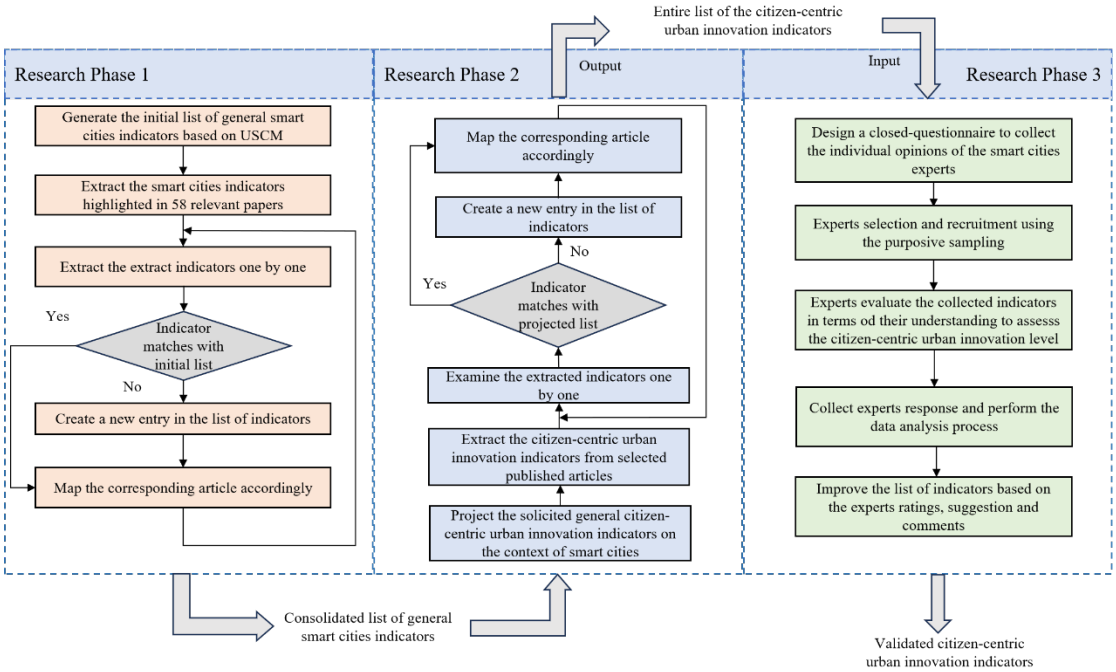

Figure 1: Methodology of the Study

3.1 Phase 1: Determining The List of General Smart City Indicators

The first phase aims to extract general SC evaluation indicators from the international standard sets and existing smart city research. Firstly, inclusion and exclusion criteria aligning with the research objectives were defined. From the list of models (Table 1) that includes the Unified Smart Citizen Model (USCM) by Anthopoulos et al. (2016) and the Smart Cities Wheel organizations (Cohen, 2015). This study adopts USCM as the basis framework, providing 8 dimensions to accommodate the SC indicators.

Additionally, published literature constitutes a significant source to solicit the indicators highlighted by other researchers and map them to the USCM dimensions. This phase adopted search keywords “smart cities indicators” OR “smart cities metrics” OR “smart cities KPI” OR “smart cities performance” OR “indicators for smart cit*” OR “smart cities criteria” using three databases, Web of Science, Scopus, and Google Scholar. These databases were selected for the most comprehensive coverage of academic resources.

The indicators within the eight USCM dimensions provide the baseline framework for Phase 1 CCUI. This initial indicator list is used to add more smart city assessment indicators discovered in selected research articles. A structured preliminary framework is established to summarise the categories and subcategories identified within each SC dimension, along with the number of indicators representing each and the 58 references used for their extraction.

3.2 Phase 2: Selecting Smart City Indicators Related to The CCUI

The output of Phase 1 serves as the foundational input for Phase 2 of the research, which aims to examine the most suitable indicators to assess CCUI, as presented in Phase 2 of Figure 1. In Phase 2, the literature review was conducted using the same three databases as Phase 1. The first search was mainly restricted to the selected keywords ‘smart cities’, ‘urban innovation’, and ‘citizen-centric’, and alternative keywords were also employed, resulting in a total of 680 articles. Following the previous research strategy, smart cities indicators were derived and explored, distinct new entries were integrated into the list, and references were mapped accordingly. The next search strategy employed the keywords “cities-centric or cities-cen*” “urban innovation” and（“smart cities” or “smart citi*” and（“indicator*” or “framework” or “index”. The retrieved articles were then systematically screened to exclude duplicates and grey literature, and studies not aligned with the study’s objectives. Furthermore, the review strictly excluded literature unrelated to the operational definition of UI. This research on the CCUI considers citizen participation broadly active across SC eight dimensions, which collectively provide enabling conditions for active citizen involvement in the UI, as described in Table 2.

Table 2: Definitions of Citizen Participation Capacity in Smart Cities and The Enabling Conditions Provided by Smart Cities for Broad and Active Citizen Engagement in Urban Innovation Development

Type of citizen- centric urban innovation	Author’s definition
Citizen participation ability in smart cities broadly and actively	Citizen participation ability in smart cities broadly and actively include that citizen will participation actively and have active participation ability to give city’s daily life information or support active development suggestion as a city owner to drive the urban innovation in smart cities
Smart cities provide the conditions for citizen participation broadly and actively	Smart cities provide the condition for citizens participation broadly and actively include smart cities supply smart cities dimension as a condition for citizen participating and getting feedback the smart cities to attain the urban innovation development ability.

After applying all inclusion and exclusion criteria, 61 relevant data sources were retained. From this curated literature, a preliminary set of 57 CCUI indicators was extracted for further expert validation.

3.3 Phase 3: Conducting expert judgement for relevant CCUI

Expert judgment can be operationalized through various methods, such as qualitative content

analysis, analytic hierarchy process of qualitative content transforming to quantitative（AHP）(Awad & Jung, 2022), Delphi method (Mitchell et al., 2022; Saputri et al., 2021), and Content Validation Index (Hair et al., 2019). Whilst qualitative verification methods are frequently criticized as too subjective, quantitative expert verification methods have developed robustly (Falotico & Quatto, 2015; Luque-Vara et al., 2020; Wynd et al., 2003). Quantitative expert judgment methods are generally perceived as more objective, which is supported by this study. Therefore, Phase 3 employed a direct and effective quantitative research design based on descriptive statistics. A questionnaire was utilized to determine the relevance level of the indicators for the proposed CCUI framework beginning with the Phase 2 result.

3.3.1 Participants

Experts were selected based on their extensive work experience in SC industries while assessing SCs' relevant projects or standards. Given their professional knowledge backgrounds, it was anticipated that these experts would provide highly valuable insights (Awad & Jung, 2022; Fleary, 2022; Mitchell et al., 2022). Accordingly, purposive sampling was employed, and ten smart city experts with over five years of experience were recruited to complete the questionnaires (Creswell & Poth, 2018; Merriam & Tisdell, 2016). While a sample size of ten experts may appear limited for general survey research, methodological literature on expert judgment panels suggests that a homogenous group of 10 to 15 highly specialized experts is optimal for achieving robust consensus without causing data redundancy (Ahmed, 2025). Content judgment includes an adequacy sample to test possible data based on the expected measurement. To ensure data integrity, online questionnaires were administered individually to each expert.

This study chooses Guiyang in China for research as the case city. As one of the earliest and most advanced national pilot cities for big data and smart governance, this research leverages Guiyang's unique position as the vanguard of China's SC trajectory (Su et al., 2022). Guiyang SC is one of the earliest SCs launched in China in 2012 (Group, 2016). In the past ten years, Guiyang SC has achieved significant achievements in policy-making, facilities construction, standard setting, and digital expos (Ansheng, 2016). Notably, while the panel consists of ten local experts who came from Chinese smart governance (see Table 3), their insights capture the most cutting-edge of SC developments. Therefore, the framework validated by this panel serves as a rigorous foundational model, providing a critical baseline that requires subsequent cross-regional validation in future studies.

Table 3: The Ten Smart Cities Experts' Basic Information

Interviewee	Current position in the organization	Research area/expertise	Years of work Experience	Years of Experience with the smart cities industry
A1	Director of Big Data Bureau	Big Data management, smart cities information, citizen participation smart cities	15	7
A2	Director of Development and Reform Commission	Citizen digital information government affair, smart cities	14	6
A3	Director of Government Affairs Service Center	Smart government affairs service	14	8
A4	Director of City Administration Bureau	Smart urban management administrative center	13	6
B1	Manager of City Investment Group, Smart Industry Investment Co., LTD	Smart industry investment	14	8
B2	Manager of Smart City Technology Co., LTD	Smart City technology	13	7
C1	Director of Urban and Rural Planning Bureau	Smart city information and government	14	8

C2	Senior planner	Smart city development	13	7
D1	Associate Professor	Smart cities, citizen participation smart cities	15	8
D2	Professor	Smart cities, smart information, urban planning	14	8

3.3.2 Procedure and Data Analysis

In Phase 3, the ten SC experts were invited to participate in two rounds of evaluation of the relevant indicators derived from the CCUI indicators framework established in Phase 2, as described in Figure 2.

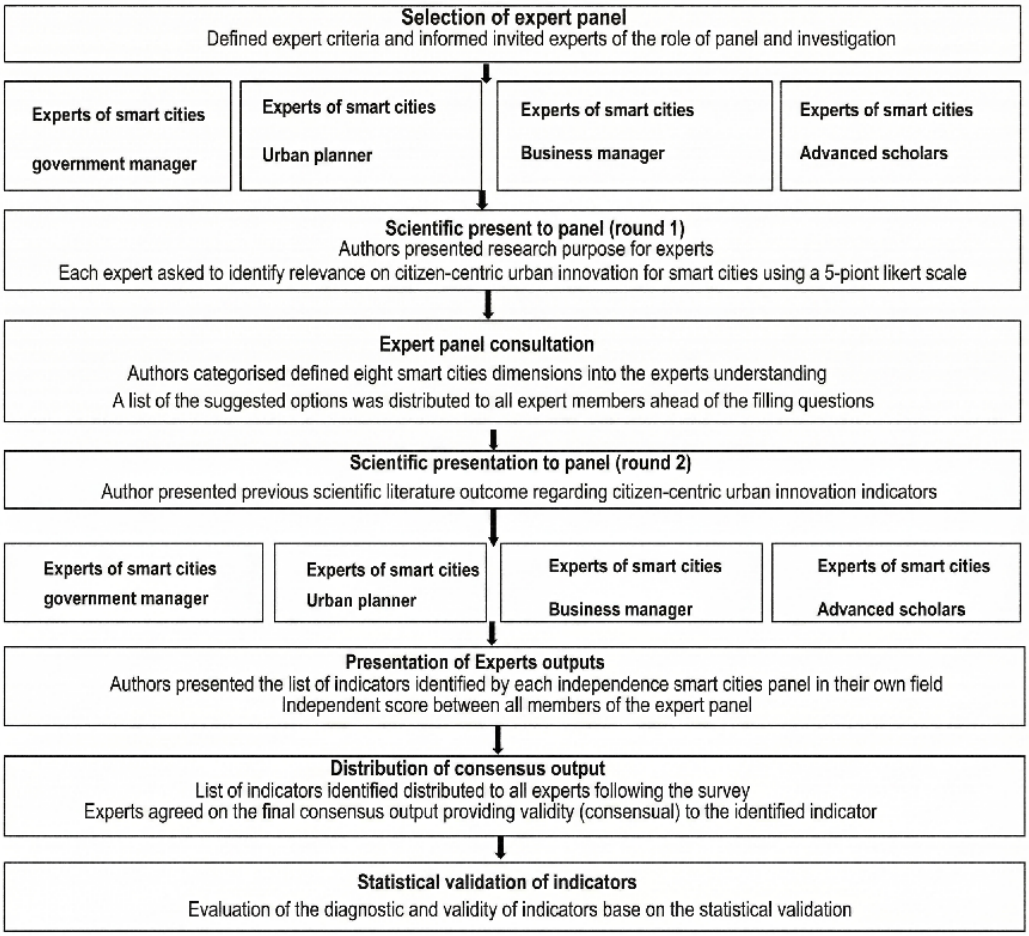

Figure 2: The Process of Expert Judgment From Phythian et al. (2011)

The questionnaire, titled "Assessment for the Relevance of Citizen-Centric Urban Innovation Indicator in Smart Cities," was distributed to all experts. The questionnaire was designed based on CCUI indicators of Phase 2 results that comprised a final instrument consisting of 57 items across eight SC dimensions. The questionnaire instrument was tested using a 5-point Likert scale of 1-5 responses of one-way to measure the relevance degree of CCUI indicators feasibility or applicability of each item, as illustrated in Fig.3. Each CCUI item was assessed following the " Template for assessing indicators through expert judgement" developed by Escobar-Pérez and Cuervo-Martínez (2008), which establishes an ordinal scale with four possible responses (Table 4). The five possible responses used include a rating scale of 1 = very not relevant, 2 = not relevant, 3 = neutral, 4 = relevant, and 5 = very relevant (Wynd et al., 2003). Considering the following item: "The participation of citizens in SCs," here are some possibilities for presentation format:

Item	Indicators (Smart architecture)	Relevant				
		1	2	3	4	5
1	Citizens actively participate in the smart city through Smart City Platform					
2	Smart City virtual platform provides a good basis for resident engagement					

Figure3: The Relevant Judgment Survey

Table 4: Categories and Indicators Used by The Judge to Validate the Tool

Categories	Indicators
Relevance The item is essential or important, i.e., it must be included	The item is somewhat relevant, but another item may be covering what this item is measuring
	The item is rather important
	The item is very relevant and should be included

(Source : Escobar-Pérez and Cuervo-Martínez , 2008)

Expert judges were provided with comprehensive information regarding the test's purpose, its intended applications, and the procedures for score verification. The online survey was conducted over six weeks, from April 15 to May 30, 2023. All 10 distributed questionnaires were completed and returned. To preserve anonymity and minimize potential bias, expert responses in both rounds were strictly anonymized.

3.3.3 Statistical Analysis

Expert judgments can be analysed using various qualitative and quantitative methods, such as the Analytic Hierarchy Process (AHP) (Awad & Jung, 2022), Delphi (Schifano & Niederberger, 2025) , or the Content Validity Index (CVI), and so on. But AHP can cause severe cognitive overload for experts when conducting pairwise comparisons across 58 indicators (Frish et al., 2025). Delphi's subjective nature risks forced consensus and lacks empirical reproducibility in complex validations (Schifano & Niederberger, 2025). Furthermore, CVI often relies on simple proportional agreement, which inadvertently masks the granular distribution of expert feedback. Consequently, this study adopts the median value as a more scientifically robust quantitative criterion. Unlike the aforementioned methods, the median is highly resistant to extreme outliers, effectively capturing the dataset's true central tendency without necessitating forced subjective compromise (Beliakov et al., 2010; Sedney, 1981; Shahzad et al., 2021). The analysis method sets the median as a standard benchmark for qualification (Sedney, 1981), with indicators scoring above their respective dimensional median classified as qualified Fredrick (1977). This adheres strictly to Sedney (1981) the recommendations for median segmentation. Specifically, the 'group median' of each respective dimension serves as a dynamic threshold. An indicator is deleted if its individual median score falls strictly below this group median. The statistical rationale for this rigorous decision-making process is to ensure that only indicators performing at or above the average relevance level of their specific category are retained, thereby filtering out marginal metrics and maximizing content validity. Furthermore, the two-round iterative process inherently tests for reliability and consensus. Indicators lacking expert consensus were eliminated in the first round, culminating in stable consensus and robust validity in the second round. To facilitate decision-making, the results are highlighted using the color code described in Table 5.

Table 5: Color Code Used for Data Analysis

Color	Interpretation
	Keep the indicator as is
	Delete the indicator
	Including a new indicator based on experts' suggestion

4. FINDINGS

4.1 The Overall Judgment Result of The CCUI Indicators

Ten SC experts (100%) completed the first round, and all (100 %) completed the second round. The measurements of relevance for CCUI Indicators, based on the findings of the survey questionnaire after statistical analysis, are presented in Table 6- 13. The first round resulted in 59 indicators being confirmed, with 7 original indicators deleted and 9 new indicators added.

In this first round, the median of each group was greater than or equal to the value of the total median of the eight dimensions 4 as the threshold value, and it was recommended to retain the eight smart city dimensions. The overall median of eight smart city dimensions is 4. The median of the 8 dimensions estimated medians across all judges is greater than or equal to 4. In this second round of expert judgment, there are a total of 58 indicators left, including 1 indicator deleted from the 59 confirmed in the first round. After the second round of expert evaluation and median discrimination, only indicator SM_4 was deleted, resulting in the final adjusted indicators for the CCUI framework.

4.2 Results from The Judgement of Smart City Architecture Indicators

Smart cities architecture indicators have undergone two rounds of the experts' judgement and show the results in Table 6.

Table 6: The judgment result of relevant indicators for smart cities architecture

Preliminary CCUI for LR according to USCM dimensions			**CCUI after expert judgement (Median value)**					
			The first-round decision on the indicators post expert validation			**The second-round decision on the indicators post expert validation**		
			Group Median	**Median**	**Decision**	**Group Median**	**Median**	**Decision**
Smart Cities Architecture								
Status of citizen' participation in the Smart City Platform								
SCA_1	(Kim et al., 2021) (Przybilovicz et al., 2020)	Residents actively participate in the smart city through the Smart City platform	4	5	Keep as is	4	5	Keep as is
SCA_2	(Reddick et al., 2020) (Wolff et al., 2018)	Smart City virtual platform provides a good basis for resident engagement	4	5	Keep as is	4	5	Keep as is
SCA_3	(Farmanbar & Rong, 2020) (Myeong et al., 2021)	Interactive use of smart cities	4	4	Keep as is	4	4	Keep as is
SCA_4	(iCity, 2016)	Support the experience of citizens' space	4	4	Keep as is	4	4	Keep as is
Citizen engagement in the effectiveness of smart city platforms								
SCA_5	(de Oliveira Neto & Kofuji, 2016; Panta et al., 2019; Prandi et al., 2017)	Smart City uses platforms and applications for city information to support residents to	4	5	Keep as is	4	5	Keep as is

	(Tura & Ojanen, 2022) (W. L. Zhang et al., 2022) (Totty et al., 2022)	provide more input and information for city development						
SCA_6	(de Oliveira Neto & Kofuji, 2016; Panta et al., 2019; Prandi et al., 2017)	Accessibility Access to information on the multifaceted development of smart cities on smart city usage platforms and applications	4	4	Keep as is	4	4	Keep as is
SCA_7	(Grigg, 2020; Reddick et al., 2020)	Affordability New technologies for smart cities that can be afforded by citizens' incomes	4	4	Keep as is	4	4	Keep as is
SCA_8	(Peng et al., 2017; Vakali et al., 2013)	Awareness Residents have the idea and awareness to actively participate in the development of smart cities.	4	4	Keep as is	4	5	Keep as is
SCA_9	(Lee et al., 2013; Lytras & Visvizi, 2018; Yu et al., 2019)	Ability to use effectively Efficient use of smart city platforms and applications or other new technologies.	4	5	Keep as is	4	4	Keep as is
Ease of access to smart city public data for residents								
SCA_{10}	(Wesseling et al., 2019)	Start data and implementation of the platform Ease of access to information resources for citizens implementing data engagement platforms	4	4	Keep as is	4	5	Keep as is
SCA_{11}	(Ingrams, 2019)	Use of public data by residents	4	5	Keep as is	4	5	Keep as is
Citizens' understanding of smart city goals								
SCA_{12}	(Myeong et al., 2021)	Clear vision and goals for public awareness	4	4	Keep as is	4	4	Keep as is
SCA_{13}	(Andrea Caragliu & Chiara F. Del Bo, 2019; Commission, 2019)	At the national level, employment in technologically advanced and knowledge-intensive sectors	4	3.5	Delete as its median is lower than the smart governance group			

					median value (1)			
SCA_{14}	(Cornell University, 2019)	Promote the shift of science and R&D expenditure to efforts to create and maintain a sound and dynamic innovation ecosystem	4	4	Keep as is	4	4.5	Keep as is
SMC_{15}	(Andrea Caragliu & Chiara F. Del Bo, 2019)	High-tech situation	4	4	Keep as is	4	4.5	Keep as is
SCA_{16}		Construction of Feedback System for citizens' Life in Smart City			new add indicator from experts (1)	4	4	Keep as is

The two-round expert evaluation of the Smart Cities Architecture dimension (Table 6) reveals that effective smart cities architecture must prioritize direct citizen utility over macro-level metrics. Analytically, the deletion of macro-economic indicators like SCA_{13} suggests that experts view such data as too disconnected from citizens' daily experiences. Instead, the panel strongly favored indicators focused on lowering daily entry barriers—specifically affordability (SCA_7), accessibility (SCA_6), and practical platform usability (SCA_9). Furthermore, the experts' spontaneous addition of SCA_{16}, which emphasizes citizen feedback systems, highlights a critical theoretical shift: smart city architectures must evolve beyond top-down information broadcasting to become closed-loop, reciprocal communication channels essential for continuous Citizen-Centric Urban Innovation (CCUI).

4.3 Results from The Judgement of Smart Governance Indicators

Smart governance indicators have been with two rounds of the experts' judgement, and the results are shown in Table 7.

Table 7: The judgement result of relevant indicators for smart governance

Preliminary CCUI for LR according to USCM dimensions			**CCUI after expert judgement (Median value)**					
			The first-round decision on the indicators post expert validation			**The second-round decision on the indicators post expert validation**		
			Group Median	**Median**	**Decision**	**Group Median**	**Median**	**Decision**
Smart Governance								
Smart governance, such as public participation in decision-making, policy and regulation, and the digitization of cities, can enhance citizen-centric innovation								
SG_1	(Nam & Pardo, 2011)	The convenience of ICT E-government affairs and citizens' cognition	4.5	5	Keep as is	4.5	4.5	Keep as is
SG_2	(Aina, 2017) (Clohessy et al., 2014)	Government online services quality (The quality of government online services can meet your service needs)	4.5	4	Keep as is	4.5	5	Keep as is

SG_3	(Parusheva & Hadzhikolev, 2020; Van Audenhove et al., 2007)	Willingness to participate in electronic information matters	4.5	4	Delete as its median is lower than the smart governance group median value (2)			
SG_4		By providing a wealth of AIoT devices, it can comprehensively perceive the dynamic information of people, vehicles, objects, and electricity in urban scenes, and provide human-computer interaction devices for specific business scenarios to create a small closed-loop scenario application that serves people			New add indicator from experts (2)	4.5	4	Delete as its median is lower than the smart governance group median value (1)

The expert evaluation of the Smart Governance dimension (Table 7) highlights a decisive theoretical preference for practical service delivery over subjective intent or heavy technological infrastructure. Analytically, the strong retention of SG_1 (ICT convenience) and SG_2 (service quality) demonstrates that effective governance relies fundamentally on meeting citizens' immediate, pragmatic needs. The deletion of SG_3 (willingness to participate) suggests experts view subjective psychological attitudes as distinct from actionable governance mechanisms. Most significantly, while the panel initially explored adding SG_4—a highly complex indicator focused on AIoT sensor networks and massive data collection—its ultimate deletion in the second round is highly revealing. It indicates a clear consensus that to maintain a Citizen-Centric Urban Innovation (CCUI) focus, smart governance must avoid becoming overly techno-centric; the practical quality of digital public services remains far more critical than the mere deployment of advanced surveillance hardware.

4.4 Results from The Judgement of Smart Planning and Management

Smart planning and management indicators have undergone two rounds of the expert's judgement, and the results are shown in Table 8.

Table 8: The judgement result of relevant indicators for smart planning and management

Preliminary CCUI for LR according to USCM dimensions			**CCUI after expert judgement (Median value)**					
			The first-round decision on the indicators post expert validation			**The second-round decision on the indicators post expert validation**		
			Group Median	**Median**	**Decision**	**Group Median**	**Median**	**Decision**
Smart Planning and Management								
SPM_1	(Lee et al., 2013)	Citizen-centric elements of the data roadmap	4	5	Keep as is	4	5	Keep as is

SPM_2	(Kuru & Ansell, 2020)	Harnessing the local knowledge, experience, and collaboration of citizens can help local officials understand the state of urban infrastructure and utilities through smart technology platforms	4	5	Keep as is	4	5	Keep as is

The unanimous endorsement of the Smart Planning and Management indicators with perfect median scores of 5 reflects a profound expert consensus on the core mechanisms of CCUI. Analytically, the strong retention of SPM_1 (citizen-centric data roadmaps) alongside SPM_2 (harnessing local knowledge) illustrates a critical synthesis of top-down data governance and bottom-up human experience. The panel clearly recognizes that technical planning tools are only as effective as the localized, experiential data provided by residents. By emphasizing citizen collaboration to understand the state of urban infrastructure, these results confirm a paradigm shift in smart planning: citizens are no longer passive subjects of urban management, but active co-creators of spatial intelligence, echoing the collaborative frameworks highlighted by Hosseini and Tayebi (2025).

4.5 Results from The Judgement of Smart Data and Knowledge

The smart data and knowledge indicators have undergone two rounds of expert judgement, and the results are shown in Table 9.

Table 9: The judgement result of relevant indicators for smart data and knowledge

Preliminary CCUI for LR according to USCM dimensions			**CCUI after expert judgement (Median value)**					
			The first-round decision on the indicators post expert validation			**The second-round decision on the indicators post expert validation**		
			Group Median	**Median**	**Decision**	**Group Median**	**Median**	**Decision**
Smart Data And Knowledge								
The ability of residents to participate in data and knowledge innovation								
SDK_1	(Lee et al., 2013; Lytras & Visvizi, 2018; Simonofski, Asensio, De Smedt, et al., 2019; Yu et al., 2019)	Availability of basic and standard skills	4	4.5	Keep as is	4	4.5	Keep as is
SDK_2	(Suciu et al., 2020)	Smart cities should encourage citizens to contribute data to public and private platforms	4	4.5	Keep as is	4	5	Keep as is
SDK_3	(Malek et al., 2021) (W. L. Zhang et al., 2022)	Citizens contributed data, consciously or subtly, as human sensors. Citizens could also volunteer to contribute time and help intrinsically	4	4.5	Keep as is	4	4.5	Keep as is

SDK_4	(W. Zhang et al., 2022)	Citizen-initiated access, availability, and use of open data	4	4.5	Keep as is	4	4.5	Keep as is
SDK_5	(Sameer et al., 2022)	Residents can also access city details such as parking spaces through the city's data visualization app	4	4.5	Keep as is	4	5	Keep as is
SDK_6	(Ricciardi & Za, 2015)	Published volume of smart data papers	4	5	Keep as is	4	4	Keep as is
SDK_7	(Gössling & Rutten, 2007; Matuzeviciute et al., 2017)	Researchers per million inhabitants	4	4	Keep as is	4	4	Keep as is
SDK_8	(Commission, 2019)	Total domestic R&D expenditure as a percentage of GDP	4	4	Keep as is	4	4	Keep as is
SDK_9	(Rodríguez-Pose et al., 2014)	Research and Development (R&D) investment	4	4	Keep as is	4	4	Keep as is
SDK_{10}	(Andrea Caragliu & C. F. Del Bo, 2019)	The annual number of patents granted per million residents	4	4	Keep as is	4	4	Keep as is
SDK_{11}	(Anttiroiko, 2015; Komninos, 2009)	Internationalisation of inventions	4	4	Keep as is	4	4	Keep as is
SDK_{12}	(Sinaeepourfard et al., 2020)	Information and communications technology	4	4	Keep as is	4	4	Keep as is
SDK_{13}	(Commission, 2019)	Corporate R&D intensity as a percentage of GDP	4	4	Keep as is	4	4.5	Keep as is
SDK_{14}	(Commission, 2019)	Global R&D company	4	4.5	Delete as its median is lower than the smart governance group median value (3)			
Knowledge innovation								
SDK_{15}	(Heitlinger et al., 2019)	Smart property rights	4	4	Keep as is	4	4	Keep as is
SDK_{16}	(Lombardi et al., 2012)	University rankings	4	3.5	Delete as its median is lower than the smart governance group median value (4)			

SDK_{17}	(Ricciardi & Za, 2015)	Published volume of papers	4	3.5	Delete as its median is lower than the smart governance group median value (5)			
SDK_{18}	(Commission, 2019; Kwon et al., 2012)	Local financial investment in science and technology and the proportion of GDP	4	4.5	Keep as is	4	4.5	Keep as is
SDK_{19}	(Commission, 2019)	The proportion of the population aged 25–34 who have completed higher education	4	4.5	Keep as is	4	4.5	Keep as is
SDK_{20}	(Lu et al., 2015)	Local education investment and GDP proportion	4	5	Keep as is	4	5	Keep as is
SDK_{21}		Construction and use of urban smart database			new add indicator from experts' suggestion (3)	4	4	Keep as is
SDK_{22}		Citizens' ability to use and use new generation information technology			new add indicator from experts' suggestion (4)	4	4.5	Keep as is

The expert evaluation of the Smart Data and Knowledge dimension reveals a fundamental redefinition of "knowledge'' within a citizen-centric framework. The deliberate deletion of traditional, macro-institutional metrics—such as SDK_{14} (global R&D companies), SDK_{16} (university rankings), and SDK_{17} (published volume of academic papers)—is highly significant. This targeted removal of conventional indicators demonstrates a clear expert consensus rejecting elitist or purely academic proxies for urban innovation. Instead, the evaluation favors democratized, actionable data engagement. The strong retention of indicators focusing on basic data skills (SDK_1), citizen-contributed data (SDK_2, SDK_3), and local educational investment (SDK_{20}), alongside the spontaneous addition of SDK_{21} and SDK_{22} (emphasizing the practical use of smart databases and next-generation technologies), highlights a critical theoretical shift. In the CCUI paradigm, smart city knowledge is not about accumulating elite institutional credentials, but about equipping everyday residents with the digital literacy and open-source tools necessary for active urban participation.

4.6 Results from The Judgement of Smart Facilities

The smart facilities indicators have undergone two rounds of expert judgment. The first round involved initial assessments, with the second further validating and refining findings. This dual review ensured their reliability. The final results from these evaluations are clearly presented in Table 10.

Table 10: The judgement result of relevant indicators for smart facilities

Preliminary CCUI for LR according to USCM dimensions			**CCUI after expert judgement (Median value)**					
			The first-round decision on the indicators post expert validation			**The second-round decision on the indicators post expert validation**		
			Group Median	**Median**	**Decision**	**Group Median**	**Median**	**Decision**
Smart Facilities								
Smart facilities for citizens								
SF_1	(Commission, 2019)	Number of Internet users per 10,000 people	4	4	Keep as is	4	4	Keep as is
SF_2	(Commission, 2019)	Broadband Internet users per 100 inhabitants	4	4.5	Keep as is	4	4	Keep as is
SF_3	(Reddick et al., 2020)	Virtual community platform	4	4.5	Keep as is	4	4.5	Keep as is
SF_4	(Yu et al., 2019)	Virtual network platform	4	4	Keep as is	4	4	Keep as is
SF_5	(Liu, 2015)	Mobile app	4	4	Keep as is	4	4	Keep as is
SF_6		The popularization and reasonable distribution of smart cameras and sensors in smart cities			new add indicator from experts' suggestion（5）	4	4	Keep as is

The expert evaluation of the Smart Facilities dimension stands out because no preliminary indicators were deleted, reflecting a strong consensus on the irreducible baseline of smart urban infrastructure. The unanimous retention of SF_1 through SF_5—metrics focusing on internet penetration, broadband access, and mobile platforms—reinforces that universal digital connectivity is the non-negotiable foundation for Citizen-Centric Urban Innovation (CCUI). Most intriguingly, while the expert panel previously rejected heavy sensor networks in the governance dimension (SG_4) for being overly techno-centric, they actively added and retained SF_6 (popularization and reasonable distribution of smart cameras and sensor) here. This highlights a critical theoretical nuance: experts reject sensors as mere top-down surveillance tools, but mandate them as essential physical infrastructure—provided their deployment ensures spatial equity and bridges the digital divide, aligning with the foundational accessibility concepts discussed by Das (2024).

4.7 Results from The Judgement of Smart Service

The smart service indicators have undergone two rounds of expert judgment. The first round included initial assessments of each indicator's rationality, while the second further verified and optimized the findings. This dual review helped ensure the indicators' reliability. The final results from these expert evaluations are clearly presented in Table 11.

Table 11: The judgement result of relevant indicators for smart service

Preliminary CCUI for LR according to USCM dimensions			**CCUI after expert judgement (Median value)**					
			The first-round decision on the indicators post expert validation			**The second-round decision on the indicators post expert validation**		
			Group Median	**Median**	**Decision**	**Group Median**	**Median**	**Decision**
Smart Service								
A good environment of smart services								
SE_1	(Mboup, 2017)	The prosperity of the urban business environments	5	4.5	Delete as its median is lower than the smart governance group median value (6)			
SE_2	(Nugent & Suhail, 2021)	Stability of urban social environment	5	5	Keep as is	5	5	Keep as is
SE_3	(Achmad et al., 2018; Dewalska–Opitek, 2014)	Cultural base, earthly facilities for integrating talents and promoting employment growth, quality of life	5	5	Keep as is	5	5	Keep as is
SE_4	(Kwon et al., 2012)	A well-educated workforce and a flexible system	5	5	Keep as is	5	5	Keep as is
SE_5		Planning, layout, utilization rate and convenience of intelligent services in urban residents' life and production			new add indicator from experts (6)	5	5	Keep as is

The expert evaluation of the Smart Service dimension reveals a definitive theoretical pivot from capital-centric metrics to social sustainability and lived experience. Analytically, the deliberate removal of SE_1 (prosperity of the urban business environment) is highly revealing; this decision suggests that experts no longer view macro-economic prosperity as an adequate proxy for citizen-centric services. Instead, the unanimous retention of SE_2, SE_3, and SE_4 with perfect median scores—indicators firmly rooted in social stability, cultural integration, and human capital—demonstrates that true smart services must be built upon a robust socio-cultural foundation. Furthermore, the expert-driven addition of SE_5 is pivotal. By explicitly emphasizing the "utilization rate and convenience" of intelligent services in daily life, this new indicator operationalizes the theoretical shift. It demands that smart city services be measured not by their economic rhetoric, but by their tangible, practical integration into residents' everyday routines, perfectly encapsulating the ethos of Citizen-Centric Urban Innovation (CCUI).

4.8 Results from The Judgement of Smart People

Smart people indicators have been with two rounds of the expert's judgement and show the result in Table 12.

Table 12: The judgement result of relevant indicators for smart people

Preliminary CCUI for LR according to USCM dimensions			**CCUI after expert judgement (Median value)**					
			The first-round decision on the indicators post expert validation			**The second-round decision on the indicators post expert validation**		
			Group Median	**Median**	**Decision**	**Group Median**	**Median**	**Decision**
Smart People								
Human capital								
SP_1	(Picatoste et al., 2018)	Employment growth	4	4	Keep as is	4	4	Keep as is
SP_2	(Karvonen et al., 2018)	Innovative talents (innovators) and the proportion of innovative talents in the population	4	5	Keep as is	4	5	Keep as is
Employment environment								
SP_3	(Kourtit & Nijkamp, 2012)	Knowledge-intensive employment	4	4	Keep as is	4	4	Keep as is
SP_4		Distribution Law and Coverage Rate of Smart People among Urban Residents			new add indicator from experts（7）	4	4	Keep as is

The expert evaluation of the Smart People dimension highlights a crucial theoretical evolution: shifting the focus from aggregate human capital accumulation to the equitable distribution of innovative capacity. Analytically, the strong retention of conventional metrics like SP_1 (employment growth) and SP_3 (knowledge-intensive employment), alongside the perfect median score for SP_2 (innovative talents), confirms that a baseline of specialized human capital remains essential. However, the most significant theoretical contribution arises from the expert-driven addition of SP_4 (Distribution Law and Coverage Rate of Smart People among Urban Residents). By introducing this specific metric, the panel implicitly critiques traditional elitist approaches that merely count the absolute number of tech professionals. Instead, SP_4 forces the evaluation to consider spatial and demographic equity—questioning whether the capabilities and benefits of "smart people" are broadly accessible to the general urban population. This addition perfectly aligns with the Citizen-Centric Urban Innovation (CCUI) framework, demanding that urban human capital development permeates the entire demographic landscape rather than remaining concentrated in isolated knowledge hubs.

4.9 Results from The Judgement of the Smart Environment

The indicators for the smart environment underwent two rounds of expert validation, with the results summarized in Table 13.

Table 13: The Judgement Result of Relevant Indicators for The Smart Environment

Preliminary CCUI for LR according to USCM dimensions			**CCUI after expert judgement (Median value)**					
			The first-round decision on the indicators post expert validation			**The second-round decision on the indicators post expert validation**		
			Group Median	**Median**	**Decision**	**Group Median**	**Median**	**Decision**
Smart environment								
Inclusiveness of urban innovation environment								
SE_1	(Cornell University,	Policymakers actively pay attention to the	4	4	Keep as is	4	5	Keep as is

	2019)	use of local wealth, crafts, and skills to promote local, frugal, and inclusive innovation						
SE_2	(Park et al., 2020; Yu et al., 2019) (Wirtz et al., 2020)	Accessibility and convenience of information education	4	5	Keep as is	4	5	Keep as is
SE_3	(Liu, 2015)	Urban innovation activities and measures in smart cities	4	5	Keep as is	4	5	Keep as is
The dynamic model of the eco-city system								
SE_4	(Commission, 2019)	Average carbon oxide (CO2) emissions per km by new passenger cars in a given year	4	3	Delete as its median is lower than the smart governance group median value (7)			
SE_5	(Commission, 2019)	The emission intensity of particular matter (PM2.5) from the manufacturing sector	4	4	Keep as is	4	4	Keep as is
SE_6		Monitoring and treatment of environmental indicators such as urban sewage discharge, and intelligent construction of human settlements			new add indicator from experts （8）	4	4	Keep as is
SE_7		Security of network environment in smart city			new add indicator from experts (9)	4	4	Keep as is

The expert evaluation of the Smart Environment dimension challenges the traditional, purely ecological definition of urban environments, expanding it into a holistic socio-digital-physical continuum. Analytically, the deletion of SE_4 (average CO_2 emissions from new cars) indicates that the panel views narrow, consumer-level carbon metrics as too disconnected from the systemic, daily well-being of residents. In contrast, the retention of SE_5 (PM2.5 emissions) alongside the expert-initiated addition of SE_6 (sewage monitoring and human settlements) demonstrates a clear preference for metrics that capture the tangible, lived environmental realities and foundational public health infrastructure. Furthermore, the unanimous support and perfect median scores for SE_1, SE_2, and SE_3—metrics prioritizing local crafts, inclusive innovation, and educational accessibility—coupled with the addition of SE_7 (network security), underscore a profound theoretical shift. Within the CCUI framework, a "smart environment" transcends green ecology; it requires an inclusive cultural milieu, a secure digital space, and an actively managed, health-oriented physical habitat.

4.10 Synthesis and Comparative Insights of the CCUI Framework

To further elucidate the analytical contribution of the CCUI framework, it is essential to compare our validated 58-indicator set with established international practices and previous assessment frameworks. Traditional international standards, such as the ISO 37122 model and ITU benchmarks, predominantly feature technology-led indicators that prioritize IoT sensor density, broadband coverage, and algorithmic efficiency (Organisation, 2018; Union, 2014). In contrast, the CCUI framework fundamentally shifts the evaluative lens from technological provision to human capability and institutional responsiveness. For instance, while traditional frameworks measure the mere existence of digital platforms, our validated CCUI indicators specifically emphasize citizen ability to use new-generation information technology (SDK_{22}) and the Construction of Feedback System for citizens' life (SCA_{16}).

Furthermore, when compared to other similar citizen-centric models like the Smart Cities Wheel or the Citi Voice framework —which often conceptualize citizen participation primarily through the lens of bottom-up democratic co-creation—the Chinese CCUI framework reflects a distinct socio-technical ecosystem. The expert validation results demonstrate a strong reliance on state-led digital enablers, such as the 'Construction and use of urban smart database'(SDK_{21}). This comparison underscores that, within the Chinese context, assessing citizen-centric urban innovation cannot rely solely on measuring spontaneous grassroots engagement. Instead, this approach requires evaluating the concrete enabling conditions: demonstrating how accessible digital infrastructures and smart governance systems effectively pull citizens into a structured, responsive innovation loop (Almulhim & Yigitcanlar, 2025).

5. DISCUSSION AND IMPLICATIONS

Citizen-centricity is among the most ubiquitously invoked tenets of smart city discourse, yet it concurrently remains one of the least empirically operationalized constructs. While dominant international frameworks-such as the IESE Cities in Motion Index and ISO 37122-proffer robust, multi-dimensional benchmarks, they systematically privilege technological readiness, infrastructural expansion, and operational efficiency (Berrone et al., 2019; Organisation, 2018). These international framework approaches inadvertently relegate urban residents to passive consumers of top-down services (Kougias and Papadakaki (2025). As part of a broader research trajectory, this study bridges this critical lacuna by synthesizing and validating a comprehensive framework of CCUI indicators tailored to the institutional landscape of Chinese smart cities. Grounded in the USCM advanced by Anthopoulos et al. (2016) and refined through rigorous expert elicitation, the proposed framework validates 58 discrete CCUI indicators mapped across eight core dimensions: smart architecture, governance, planning and management, data and knowledge, facilities, services, people, and environment.

5.1 Theoretical and Societal Implications

The epistemological value of the proposed 58-indicator framework lies in operationalizing the abstract concept of "citizen-centric innovation" into measurable metrics, rather than merely adding another scorecard to the literature. Theoretically, this study challenges prevailing technological determinism by conceptualizing smart cities as complex socio-technical configurations where urban governance and citizen agency intersect. Furthermore, this study reinterprets "citizen-centricity," demonstrating that participatory citizenship is primarily a structural outcome of institutional design rather than merely an intrinsic individual trait. In practice, citizens engage when socio-technical systems lower entry barriers and institutions proactively absorb grassroots inputs (Kim, 2024; Lindkvist et al., 2020). Societally, this structural pivot profoundly impacts digital equity and urban inclusivity. Expert consensus on "smart data and knowledge" indicators emphasizes that true empowerment necessitates accessible digital literacy and transparent data repositories (Cortés-Cediel et al., 2019; Storme & Meers,

2020). Consequently, smart city strategies must actively dismantle entrenched digital divides, ensuring marginalized populations are active participants in, rather than casualties of, the urban innovation feedback loop.

5.2 Practical and Policy Implications

The CCUI framework offers an actionable, diagnostic instrument for municipal authorities, urban planners, and smart city administrators seeking to transcend technocentric developmental models. Rather than relying exclusively on macro-economic or technological proxies, municipal governments can directly integrate these 58 validated indicators into their localized Key Performance Indicators (KPIs) (Alsaid & Ambilichu, 2024). For instance, the framework embedded within the "smart planning and management" dimension can be utilized to mandate co-creation and participatory deliberation phases before the deployment of new digital public services. Moreover, city administrators can operationalize this framework as an empirical baseline for annual "Citizen-Centric Readiness" audits. This auditing mechanism enables strategic budgetary allocations to shift from speculative hardware upgrades to targeted interventions that measurably enhance citizen digital capabilities and service accessibility, thereby transforming residents from passive service beneficiaries into co-producers of urban innovation.

5.3 Limitations and the "Top-Down" Paradox

Despite providing a theoretically robust approach to evaluating CCUI, this study has several notable limitations. Methodologically, empirical validation relies on a relatively encapsulated expert panel and is localized to Guiyang City, China, potentially restricting cross-contextual generalizability. Additionally, while relying on median comparisons is sufficient for preliminary indicator screening, future research should enhance the framework's reliability by incorporating supplementary analytical techniques—such as inter-rater reliability, the interquartile range (IQR), or Kendall's W coefficient—to statistically validate expert consensus (de Noray et al., 2025).

More fundamentally, the expert panel was primarily comprised of government officials, urban planners, and executives, inherently codifying a top-down administrative perspective. This creates a conceptual paradox: the final 58 indicators reflect what institutional elites perceive as citizens' priorities, which may not seamlessly align with the actual bottom-up, lived experiences of the citizenry. Consequently, the current CCUI framework should be rigorously interpreted as an evaluation of a city's "institutional readiness" and systemic capacity to facilitate citizen-centricity, rather than a direct measure of grassroots civic demand in this research stage.

5.4 Future Research Directions

Navigating the aforementioned boundaries delineates several critical pathways for prospective scholarship. Future longitudinal research must empirically test and calibrate this framework by deploying large-scale, representative citizen-based quantitative surveys, thereby cross-referencing top-down expert axioms with bottom-up public perceptions. Additionally, comparative multi-city applications—spanning disparate urban tiers within China and diverse regulatory regimes internationally—are imperative to statistically establish the framework's cross-cultural reliability and structural validity. Ultimately, deeply investigating the conceptual friction between top-down institutional affordances and bottom-up citizen life worlds will be paramount to refining a truly reflexive, inclusive, and democratized paradigm for smart city evaluation.

6. CONCLUSION

Existing smart city (SC) frameworks frequently lack a citizen-centric perspective that aligns local contexts with international experiences of citizen participation. Unlike traditional technology-based international standards, the proposed Citizen-Centric Urban Innovation (CCUI) methodology provides practical, measurable evidence to guide national SC development based on actual citizen needs. While this framework adopts a top-down institutional perspective on enabling citizen engagement, it avoids duplicating technocentric models by focusing specifically on institutional readiness. Our results indicate that 'smart architecture' and 'smart data and knowledge' are the most relevant dimensions in the Chinese context, with indicators like citizen participation and feedback showing particularly high relevance.

Despite acceptable test results, this study has limitations. Because certain core aspects during the expert judgment process were beyond researchers' control, we recommend regular reviews of the tool's content validity. Ultimately, this framework establishes a critical baseline for future research to survey actual residents' perceptions, systematically bridging this top-down institutional framework with bottom-up civic validation. Future studies should integrate specific SC development contexts, analyze indicator variations across different cities, and guide policy improvements in weaker areas such as comprehensive urban innovation and participatory development.

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