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A PRISMA-based Thematic Analysis of Smart City Maturity Models: Mapping Key Dimensions and Maturity Levels

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Abstract−In the era of rapid urbanization and the increasing demand for sustainable urban development, smart cities have emerged as a critical focus for enhancing the quality of urban life. However, existing smart city maturity models lack standardization, making it challenging for cities to evaluate their progress comprehensively. This study addresses these challenges by identifying and analyzing the key dimensions and maturity levels across 11 smart city maturity models. Using a systematic literature review guided by the PRISMA approach and thematic analysis, this research uncovered significant insights. Eight key dimensions were identified, with the smart environment dimension appearing in 10 models, highlighting its centrality in addressing environmental and sustainability issues. Smart governance and smart society were also frequently highlighted, emphasizing their critical roles in fostering effective urban management and promoting social inclusion in smart city development. Additionally, 8 models employed a five-level maturity structure, demonstrating its widespread acceptance for balancing detail and simplicity in assessing a city's growth. These findings provide cities with a structured framework to evaluate and enhance their smart city strategies while facilitating comparisons among existing models. The results emphasize the need for a standardized yet flexible approach to smart city maturity, enabling cities to navigate their unique challenges effectively and achieve sustainable growth.

Keywords: Smart City; Maturity Model; Key Dimensions; Maturity Levels; Thematic Analysis

1. INTRODUCTION

Smart cities represent a revolutionary approach to urban development, integrating advanced technologies and sustainable practices to address complex urban challenges such as rapid urbanization, resource management, and environmental sustainability [1], [2]. This concept goes beyond adopting technology, focusing on improving the quality of life for residents, fostering economic growth [3], and building resilience against global challenges like climate change and demographic pressures [4]. With increasing populations and the growing need for more efficient services, cities worldwide strive to become smarter and more sustainable [5]. However, the success of this transformation requires systematic evaluation to ensure that implemented initiatives effectively address specific urban needs and achieve desired outcomes [6]. A structured evaluation framework is necessary to measure progress, providing systematic guidance in assessing and benchmarking a city's advancement [5], [7]. One widely used approach is the maturity model. This model enables cities to evaluate their position in their journey toward becoming smart cities while identifying areas for improvement [5]. However, existing maturity models exhibit significant focus, dimensions, and applicability variation. This challenges standardization and practical implementation, hindering efforts to compare progress between cities effectively.

Smart city maturity models are essential for assessing smart city initiatives' effectiveness across various urban contexts [8]. These models act as diagnostic tools to identify weaknesses and areas for improvement in city strategies [5]. While numerous models have been developed, each has limitations in scope and applicability. For example, Warnecke et al. [9] introduced a web-based benchmarking tool that allows European cities to self-assess and track their progress. However, this tool focuses solely on the domain of smart mobility. Similarly, Santana et al. [10] proposed the Sustainability Maturity Model (SMM), which leverages ISO 37122 sustainability indicators but struggles to adapt to local contexts. Other models, such as Bernal and Espitaleta's framework [11], emphasize information technology (IT) for cities in developing countries but neglect critical aspects such as society and the environment. Aljowder et al. [12] developed a more holistic model encompassing seven domains: economy, environment, and governance. However, its complexity poses challenges for smaller cities with limited resources. Conversely, Anschütz et al. [13] designed a simplified model for small and medium-sized cities, but its relevance diminishes for larger urban centers. This fragmentation reflects a lack of standardization, complicating efforts to benchmark and compare maturity levels among cities.

Most of these models encompass various dimensions, such as governance, society, environment, infrastructure, and economy, with specific maturity levels that cities must achieve to be considered prosperous smart cities [5]. Despite their strategic value, inconsistencies in terminology and descriptions across models hinder practical application and benchmarking efforts. Cities often struggle to compare maturity levels when definitions and categories vary significantly accurately. This inconsistency underscores the need for a more structured approach to developing a comprehensive and integrated understanding of smart city maturity. Previous literature reviews, such as those by Aljowder et al. [14] and Mohsin et al. [15], reveal significant gaps in the comprehensiveness and consistency of existing models. Aljowder et al. [14] argue that many maturity models

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primarily focus on technological or IoT aspects, neglecting critical dimensions such as governance and the environment. Meanwhile, Mohsin et al. [15] point out that many models lack clear guidance on transitioning between maturity stages. These gaps highlight the importance of research in identifying key dimensions and maturity stages, offering a more structured and adaptable framework for various urban contexts.

This study addresses these gaps by conducting a systematic literature review using the PRISMA methodology [16]. The primary objectives of this research are (1) to classify the most commonly used dimensions in smart city maturity models to identify key elements frequently applied in studies and (2) to categorize smart city maturity stages by examining similarities across models. By employing a thematic analysis approach, this study seeks to identify key patterns emerging across various models and map essential dimensions and maturity stages consistently used in the literature. With a clearer understanding of key dimensions and maturity stages, cities can more accurately assess their progress and identify areas for improvement. By identifying recurring patterns and common themes across models, this research aims to develop a comprehensive framework that cities can use to evaluate progress and plan future growth. This approach will support more effective decision-making, ensuring cities adopt the right technologies and create sustainable, inclusive urban environments.

To achieve these objectives, the following research question is posed: How can the key dimensions and maturity stages in smart city maturity models be mapped through thematic analysis? This question will guide the research, helping to categorize dimensions, identify common themes, and uncover patterns across the reviewed models. The findings of this study are expected to contribute significantly to understanding the key factors that define smart city maturity and guiding future smart city initiatives.

2. RESEARCH METHODOLOGY

This study requires a methodology explaining the research process while providing insight into the assessment criteria for systematizing the literature review. The systematization process of this literature review follows the PRISMA guidelines, which guide to ensure transparency and clarity in the process of selecting and analyzing relevant literature [16]. Figure 2 illustrates the stages implemented to ensure the selected articles are relevant and substantially contribute to achieving the research objectives. A protocol has been established to guide the process, outlining the key components, including information sources, search strategies, selection criteria, data extraction, and analysis. The search strategies are designed to identify relevant keywords, databases, and search strings, ensuring comprehensive topic coverage. The selection criteria set explicit inclusion and exclusion parameters to filter out irrelevant or low-quality studies. Data extraction is conducted systematically to gather essential information from the selected studies. Finally, the analysis synthesizes the extracted data to generate meaningful insights aligned with the research objectives. A detailed explanation of each stage is as follows:

Figure 1. Research Stages

2.1 Data Collection

The first stage aims to identify literature relevant to the research topic, namely the smart city maturity model. A systematic literature search was conducted on reputable academic databases, such as Scopus, IEEE Xplore, Google Scholar, and Web of Science, to ensure a broad and high-quality coverage of articles. This process uses specially designed keywords, such as: “Smart City,” “Maturity Model,” “Assessment Model,” and “Evaluation Model” to refine the search results. These keywords are combined using Boolean operators such as AND and OR to produce relevant and focused search results. For example, one of the queries used is: (“Smart City”) AND (Maturity Model* OR Assessment Model* OR Evaluation Model*) AND (LIMIT-TO (LANGUAGE, “English”)). This search was limited to articles published between 2018 and 2024 to ensure relevance to the latest developments in the smart city field. Only English-language articles that have undergone a peer-reviewed process are considered to ensure the accuracy and credibility of the data produced.

2.2 Literature Screening

After the identification of the study is done, the next stage is literature screening. In this stage, the articles found are screened based on the inclusion and exclusion criteria to ensure that only relevant and quality articles are considered in further analysis. Screening is done by checking the suitability of articles with specific pre-determined criteria to ensure that the remaining articles contribute substantially to the research focus. Table 1 summarizes the inclusion and exclusion criteria used in literature screening:

Table 1. Criteria selection

Inclusion	Exclusion
Publication during the period of 2019 to 2024	Publications not written in English

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Inclusion	Exclusion
Titles, abstracts, or keywords include search terms Publications are written in english The publication goes through the peer-review process.	Publications not subjected to the peer-review process

Articles not meeting the inclusion criteria, such as those written in English or irrelevant to smart cities and maturity models, will be excluded from the analysis. This strict screening focuses the analysis only on genuinely relevant and helpful literature for this research.

2.3 Eligibility Evaluation

After screening, the next stage is the feasibility evaluation. At this stage, articles that pass the screening are examined in more depth to evaluate whether the article follows the research objectives and the topic's relevance. The feasibility evaluation assesses how much the article can provide helpful information for research on smart city maturity models. Each article is examined based on the following criteria:

a. Key Dimensions: Relevant articles should address key dimensions in the smart city maturity model, such as technology, environment, society, and economy. The maturity model discussed in the article should describe the development and stages of maturity in a structured manner.
b. Level Structure: Relevant articles should explicitly mention the levels of smart city maturity and explain the characteristics of each level and how the levels relate to each other. The article should provide a clear picture of the progress of smart city maturity from one level to the next.

This eligibility evaluation aims to ensure that the articles under consideration truly focus on relevant topics and contribute meaningfully to building a deeper understanding of smart city maturity models.

2.4 Data Extraction

The next stage is data extraction, where relevant data from articles that have passed the eligibility evaluation are extracted for further analysis. The data extraction process is carried out using a standard template prepared to maintain the consistency and integrity of the data collected. This template helps ensure the extracted data includes essential information needed for further analysis. The extracted data includes:

a. Key Dimensions: The smart city maturity model uses dimensions such as governance, environment, society, economy, etc.
b. Maturity Levels: The maturity levels discussed in each article, including a detailed description of the characteristics and features of each maturity level.

The data extraction process was carried out manually to ensure the accuracy and relevance of the data obtained. This also helps ensure that all information extracted follows the research objectives and that no information is missed.

2.5 Analysis and Synthesis

The final stage in this research is analyzing and synthesizing the extracted data. This process involves a thematic analysis approach, which aims to identify the main themes that emerge from the collected literature data. This study employs thematic analysis to identify and categorize key themes and patterns emerging across the selected smart city maturity models. Thematic analysis is a qualitative method commonly used to analyze patterns within data [17]. In the context of this research, thematic analysis facilitates the identification of recurring themes across various smart city maturity models, such as standard dimensions, stages of maturity, and critical factors contributing to smart city success.

The thematic analysis process begins with familiarizing the researcher with the collected data, which involves reading and reviewing the selected literature to ensure a deep understanding of the findings from each study. Next, the data is coded, where relevant themes and sub-themes are identified and categorized. This coding process allows the grouping of related ideas that address the research questions. After coding is completed, the researcher analyzes these themes to identify patterns that can be generalized across models, providing a better understanding of how smart city maturity is defined and assessed. This analysis and synthesis will formulate a more structured smart city maturity model that can be applied across studies and contexts. This synthesis process also allows researchers to identify gaps in the existing literature and provide insights for further research in this area.

3. RESULT AND DISCUSSION

3.1 Results of The Literature Review

The systematic literature review begins with identifying and collecting relevant literature, which is then processed using the PRISMA method to ensure transparency and completeness in document selection. A total of 38 documents related to the development of smart city maturity models were found through searches in various

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academic databases. The first stage of PRISMA, namely identification, involves searching for relevant literature using keywords related to "smart city maturity models," resulting in many articles from various leading journals. The second stage, screening, involves evaluating abstracts to ensure the topic's relevance and methodology used in each study. Articles that do not meet the inclusion criteria, such as those that do not focus on smart city dimensions or do not have a maturity level assessment, are eliminated. The eligibility stage is completed by reading the remaining full text, ensuring the models described adequately meet the research objectives. After going through the screening and eligibility process, 11 smart city maturity models were finally included in this systematic review, providing a strong basis for further analysis in this study.

The PRISMA flowchart in Figure 2 visualizes these selection steps, from the initial number of articles found to the final number of models considered. It shows the screening process and the decisions taken at each stage to ensure that the selected literature is relevant and of high quality.

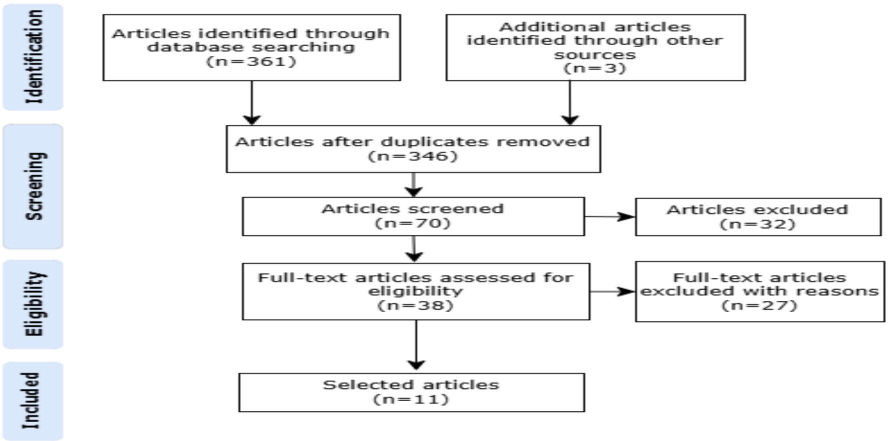

Figure 2. PRISMA Flow Diagram

After the literature selection, an analysis was conducted to identify the general characteristics of the 11 selected smart city maturity models. Each model offers a different framework, although there are similarities in the main focus on dimensions and maturity levels. The main characteristics of the identified models include the number of dimensions measured, the leading indicators used to assess each dimension, and the maturity levels applied. Table 2 presents a summary of each maturity model considered in this review. The table includes information on the number of dimensions evaluated, the main components used to measure each dimension, and the number of maturity levels implemented in each model. The models vary in complexity, with some using five maturity levels to describe the development of a smart city from early to optimal stages. Others may adopt three to seven levels to provide more detail. The table provides a clear overview of the framework of each model and allows for direct comparison between different models based on the components and maturity levels used.

Table 2. Smart city maturity models

Maturity Model	Component	Reference
The Smart City Maturity Assessment and Benchmarking (SCMAB)	6 Themes, 36 Indicators, 5 Levels	[9]
The Sustainability Maturity Model (SMM)	6 Dimensions, 9 Sub-dimensions, 45 Indicators, 5 Levels	[10]
Framework IT Maturity Model for Smart City Services In Emerging Economies (FSCE2)	4 Dimensions, 20 Indicators, 3 Levels	[11]
Smart City Maturity Model (SCMM)	7 Focus Ares, 5 Levels	[12]
Small and Medium-Sized Cities (SMCs)	6 Domains, 5 Levels	[13]
The Smart Cities Maturity Model (MMSC)	6 Smart Axes, 19 Dimensions, 5 Levels	[18]
CSR Maturity Model	3 Dimensions, 5 Levels	[19]
Bandung Smart City Assessment Model	6 Dimension, 17 Sub-Clusters, 5 Levels	[20]
Smart City Maturity Assessment Model for South African	11 Key Elements, 5 Levels	[21]
CityDNA Dynamics	4 Dimensions, No Level Specified	[22]
inteli.gente Platform	4 Dimensions, 7 Levels	[23]

3.1.1 Smart City Key Dimension

Based on thematic analysis, the dimensions from various smart city maturity models were identified by recognizing the main dimensions that frequently appear in the literature. According to Table 3, the results show that eight dimension groups are most often adopted in various models. Although some models use different terms, this

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clustering simplifies and integrates the existing dimensions, providing a uniform focus among the models despite variations in terminology. The smart environment dimension is the most frequently mentioned across 10 models, highlighting the critical role of addressing environmental challenges in smart city development. Key issues within this dimension include climate change, waste management, energy efficiency, air quality, pollution control, and water and sanitation systems [9], [10], [12], [13], [18], [19], [20], [21], [22], [23]. Similarly, the smart society dimension, featured in 9 models, underscores the importance of fostering education, addressing population and social conditions, promoting recreation, sports, and cultural activities, and ensuring community safety as foundational elements of smart city maturity [9], [10], [12], [13], [18], [20], [21], [22], [23]. The smart governance dimension in the eight models emphasizes the significance of good governance practices, strategic policy planning, efficient public services, visionary leadership, and strong partnerships in creating practical and attractive smart cities [9], [10], [11], [12], [13], [18], [20], [21].

Meanwhile, the smart economy dimension, covered in 7 models, reflects the importance of building a robust and sustainable economic foundation. This includes financial transactions, entrepreneurship, and enhancing public welfare [10], [12], [13], [18], [20], [22], [23], all pillars of a thriving smart city. The smart technology dimension is present in 5 models, emphasizing the role of intelligent connectivity, ICT infrastructure, digital transformation, data management, and intermodal integration in driving urban innovation and transformation [9], [11], [12], [19], [21]. Although technology is integral to smart cities, its mention in fewer models compared to other dimensions indicates that it is viewed as an enabler rather than a standalone pillar. Smart mobility and smart living, each included in 4 models, focus on enhancing urban efficiency and quality of life. Smart mobility encompasses efficient transportation systems, parking management, and overall infrastructure [9], [10], [13], [18]. Smart living, on the other hand, prioritizes high-quality housing, health services, and citizen well-being [10], [13], [18], [20]. These dimensions reflect the intertwined relationship between physical infrastructure and societal welfare, although they are less emphasized in the analyzed models.

Finally, the smart branding dimension is found in only two models, indicating that while city branding is not a primary focus in most frameworks, it remains essential for enhancing a city's global image and attractiveness. Key aspects of smart branding include tourism development, regional business ecosystem integration, and aesthetic city styling [20], [23]. Table 3 presents the key dimensions frequently appearing in the various smart city maturity models analyzed. Each category describes a critical aspect that needs to be considered in smart city development, and each category includes several in-depth elements or sub-dimensions that shape the overall smart city development. These results suggest that despite variations in terminology and focus, most smart city maturity models encompass similar key dimensions, reflecting a shared understanding of the critical elements needed for smart city development.

Table 3. Smart city key dimension

Category	Key Dimension
Smart Environment	Environment and Climate Change, Waste Management, Energy, Air Quality and Pollution Control, Water and Sanitation
Smart Society	Education, Population and Social Conditions, Recreation, Sport and Culture, Community Safety
Smart Governance	Governance, Policy and Strategic Planning, Public Services, Leadership, Partnership
Smart Economy	Economy, Financial Transactions, Entrepreneurship, Public Welfare Ecosystem, Labor Market and Industrial Ecosystem
Smart Technology	Intelligent Connectivity, ICT Infrastructure, Digital Transformation, Data Management, Intermodal Integration
Smart Mobility	Mobility, Transport, Parking
Smart Living	Living, Housing, Health
Smart Branding	Characterization, Tourism, Regional Business Ecosystem Platform, City Face Styling

3.1.2 Smart City Maturity Level

Grouping the maturity levels across various smart city maturity models shows a strong preference among model developers for a five-level structure. Eight models adopt five maturity levels [9], [10], [12], [13], [18], [19], [20], [21], making it a widely accepted standard for defining and evaluating smart city development. This five-level structure strikes an ideal balance, offering enough detail while maintaining simplicity. It allows cities to assess their progress across different smart city dimensions, from initiation to optimization, providing a clear progression while avoiding excessive complexity. In contrast, one model employs a three-level maturity structure [11], offering a simplified approach focusing on key developmental stages. While this model provides clarity and ease of use, it may not capture the complexities of the smart city development process, lacking the granularity needed to reflect nuances in growth. Another model adopts a seven-level maturity structure [23], which provides more detail but is less commonly used due to its complexity. The additional levels may pose challenges for implementation,

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particularly for smaller cities with limited resources, and can make practical application more difficult due to the intricacies involved.

The classification of maturity levels across these models demonstrates a consistent understanding of the smart city development process, which generally progresses from initiation to optimization. However, variations exist in the terminology and descriptions used to define each stage, reflecting the diversity in how models conceptualize the developmental journey of smart cities. For instance, the model with three maturity levels begins its assessment at level 3 [11], typically representing a phase where basic structures or initiatives are established. Still, integration and optimization have not yet been achieved. Meanwhile, the model initially structured with seven maturity levels has been streamlined into a five-level framework [23], where each stage's definition has been integrated and adjusted to align with this more generalized scale. This adjustment highlights an effort to balance complexity and usability, ensuring detailed evaluation without compromising the clarity and practicality of the assessment process.

This variation in the number of maturity levels across models underscores the flexibility required in assessing smart city development. While a five-level structure remains the most common and practical choice, each city may find different models more suitable depending on its specific context, resources, and developmental goals. For example, smaller cities may prefer simpler models with fewer levels, allowing them to track essential progress without getting bogged down by complexity [13]. Conversely, larger cities with more sophisticated infrastructure and resources might lean toward models with more levels, enabling a more granular analysis of their smart city initiatives. The key challenge is ensuring that the chosen model accurately reflects the city's unique circumstances while offering a meaningful growth framework. Moreover, the differences in how models describe and categorize the stages of smart city development suggest no one-size-fits-all approach exists. While some models focus heavily on technological integration, others may emphasize citizen engagement, sustainability, or economic factors as primary drivers of progress.

This diversity in focus points to the multifaceted nature of smart city development, where multiple factors, such as governance, social equity, and environmental impact, must be considered in tandem [24]. As such, it is crucial for city planners and stakeholders to carefully evaluate which model aligns best with their overarching vision and priorities, ultimately guiding them toward a successful and sustainable smart city transformation [8]. Figure 2 provides a comprehensive visual representation of the key dimensions and maturity levels in smart city development, illustrating the interconnectedness among these dimensions. This mapping highlights the collective importance of these elements, demonstrating how their integration is key to driving the sustainable progress of smart cities. Each dimension contributes individually and complements one another in shaping a city's overall maturity and advancement.

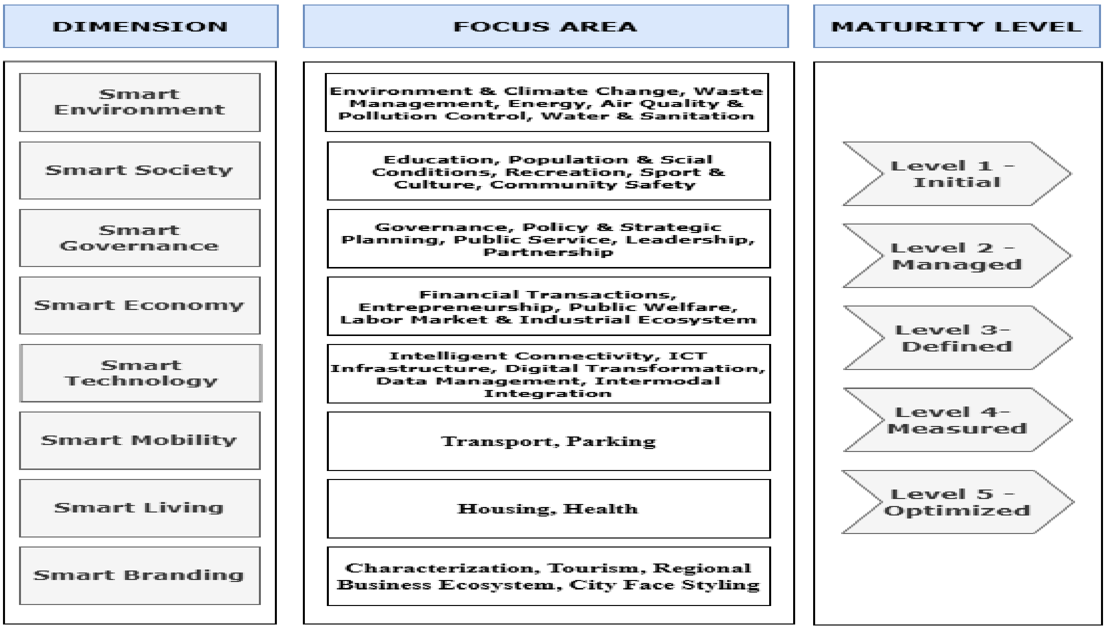

Figure 3. Smart City Maturity Model Mapping

The smart city maturity model can be categorized into distinct maturity levels, each reflecting a city's journey toward being fully optimized and sustainable. As defined by various models, these levels outline the evolution from foundational efforts to advanced, integrated operations. Based on thematic analysis, the description of each level can be summarized as follows:

a. Level 1-Initial: The eight models adopt a similar definition for level 1, which generally describes the initial or initiation stage in the smart city journey. At this stage, cities typically formulate their vision, strategies, and initial plans for becoming smart cities, often focusing on essential planning and strategy development.

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b. Level 2-Managed: 9 models share the definition of level 2. This definition generally focuses on the stage where smart city initiatives are starting to be implemented but are still in their early stages and not yet fully integrated. At this stage, cities may have begun using essential technologies and infrastructure, but the implementation is still limited and poorly structured.
c. Level 3-Defined: This level is represented by 10 models and is usually defined as the stage where smart city initiatives are more clearly defined and begin to integrate. At this stage, there is increased coordination between smart city projects and infrastructure, as well as an emphasis on interoperability and increased efficiency of city services.
d. Level 4-Measured: 10 models include similar definitions for level 4. Smart city strategies and initiatives have matured at this level and show tangible results. Advanced technologies such as IoT, artificial intelligence, and cloud computing are often implemented to support broader system integration and improve the quality of public services.
e. Level 5-Optimized: The definition for level 5 is also represented by 10 models and describes the optimization stage where all aspects of the smart city operate at maximum and sustainable levels. At this stage, the city has achieved high operational efficiency, with ongoing innovation and collaboration supporting long-term sustainability and citizen well-being.

3.2 Discussion

The literature review identifies key dimensions commonly featured in smart city maturity models, including the smart environment, governance, and society. Among these, the smart environment dimension is most frequently highlighted, reflecting the growing emphasis on sustainability and resource management in urban development. This finding contrasts with earlier studies, such as those by Aljowder et al. [14], where technological aspects often dominate. Additionally, the dimensions of smart governance and smart society underscore the importance of good governance and social inclusion, aligning with Anschütz et al. [13] but offering a more balanced perspective. In contrast, dimensions like smart mobility and smart living received less attention, consistent with their emerging status in the literature but diverging from models prioritizing mobility infrastructure in early maturity stages.

Most models (8 out of 11) adopt a five-level maturity structure, which balances clarity and comprehensiveness. This preference aligns with studies like Warnecke et al. [9] but contrasts with earlier frameworks employing three or seven levels. For example, models with three levels focus on foundational assessments but lack granularity, while seven-level frameworks, although detailed, are often simplified for practical application. This research highlights the trend toward standardizing maturity levels while retaining flexibility for varying urban contexts and developmental needs. This study emphasizes the need for flexible, context-specific maturity models that cohesively integrate environmental, technological, and social dimensions. While earlier models targeted specific contexts, such as small cities or particular aspects of urban development, this research advocates for a broader, adaptable framework that addresses diverse local challenges. By mapping key dimensions and maturity levels, this study provides a comprehensive understanding of smart city development, offering guidance for creating a sustainable, inclusive, and technologically advanced urban environment.

4. CONCLUSION

This study comprehensively reviews smart city maturity models by analyzing key dimensions and maturity levels across 11 models. The findings underscore a consistent focus on critical dimensions such as smart environment, smart governance, and smart society, which highlight the interconnected roles of sustainability, governance, and citizen participation in urban development. These dimensions signify a global trend toward integrating technology, inclusivity, and sustainability in urban planning to create more livable, efficient, and resilient cities. Most models employ a five-level maturity framework, balancing simplicity and detail to evaluate a city's progress from initiation to optimization. Alternative structures, including three or seven levels, demonstrate adaptability in addressing specific urban needs. However, the study also identifies gaps, such as limited attention to dimensions like smart mobility and smart living, which are pivotal for fostering holistic urban development that blends technological advancement with quality of life. Despite these insights, the research has limitations, as it primarily focuses on existing models and may overlook newer or region-specific frameworks. Future research should explore applying these models in diverse contexts, integrate empirical data to validate maturity levels and examine emerging dimensions like smart branding and smart living. Addressing these aspects will enhance the understanding and applicability of smart city maturity models, ensuring they remain relevant in capturing the evolving complexity of urban development.

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