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MATURITY MODELS IN SMART CITY DEVELOPMENT MANAGEMENT – A SYSTEMATIC LITERATURE REVIEW

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Purpose: The subject of smart city development in the face of increasing challenges related to digitalization, as well as social, economic, and environmental pressures, remains highly topical. The aim of this article is to provide a systematic review and synthesis of the literature on maturity models in the context of managing smart city development.
Design/methodology/approach: The study was conducted in accordance with the PRISMA 2020 guidelines, ensuring the rigor, transparency, and reproducibility of the research process. An analysis of 33 smart city maturity models was performed based on criteria such as the conceptualization of the smart city notion, the number of maturity levels, the domains of intelligent solution implementation, and the practical application of the models for assessing city maturity.
Findings: The systematic literature review indicates that the evolution of smart city maturity models reflects a paradigm shift from a technologically oriented perception of the smart city as a set of ICT-based solutions towards an integrated, systemic approach in which governance, data, participation, and resilience constitute mutually interlinked pillars.
Research limitations/implications: The literature review covers publications in English, which may limit access to information on national or local maturity models developed for specific countries or communities.
Practical implications: Urban stakeholders – taking into account city size, historical and cultural background, and their own development objectives – may apply the most appropriate model identified in the review to suit their specific needs, as well as conduct comparative analyses with selected cities for which maturity assessments have already been performed.
Originality/value: The study provides a comprehensive and the most extensive literature review published to date on existing smart city maturity models, including an indication of their practical application.
Keywords: smart city, maturity model, systematic literature review.
Category of the paper: Systematic literature review.

1. Introduction

Contemporary cities operate under conditions of increasing complexity within socio-economic systems, intensified urbanization, demographic pressures, and escalating environmental challenges. According to projections by the United Nations Department of Economic and Social Affairs (2019), by 2050 more than 68% of the global population will reside in urban areas, creating the need for new approaches to managing space, resources, and the quality of life of residents. In light of these developments, traditional models of urban growth are giving way to concepts that integrate technology, data, and social participation to build cities that are more resilient, sustainable, and human-centred.

Within this context, the smart city paradigm has gained increasing significance. It brings together elements of public management, digital transformation, sustainable development, and social innovation (Höjer, Wangel, 2015; Ahvenniemi et al., 2017; Moura, de Abreu e Silva, 2019). Smart cities employ information and communication technologies (ICT), the Internet of Things (IoT), big data analytics, and artificial intelligence (AI) to optimize urban processes, enhance the quality of public services, and increase citizen engagement in co-governance (Nam, Pardo, 2011; Hashem et al., 2016; Winkowska et al., 2019; Zhuang et al., 2024). In contrast to traditional urban planning models, the smart city concept views the city as a complex, dynamic ecosystem in which infrastructure, technology, institutions, and residents interact. The implementation of digital solutions therefore requires not only investments in technological infrastructure but also the development of organizational capabilities, an innovation-oriented culture, and institutional openness (Gracias et al., 2023), as the notion of the smart city has evolved from technology-driven Smart City 1.0, through technology-enabled and city-led Smart City 2.0, and citizen co-created Smart City 3.0, to Smart City 4.0, which aims at economic, social, and environmental sustainability (Marchlewska-Patyk, 2023; Jonek-Kowalska, Wolniak, 2024). Key factors supporting the development of smart cities include access to external financing sources, advanced digital infrastructure, data integration, and high levels of cybersecurity and data protection. Conversely, barriers include low levels of integration among urban systems and a lack of data interoperability, limited financial capacity of local governments, and institutional resistance to change and to digital-climate transformation (Szpilko et al., 2025).

It may therefore be concluded that, as digitalization progresses and intelligent solutions proliferate in urban environments, the need to measure the degree of advancement of cities undergoing this transformation becomes more pronounced. Cities vary in terms of resources, development visions, stakeholder involvement, and regional conditions; consequently, no universal pathway to becoming a smart city exists. In response to this diversity, maturity models are increasingly used in both the academic literature and urban management practice. These models enable the diagnosis of the current state of development, the identification of gaps, and the planning of subsequent stages of transformation (Pliatsios et al., 2023).

Maturity models – particularly those originating in project management and organizational development – have become key tools for assessing the digital and organizational readiness of cities (Lombardi et al., 2012). They facilitate the classification of technological, social, and institutional development levels and support data-driven governance. Recent years have seen a significant increase in publications and tools based on smart city maturity models, which differ in scope, structure, and intended applications (Aljowder et al., 2019). Despite this diversity, however, a coherent comparative analysis capable of capturing shared features, methodological differences, and trends in the evolution of these models remains lacking.

Given the growing importance of sustainable digital transformation in urban environments, it is essential to systematically organize and critically evaluate existing maturity models. Such a review not only helps determine which aspects of "urban intelligence" are most frequently measured but also reveals conceptual gaps and opportunities for developing new, more comprehensive assessment tools that account for contemporary challenges such as resilience, cybersecurity, social inclusiveness, and alignment with ESG (Environmental, Social, Governance) principles (Kumar et al., 2023).

The purpose of this article is to conduct a systematic review and synthesis of the literature on maturity models in the context of managing smart city development. The study follows the PRISMA 2020 guidelines, which ensures rigor, transparency, and reproducibility throughout the research process. Its systematic character makes it possible not only to identify and classify existing maturity models but also to compare them critically in terms of theoretical assumptions, assessment criteria, and implementation contexts.

The article adopts an analytical and comparative perspective and seeks to structure the existing scientific body of knowledge on smart city maturity assessment, encompassing both conceptual and empirical approaches. The primary research problem concerns how the notion of maturity in smart cities has evolved – from approaches dominated by information and communication technologies to contemporary models that integrate sustainability, resilience, and social inclusiveness.

2. Methodology

The study was conducted as a systematic literature review in accordance with the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Page et al., 2021), which ensured scientific rigor in synthesizing research on smart city maturity models. The process involved the following stages: (1) formulation of the research problem, (2) development of a protocol specifying inclusion and exclusion criteria, data sources, search strategy, publication selection procedure, data extraction approach, and assessment of study quality, and (3) synthesis of findings (Figure 1). The inclusion criteria covered all available scientific publications presenting smart city maturity models from their emergence up to 2025. Given that the topic of urban maturity in terms of the implementation of information and communication technologies in various domains of city functioning is relatively new, the earliest publications date from the second decade of the twenty-first century. All articles were required to exhibit a clear focus on assessing the maturity of cities in terms of smart solutions.

The exclusion process followed two stages. Initially, duplicated or misclassified studies that did not include descriptions of urban maturity models were identified and removed. Subsequently, a qualitative assessment was carried out based on thematic relevance and methodological rigor. Titles, keywords, abstracts, and full texts were examined. Articles that merely applied existing, previously described maturity models to assess the maturity level of a given city were excluded.

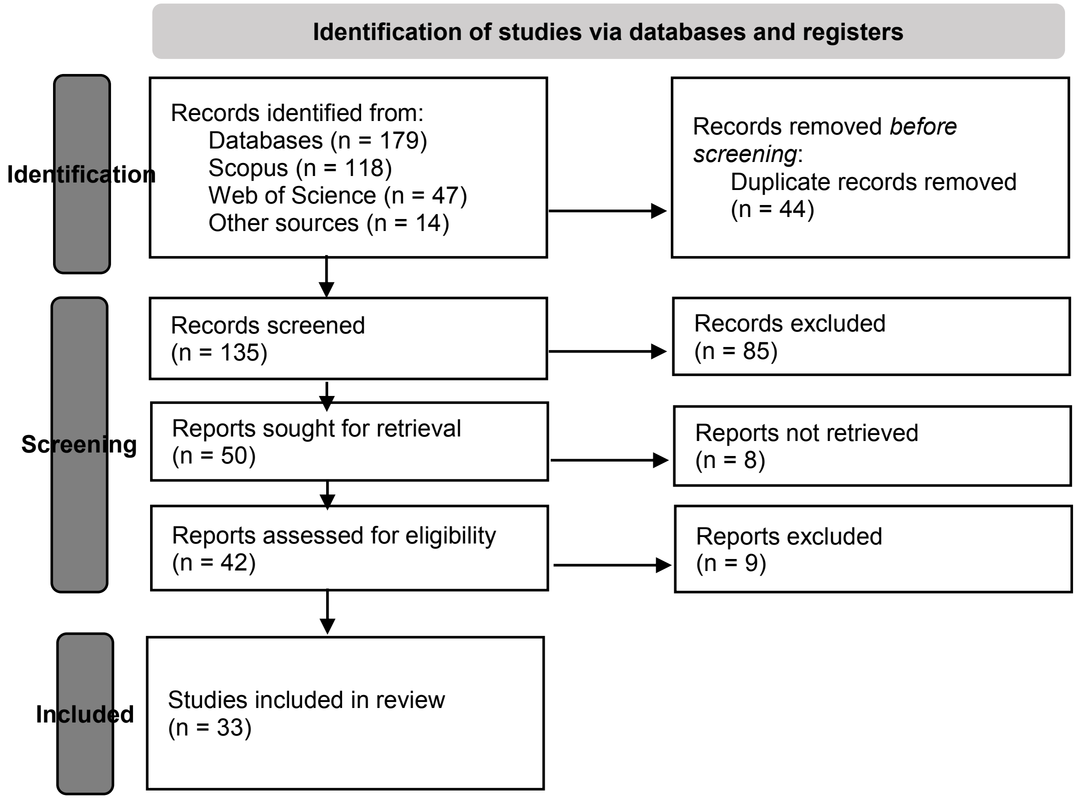

Figure 1. PRISMA flow diagram chart for search for academic articles on smart city maturity models.
Source: own elaboration based on PRISMA.

Searches were conducted in the Scopus and Web of Science databases, which contain scientific studies published in reputable, high-impact journals and maintain robust indexing standards and advanced bibliometric tools. Due to the need to exclude numerous publications that did not meet the eligibility criteria, the search was extended to Google Scholar and ResearchGate, with particular attention given to source credibility. Peer-reviewed publications in English from the years 2013–2025 were included.

In each database, search strings were formulated in a comparable manner, adjusted to reflect platform-specific constraints. In Scopus, searches were carried out by identifying occurrences of selected terms in titles, abstracts, and keywords using the string: TITLE-ABS-KEY ("smart cit*" OR "intelligent cit*" OR "digital cit*" AND "maturity model" OR "maturity level") AND PUBYEAR < 2026. The Web of Science string was adapted to the platform's syntax as TS=("smart cit*" OR "digital cit*" OR "intelligent cit*" AND "maturity"), supplemented with the keywords "maturity model" and "smart cities" or "smart city". In ResearchGate and Google Scholar, keyword searches such as "smart city maturity model" resulted in excessively large numbers of publications that precluded a rigorous screening process. Therefore, only the first ten pages of results ranked as most relevant were reviewed.

Following the searches, the selection process proceeded in three stages: (1) removal of duplicates, (2) analysis of titles and abstracts, and (3) full-text evaluation against inclusion criteria. The screening was performed independently by two reviewers, and discrepancies were resolved through consensus. The selection process was summarized and visually structured using a PRISMA flow diagram (Figure 1). Microsoft Excel was used to manage and analyze the data. From the included studies, key information was extracted regarding authorship, year of publication, purpose, methodology, practical implementation, and conclusions. The risk of bias in the selected studies was assessed by carefully examining methodological rigor, transparency of results, and potential conflicts of interest. Ultimately, 33 publications were qualified for qualitative analysis.

3. Research results

3.1. Keyword analysis

As part of the analysis and synthesis of the literature on smart city maturity models, a keyword analysis was conducted as an initial step. The technique of Visualisation of Similarities (VOS) was applied, enabling the visualization of relationships between concepts by showing networks of keyword co-occurrence in scientific publications. The connections among keywords were mapped using VOSviewer (Figure 2). The visualization reveals several distinct thematic clusters, differentiated by colour. The distances between nodes reflect the strength of semantic relationships: the closer two concepts are positioned, the more frequently they co-occur in the scholarly literature.

The keyword analysis conducted with VOSviewer 1.6.20 made it possible to identify ten thematic clusters covering issues related to smart cities and maturity models. The results highlight the main research areas and confirm the multidimensional nature of the discourse on smart city maturity models. The network consists of 1,254 links with a total link strength of

1,694, indicating a high degree of coherence and strong interdependencies among the examined topics. The concepts smart city and maturity model occupy a central position in the network, acting as nodes that integrate different research streams. Their proximal neighbourhood includes terms related to decision-making, sustainable development, and urban planning, confirming their significance as meta-frameworks for assessing and directing smart city development.

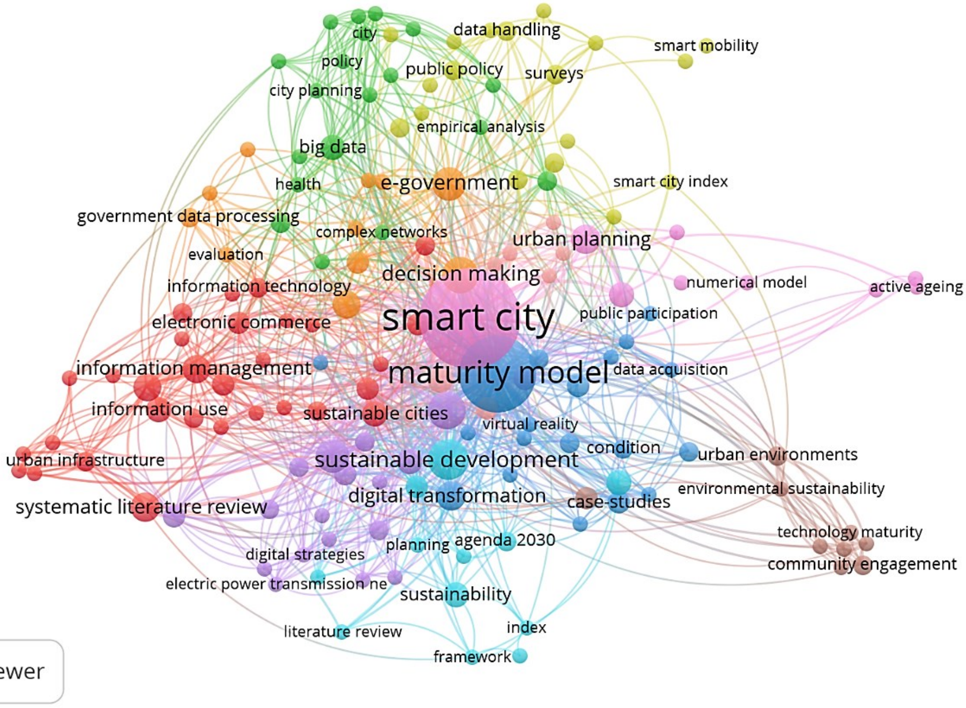

Figure 2. Results of keyword analysis using the VOSviewer tool.

Source: own elaboration.

Among the identified thematic clusters, four dominant areas stand out.

The red cluster – information and technology management (*information management, information technology, government data processing*) – relates to the management of information and the use of information and communication technologies in urban processes. It covers data collection, processing, and dissemination, as well as the use of data to support administrative decision-making and strategic planning. In the context of smart cities, the management of public sector data (*government data processing*) is of particular importance, as such data form the basis for open data services, urban analytics, and predictive infrastructure management. The guiding objective is to create an integrated information ecosystem in which data from various sectors (*transport, energy, environment, waste management, public safety*) can be combined and analysed in ways that support effective urban governance and enhance the transparency of public administration.

The second prominent area is the orange cluster – public policy and urban planning (*public policy, e-government, city planning*). This thematic area focuses on the institutional and regulatory dimensions of urban transformation towards smart cities. Public policy relates to the development and implementation of strategies that facilitate sustainable urban development and the effective use of new technologies. E-government refers to the digitalization of public services and improvements in interactions between authorities and citizens through information technologies. Urban planning encompasses the use of digital tools in designing urban space, transport systems, environmental protection, and infrastructure development. The common objective of these activities is to build coherent public governance frameworks in which policy, law, and technology work together to support innovation, citizen participation, and urban resilience.

The third dominant cluster (blue) – digital transformation and sustainable development (*digital transformation, sustainable development, Agenda 2030*) – emphasizes the integration of digital technologies with sustainable development objectives. Digital transformation implies a profound shift in the functioning of urban institutions through technologies such as the Internet of Things, artificial intelligence, data analytics, and blockchain. Sustainable development refers to the need to balance environmental, social, and economic dimensions in urban growth. Agenda 2030 (*The United Nations 2030 Agenda for Sustainable Development*) provides a strategic framework, particularly through SDG 11 (*Sustainable Cities and Communities*) and SDG 9 (*Industry, Innovation, and Infrastructure*). In this perspective, the smart city becomes an instrument for implementing global development goals, where digitalization serves as a means to enhance quality of life, reduce emissions, and increase the resilience of urban systems.

The fourth cluster, the brown cluster – community engagement and technological maturity (*community engagement, technology maturity, environmental sustainability*) – refers to the social dimension of smart city transformation and the technological maturity of cities, understood as the ability of urban institutions to effectively use technology. Community engagement denotes the active involvement of residents in planning, co-decision-making, and monitoring urban initiatives. Such participation increases acceptance of innovation and improves the alignment of solutions with actual resident needs. Technological maturity refers to the level of development of digital infrastructure, organizational capabilities, and innovation culture that enable effective implementation of smart city solutions. Environmental sustainability signals the need to incorporate ecological considerations – such as energy efficiency, emissions reduction, and circular economy principles – into urban planning and technology projects. This cluster highlights that digital transformation must be accompanied by the development of social competencies and a culture of shared responsibility, which collectively contribute to more sustainable and resilient urban communities.

It should be emphasized that peripheral clusters identified through the VOSviewer analysis – such as *active ageing* or *virtual reality* – indicate emerging research directions that extend classical technological approaches to include social, demographic, and immersive dimensions.

3.2. Comparison of smart city maturity models

The analysis of the collected literature enabled the identification and characterization of a range of smart city maturity models developed between 2013 and 2025. This section presents the main assumptions of these models, the conceptualization of the smart city notion, the description of maturity levels, the domains of intelligent solution implementation, and the empirical applications of the models (Table 1). Based on a search conducted in academic databases (Scopus, Web of Science, ResearchGate, and Google Scholar), 33 maturity models were identified. It is noteworthy that the highest level of interest in the issue of city maturity was observed in 2018-2019, during which the largest number of proposals for assessing cities in terms of their advancement in implementing modern technologies across various domains was published. The development of new models was likely interrupted by the outbreak of the COVID-19 pandemic, which revealed the need to focus not only on ICT in cities but also on building urban resilience to unforeseen circumstances (including electricity supply disruptions, infrastructural inefficiencies, the physical lack of access to public services for stakeholders, or limited internet access).

Considering the countries of origin or employment of the researchers, the greatest number of maturity model proposals emerged in Brazil (4), Indonesia (3), India (3) and the United Kingdom (3). In addition, intensive work on smart city maturity was conducted by scholars from Germany, Greece, Turkey, Colombia, Canada, Poland, Morocco, Iran, Jordan, El Salvador, Bahrain, Australia, China, and Taiwan, often collaborating within international research teams.

The IDC Smart City Maturity Model (Clarke, 2013) should be considered a pioneering framework, introducing a five-stage concept of the evolution of cities toward intelligent solutions – from ad hoc activities to full optimization. A key assumption of the model is the view of the city as a "learning organization," in which subsequent stages reflect increasing integration of information technologies, data management, and decision-making processes. This model established the foundations for numerous later proposals. In 2017, the model was structured into a set of stages, dimensions, and subdimensions (still across five levels), oriented toward benchmarking and "system-of-systems" planning (Yesner et al., 2017).

In 2014, the UK government published its own model – PAS 181 – which describes a strategy for building a city's capability to become "smart" through the integration of people, processes, and technology (BSI, 2014). This model was created in response to the need for a framework to guide urban transformation in an integrated, data-driven manner. PAS 181 does not introduce formal levels; instead, it emphasizes the importance of political leadership and interoperability, becoming a basis for numerous self-assessment tools. PAS 181 has been applied in practice, including in Glasgow, Birmingham, and Bristol.

Table 1.
Comparison of city maturity models in terms of smart solution implementation

No	Year	Model	Authors	Country	Maturity levels	Smart city domains	Practical verifiability
1	2013	IDC Smart City Maturity Model	Clarke (IDC Government Insights)	International	5: Ad-Hoc → Opportunistic → Repeatable → Managed → Optimized	Strategic Intent; Data; Technology; Governance and Service Delivery Models; Stakeholder Engagement	–
2	2014	PAS 181 Smart City Framework	British Standards Institution (BSI)	United Kingdom	–	Business management, Citizen-centric service management, Technology & digital asset management	–
3	2014	Smart Cities Maturity Model (SCMM)	Sustainability Outlook	India	4: 1 – Access → 2 – Efficiency → 3 – Behavior → 4 System Focus	Transport, Spatial Planning, Water Supply, Sewerage & Sanitation, Solid Waste, Storm Water Drainage, Energy & Electricity, Telecom & WiFi, Economy, Finance, Education & Health (Grouped), Environment	–
4	2014	Smart City Governance Maturity Framework (SCGMF)	Lee, Hancock, Hu	South Korea, USA, Taiwan	–	Urban openness, Service innovation, Partnership formation, urban proactiveness, Smart city infrastructure integration, smart city governance	San Francisco, Seul
5	2015	Smart Cities Scotland Maturity Model	UrbanTide / Scottish Government	United Kingdom (Scotland)	5: Ad Hoc → Opportunistic → Purposeful & Repeatable → Operationalized → Optimized	Strategic Intent, Data, Technology, Governance & Service Delivery Models, Stakeholder Engagement	Aberdeen, Dundee, Edinburgh, Glasgow, Inverness, Perth, Stirling
6	2015	Smart City Maturity Model (SCMM)	Mani, Banerjee (ISB India)	India	5: Information Dissemination → Services Optimization → Services Replication → Services Integration → Connected Services	Smart governance, smart people. Smart economy, smart environment, smart living, smart mobility	–
7	2015	Brazilian Smart City Maturity Model (Br-SCMM)	Afonso, Brito, Alvaro	Brazil	5: Simplified → Managed → Applied → Measured → Turned	Water, education, health, environment, energy, transport, housing, governance, security, technology	27 Brazilian cities
8	2017	CityDNA Dynamics – Smart City Maturity & Performance Benchmarking	Moustaka, Vakali, Anthopoulus	Greece	–	Smart governance, smart people. Smart economy, smart environment, smart living, smart mobility	–
9	2018	Unified Smart City Model (USCM)	Anthopoulus, Marjin, Vishanth	Greece	–	Smart governance, smart people. Smart economy, smart environment, smart living, smart mobility	–
10	2018	Maturity Model and Assessment for Indian Cities	Prasad	India	4: Basic → Improvised → Intermediate → Advance	Mobility, Water Management, Sewerage & Sanitation, Solid Waste, Storm Water, Energy, Healthcare, Environment, Security, Parking, ICT	20 Indian cities
11	2018	Garuda Smart City Model (GSCM)	Firmanyah, Supangkat, Arman, Adhitya	Indonesia	5: Ad hoc → Initiative → Scattered → Integrative → Smart	Economy; Society; Environment; ICT; Governance; People	Bandung, Palembang, Makasar and Surabaya, Magelang, Pontianak, Denpasar, Bontang
12	2018	Smart City Maturity Level Analysis Using ITIL Framework	Nur, Batmetan, Manggopa	Indonesia	–	Smart governance, smart people. Smart economy, smart environment, smart living, smart mobility	Manado

Cont. table 1.

13	2018	Data-Quality Smart City Maturity Model (DQSC-MM)	Korachi, Boulmakoul	Morocco	5: Initial → Developing → Defined → Managed → Integrated	Data governance, data quality management, data integration and interoperability, data usage and analytics	–
14	2019	Smart City Evaluation Model	Nuraeni, Firmansyah, Pribadi, Munandar, Herdiani, Nurwathi	Indonesia	5: 0, 1, 2, 3, 4	Smart governance, smart people. Smart economy, smart environment, smart living, smart mobility	Bandung
15	2019	ISO 37122 – Indicators for Smart Cities (basis for maturity assessment)	International Organization for Standardization (ISO)	International	–	Economy; Education; Energy; Environment & Climate Change; Finance; Governance; Health; Housing; Population & Social; Recreation, Culture & Sports; Safety; Solid Waste; Telecommunication & Innovation; Transportation; Urban Planning; Water & Sanitation; Wastewater; Innovation Ecosystem; Resilience	Dubai, Toronto, Buenos Aires, London, Växjö, Bogotá, Los Angeles
16	2019	ITU-T Y.4904	International Telecommunicatio n Union	International	5: 1 – The overall strategy is developed → 2 – SSC initiatives are aligned with the strategy → 3 – Evaluation of SSC initiatives is carried out → 4 – Strategy is developed for improving integration and cooperation → 5 – Improvement and optimization potential is explored	3 dimensions: economic, environmental, social	Brazilian and Ecuadorian cities
17	2019	Smart City Maturity Assessment and Benchmarking (SCMAB)	Warnecke, Wittstocki Teuteberg	Germany	5: No smart urban mobility system is in place (x ≤ 10%) → Conceptualization of basic initiatives (10–40%) → Implementation of basic initiatives (40–70%) → Strategic planning and implementation of smart initiatives (70–90%) → Continuous smart initiatives planning (≥ 90%)	Environmental impact; ICT integration; Intermodal integration; Policy and Planning; Public transport performance;, Social impact	London, Vienna, Amsterdam, Stockholm, Berlin
18	2019	Smart City ICT Adoption Maturity Model (SCIAMM)	Maestre, Astudillo, Concha, Nieto	Colombia	5: 0 – initial city, 1 – intentional city, 2 – emerging city, 3 – adapter city, 4 –integrated city	E-Government strategy, Public innovation, IT services, Data management, IT infrastructure	Bogotá, Medellín, Cali, Bucaramanga, Manizales, Barrancaberm eja, Popayán
19	2019	Sustainability Maturity Model (SMM)	Da Silva of Santana, de Oliveira Nunes, Passos, Santos	El Salvador	5: Initial → Managed → Defined → Quantitatively Managed → In Optimization	Smart governance, smart people. Smart economy, smart environment, smart living, smart mobility	–
20	2019	Maturity-Based Scale for Smart Cities: A Conceptual Framework	Suliman, Rankin, Robak	Canada	5: Initial → Improved → Sustainable → Preventive → Proactive	Natural environment; Built infrastructure and ICT; Services including education and health; Mobility including transportation; Economy and Finance; Governance, policy, management and administration; People, living, and society; Quality of life.	–

Cont. table 1.

21	2020	Smart City Maturity Assessment Model of Turkey (SCMAM)	Bayraktar, Bayar, Kara, Bilgin	Turkey	–	Smart City Applications: Smart Environment, Smart Security, Smart Resident, Smart Building, Smart Economy, Smart Space Management, Smart Health, Geographic Information Systems, Information Technologies, Smart Transportation, Smart Energy, Communication Technologies, Information Security, Smart Infrastructure, Smart Governance, Natural Disaster and Emergency Management. Smart City Management: Governance, Strategy Management, Policy Management, Integrated Service Management, Business Management	4 Turkish cities
22	2021	Information Technology Maturity Model for Smart City Services	Bernal, Espitaleta	Colombia	3: Integrated [0…1] → Analytically Managed [1…2] → Optimized Automated [2…3]	Quality of Citizen Life; Sustainable Environment; Economics Opportunity; Infrastructure; Inclusive Government; IT Dimensions and Indicators	Cereté
23	2022	Maturity Model for Smart and Sustainable Brazilian Cities	Loureiro, Muniz, Pereira, Paseto, Martinez, Alves	Brazil	7: Accession → Commitment → Planning → Alignment → Development → Integration → Optimization	Economic, Socio-cultural, Environment and Institutional Capacity	Selected Brazilian cities
24	2022	Resilient Smart City Model (RSCM)	Baran, Kłos, Chodorek, Marchlewska-Patyk	Poland	–	Smart governance, smart people. Smart economy, smart environment, smart living, smart mobility	–
25	2022	Innovative Digital Maturity Assessment Model for Smart Cities	Topuz, Coskun, Tütek, Çakır, Temur, Sivri	Turkey	6: 0 – Outsider → 1 – Beginner → 2 – Intermediate → 3 Experienced → 4 – Expert → 5 – Top performer	Smart society; smart mobility; smart administration; smart resources; smart technology management	Istanbul
26	2022	Maturity Model-Based Service Evaluation (MMSE)	Sheng, Zhang, Wang, Shan, Fang, Lyu, Xiong	China	3: Performance, Process, Input & Output	Social benefiting; Accurate governance; Ecological livability; Intelligent facilities; Information Resources; System innovation; Life experience	10 Chinese cities
27	2023	Multicriteria Smart City Maturity Model (MSCMM)	Aragão, Chiroli, Zola, Aragão, Marinho, Correa, Colmenero	Brazil	5: Level 1 – No smartness infrastructure working; • Level 2 – Smartness working but not meeting future needs; • Level 3 – Smartness meets current needs; • Level 4 – Smartness partially initiated for future needs; • Level 5 – Smartness continuously improving to meet future needs	Smart governance, smart people. Smart economy, smart environment, smart living, smart mobility	London
28	2023	Focus-Area Smart City Maturity Model	Aljowder, Ali, Kurnia	Bahrain, Australia	5: 0, 1, 2, 3, 4	ICT, Economy, Environment, Social, Resources, Services, Governance	–
29	2023	Smart Circular City Maturity Model	Damianou, Vayona, Demetriou, Katos	United Kingdom, France	4: Instrumented City → Connected City → Smart City → Responsive City	Citizen participation; ICT infrastructure; IoT devices	–

Cont. table 1.

30	2024	Maturity model for small and medium-sized cities (MMSMC)	Anschütz, Ebner, Smolik	Germany	5: 0 – No smart city initiative is in place → 1 – Initial smart city initiatives have been conceptualized and started to be implemented → 2 – Initial smart city initiatives have been implemented → 3 – Strategic planning and implementation of smart city projects and documentation of all relevant data → 4 – Continuous smart city developing and implementing; focus on improvement of the existing smart city solutions	Smart governance, smart people. Smart economy, smart environment, smart living, smart mobility	–
31	2025	Process-aware Digital Transformation Capability Maturity Model for Smart Cities (PDTCMMSC)	Ajoudanian, Aboutalebi	Iran	5: Incomplete → Performed → Managed → Established → Predictable → Innovating process	Strategic Governance, Information and Communication Technology, Digital Process Transformation, Citizen and Workforce Management	–
32	2025	Smart City Technology Maturity Model (SCTMM)	Jacques, Neuenfeldt Junior, De Paris, Gutierrez, Siluk	Brazil	5: Initial → In evolution → Intermediate → In improvement → Advanced	Living environmental and infrastructure; governance and engagement; entrepreneurship; health and assistance; education and training; energy; technology and innovation; economy and sustainable consumption; security and protection; coexistence and reciprocity; mobility	Santa Maria
33	2025	Dynamic quantitative model for measuring smart city maturity (DWMMSCM)	Kalaldeh, Tarawneh	Jordan	Quantitative model (continuous scale)	Connectivity; Mobility; Jobs and firms; Housing and built environment; Health and Safety; Education and skills; E-government; Energy, water, and waste	Amman

Source: own elaboration.

At the same time, the Indian government recommended the use of a set of benchmark indicators for key smart city parameters. Based on government recommendations and ISO 37120 standards, Sustainability Outlook developed a maturity model applicable to such areas as transport, spatial planning, water supply, sewerage and sanitation, solid waste management, stormwater drainage, electricity, telephone connectivity, and Wi-Fi access. The maturity of a smart city consists of four levels: availability of urban infrastructure and technology; efficiency in the use of resources and energy; behavioral change through interactions between people and physical assets that open new pathways for sustainable development; and a focus on systems of resource and energy exchange.

In 2014, Lee and his team published a study presenting the Smart City Governance Maturity Framework (SCGMF), which is not a formal maturity model in the sense of staged development, but rather a comprehensive assessment model of cities' smart activities, enabling comparative analyses of cities based on measurable dimensions and subdimensions. The overarching goal was to create a tool for assessing the maturity and effectiveness of smart city implementation across diverse cultural and organizational contexts. Six dimensions are evaluated: openness of urban systems, service innovation, partnership creation, municipal proactiveness (in green smart solutions), infrastructure integration, and intelligent city management. The model was applied in studies conducted in Seoul (South Korea) and San Francisco (United States).

In 2015, the Scottish Cities Alliance developed the Smart Cities Scotland Maturity Model (SCSMM), which incorporated PAS 181 and IDS MaturityScape, combining a strategic management approach with a practical digital development pathway (UrbanTide, 2015). The key areas include strategic purpose, data and ICT, technology and innovation, service delivery, and stakeholder engagement. In this model, maturity is understood as a gradual transition from incidental implementations to systemic integration of smart city solutions and increased citizen participation. The model was applied to assess the seven largest Scottish cities (Aberdeen, Dundee, Edinburgh, Glasgow, Inverness, Perth, and Stirling) (Scottish Cities Alliance, n.d.). It was also used to evaluate the maturity level of Depok City (Indonesia) (Janiawan et al., 2017).

At that time, India saw the development of the Smart City Maturity Model (SCMM) by Mani and Banerjee (2015). Its structure reflects the characteristics of developing countries: the model accounts for infrastructural constraints and lack of resources, defining five levels from "basic" to "optimizing." A similar approach was adopted in Brazil, where the Br-SCMM was created (Afonso et al., 2015). Unlike the Indian model, the Brazilian version places stronger emphasis on social issues and inequalities, arguing that intelligent transformation must be inseparable from improving quality of life and social inclusion. The authors assumed that a city's maturity can be assessed through an analysis of its governance structures, technological infrastructure, level of data integration, citizen orientation, capacity for organizational learning, and innovation. Br-SCMM can be considered the first national Smart City maturity model developed for South America and represents an attempt to locally adapt Western concepts such as IDC or PAS 181 to the realities of territorial diversity, limited resources, and technological asymmetry in Brazilian cities. Its validation across 26 Brazilian cities makes it one of the most empirically verified models.

In 2017, Moustaka and her team began work on developing the CityDNA model, later expanded in 2020. The objective of CityDNA (similar to SCGMF) is to enable benchmarking of cities in terms of development, sustainability, and the level of "intelligence", while considering their unique social and cultural characteristics. CityDNA focuses on three dimensions of city analysis – economy, environment, society and culture. The model assumes that each domain (e.g., transport, energy, health, data management) has its own "gene" – an indicator or a set of KPI metrics – describing the level of development and condition of that area. The model does not define classical maturity levels, but it indicates that a city with high integration, efficiency, and civic engagement exhibits a "stable" DNA structure, whereas imbalances between domains appear as "mutations" or breaks in the helix. In parallel, Anthopoulus, Marjin and Vishanth (2018) developed the Unified Smart City Model (USCM). USCM is based on an analysis of eight classes of conceptual models and six classes of benchmarking tools, integrating them into a coherent framework. It includes dimensions such as technical architecture and infrastructure, urban governance and policy, planning and development, data and knowledge, sectoral infrastructures (energy, transport, health, environment), and human and social factors (people, living, governance, economy, mobility, environment).

Prasad (2018) proposed a four-level model for assessing Indian cities, aligned with the Smart Cities Mission program. Its purpose was the practical diagnosis of infrastructural and technological gaps and the definition of development pathways within the Indian context. The levels – basic, improvised, intermediate, and advanced – cover 11 functional domains (Mobility, Water Management, Sewerage & Sanitation, Solid Waste, Storm Water, Energy, Healthcare, Environment, Security, Parking, ICT). The model was applied to assess 20 Indian cities, most of which were found to be at the basic maturity level at the time of the study.

Another Asian maturity model is the one developed by Firmanyah and his team (2018). To assess the maturity level of cities regarding the implementation of smart solutions, they proposed the use of organizational maturity model concepts (CMMI, OPM3, PMBOK) adapted to the urban context. Five maturity levels were identified: (1) the ad-hoc level, indicating the absence of ICT infrastructure, management, and human resources; (2) the initiation level, where fragmented and uncoordinated ICT initiatives appear; (3) a level characterized by dispersed but better-planned smart projects; (4) the level of integrated actions for ICT services and stakeholder collaboration; and (5) the intelligent level, where full technological integration, high quality of life, and effective management are present. The assessed city areas include the economy, society, and environment. The model was empirically tested through interviews with urban stakeholders in 10 Indonesian cities: five large cities with over 1 million inhabitants (Bandung, Palembang, Makasar, and Surabaya), three medium-sized cities (Magelang, Pontianak, and Denpasar), and one small city (Bontang). At nearly the same time, another research team (Nuraeni et al., 2019) assessed Bandung's maturity level based on the Giffinger model, using a continuous scale from 0 to 4. According to the researchers, the city was positioned at level 3. Owing to its flexible structure and adaptability of indicators, this model was recognized as a practical tool for local monitoring of smart city digital transformation progress.

A distinct approach was presented by Nur, Batmetan and Manggopa (2018), who based their maturity assessment on the ITIL framework, which describes the lifecycle of IT services: Service Strategy, Service Design, Service Transition, Service Operation, and Continual Service Improvement. The authors argued that smart city maturity can be measured as the readiness level of the organization managing municipal services and ICT – hence the adoption of ITIL as the analytical basis. The model assumes that smart city maturity is a function of three main resources: technology (ICT and smart city applications), organization (management, human resources), and use (citizens' awareness and adoption). Empirical verification was conducted in Manado (Indonesia) using a survey questionnaire containing items evaluating maturity levels in the “Service Design” and “Service Transition” domains on a scale of 1-9. The study found that although technology and command centers were present in Manado, users and human resources were insufficiently prepared. Respondents often did not perceive the benefits of smart city applications, and their knowledge and usage levels were low.

Korachi and Boulmakoul (2018) observed that existing maturity models focus primarily on technological, strategic, or organizational aspects, while neglecting data quality, which is a crucial element enabling smart cities to function effectively. Considering that inadequate data and information management is the main barrier to smart city development, the researchers presented the Data-Quality Smart City Maturity Model (DQSC-MM). This model evaluates city maturity in four dimensions (data governance, data quality management, data integration and interoperability, data usage and analytics), each assessed on a five-level scale (initial, managed, defined, quantitatively managed, and optimizing).

In 2019, the International Organization for Standardization (ISO) developed ISO 37122:2019, which includes 80 indicators across 19 areas of city functioning. The objective of ISO 37122 is to provide an international set of measurable indicators that enable cities to assess their level of intelligent development (smartness) and functional maturity in technology use, data management, and citizen participation. The standard was prepared after several years of consultations with pilot cities from the World Council on City Data (WCCD) initiative, including Toronto, Dubai, London, Buenos Aires, Los Angeles, Boston, Bristol, and Amsterdam. Although it is not formally a maturity model, the standard has been widely used as a basis for assessment tools. For example, Kutami et al. (2018) applied the ISO 37153:2017 model to evaluate transportation infrastructure in one of the cities associated with the Association of Southeast Asian Nations.

The International Telecommunication Union (ITU, 2019) proposed its own model aimed at enabling cities to evaluate their progress toward becoming a smart sustainable city – that is, a city using ICT to improve quality of life, service efficiency, and competitiveness while ensuring economic, social, and environmental sustainability. This model constitutes a global UN standard and is used to diagnose the current state, define target development levels, plan actions, and monitor progress by linking maturity with measurable KPIs. The model includes three maturity dimensions – economic, environmental, and social – which reflect the three pillars of sustainable development. Notably, each dimension may include various thematic areas listed in the document, although the list is not exhaustive. The maturity levels were not assigned specific names, but five levels were defined, each describing concrete achievements in strategy, infrastructure deployment, service activation, data and system integration, and continuous improvement. In the ITU-T Y.4904 model, achievements may extend beyond those specified, depending on the city’s characteristics. The model has been applied in assessments of Brazilian and Ecuadorian cities.

Warnecke, Wittstock and Teuteberg (2019) proposed a design science research–based model for self-assessing city maturity in the smart city domain and comparing results across European cities. The model consists of 36 indicators divided into six thematic groups: policy and planning, ICT integration, intermodal integration, public transport efficiency, environmental impact, and social impact. In their article, the authors focused on smart mobility and distinguished five levels of smart city maturity in this domain – from the absence of smart mobility systems, through sustainable approaches, basic initiatives, strategic planning and implementation of projects, to continuous planning of intelligent mobility based on real-time data, artificial intelligence, and integration of all stakeholders through knowledge exchange. The maturity model was used to evaluate five European cities: London (United Kingdom), Vienna (Austria), Amsterdam (Netherlands), Stockholm (Sweden), and Berlin (Germany).

In Colombia, Maestre et al. (2019) developed the Smart City ICT Adoption Maturity Model (SCIAMM), which analyzes ICT adoption maturity – that is, the ability of cities to progressively integrate information and communication technologies into public services. The model responds to the problem of fragmented ICT implementation in Latin American countries, where tools for comparing digital maturity across cities are lacking. SCIAMM is based on the assumption that smart city development requires sequential ICT adoption across five maturity levels (initial city, intentional city, emerging city, adopter city, integrated city), which reflect increasing organizational and technological complexity. The maturity level is measured across five main dimensions: e-government strategy, public innovation, IT services, data management, and IT infrastructure. The model was applied to assess maturity levels in seven Colombian cities (Bogotá, Medellín, Cali, Bucaramanga, Manizales, Barrancabermeja, and Popayán). The study was conducted through surveys completed by municipal officials responsible for ICT and strategic planning.

Brazilian researchers da Silva of Santana, Nunes, Passos and Brito Santos (2019) presented another model designed to assess the sustainable development of Brazilian cities. The Sustainability Maturity Model (SMM) was developed on the basis of ISO 37122 (smart city) indicators and the logic of the Capability Maturity Model for Software (Paulk et al., 1993) for maturity levels, supplemented with project management elements from Control Objectives for Information and Related Technology (COBIT) related to planning and performance monitoring. The purpose of the model is to enable the classification of a city's maturity level using harmonized, comparable indicators and to derive a synthetic "General Compliance Index". Five maturity levels were proposed: 1 – initial, 2 – manager, 3 – defined, 4 – quantitatively managed, 5 – in optimization, along with assessment across six typical smart city domains according to Giffinger (2010), namely smart economy, smart governance, smart people, smart mobility, smart living, and smart environment.

Suliman and his team (2019) argued that models proposed in the academic literature focus primarily on infrastructural or technological aspects, while lacking a tool that integrates organizational, social, and environmental components of smart city development into one structured assessment framework. Their response to this gap was the development of a meta-model combining the theoretical foundations of PAS 181:2014, ISO 37120/37122, and the Capability Maturity Model Integration. The model is built on three pillars – intelligent connectivity, sustainability, and resiliency – and includes five maturity levels: initial, improved, sustainable, preventive, and proactive.

The Turkish approach to smart city maturity assessment is based on government guidelines, specifically the National Smart City Strategy and Action Plan of Turkey (NSCSAP 2020-2023). Bayraktar and colleagues (2020) introduced the Smart City Maturity Assessment Model (SCMAM), designed to support effective investment planning and avoid resource waste through the selection of appropriate technological solutions for each city. The model consists of two main competency areas: Smart City Management – strategic management, service integration, policy, and business; and Smart City Applications – functional domains of the city. Each area is divided into competencies, components, and capabilities. Instead of fixed maturity levels, the model uses a continuous scale (0-1), where values closer to 1 indicate higher integration, maturity, and impact. Pilot testing, based on stakeholder surveys, was conducted in four Turkish cities located in different regions.

In 2021, another framework was developed in Colombia: the Framework for Developing an Information Technology Maturity Model for Smart City Services in Emerging Economies (FSCE) (Bernal, Espitaleta, 2021). Its goal is to create a practical tool for assessing the technological maturity of cities in developing economies, particularly in the context of implementing smart city services. The model consists of four IT dimensions: (1) IT management and governance, (2) IT services, (3) data management, and (4) technological infrastructure. Each dimension is assessed using a set of indicators derived from ITIL, COBIT, and TOGAF. The model structure is based on three maturity levels: 1) Integrated – data are integrated and available for smart services; 2) Analytically Managed – the city uses descriptive, predictive, and prescriptive analytics to support decision-making; and 3) Optimized Automated – systems are automated and supported by artificial intelligence in decision processes. The model encompasses five functional smart city areas: quality of life, sustainable environment, economic opportunities, infrastructure, and inclusive governance. The FSCE framework was validated empirically in a case study of the city of Cereté (Colombia), where it was used to assess IT maturity in six public service sectors (including health, education, security, and culture). The results indicated a varied maturity level – from Integrated to Analytically Managed – confirming the model's practical utility for planning investments in digital urban services.

Another Brazilian maturity model for smart cities is the Maturity Model for Smart and Sustainable Brazilian Cities (MMSSCB), developed by Loureiro and colleagues (2022). The model is based on three pillars: ITU-T Y.4904 and Y.4906 – international standards for assessing maturity and digital transformation of cities; the 2030 Agenda and the Sustainable Development Goals (SDGs); and the Carta Brasileira para Cidades Inteligentes (Brazilian

Charter for Smart Cities) with ISO 37120, 37122, and 37123 standards. MMSSCB evaluates smart city development across economic, socio-cultural, environmental, and institutional dimensions. The model uses 114 indicators, of which 80 relate to sustainable development and 34 to institutional capacity. Maturity levels are structured into seven stages: accession, commitment, planning, alignment, development, integration, and optimization. The model has been validated by the ITU and piloted in several Brazilian cities, with plans for deployment across all 5,570 municipalities as part of the national "Brazilian Program for Sustainable Smart Cities," coordinated by the Ministry of Science, Technology and Innovation (MCTI) and the RNP research network (Rede Nacional de Ensino e Pesquisa).

In 2022, the Resilient Smart City Model (RSCM) was proposed by Polish researchers (Baran et al., 2022). The authors do not build a classic maturity model with sequential development stages, but rather a systemic model of interdependencies between key dimensions of urban resilience and smartness. RSCM is used to identify determinants of resilience, analyze relationships between components of the smart city system, and design an integrated approach to urban policies. The model relies on the six typical smart city dimensions according to Giffinger. It emphasizes citizen engagement in urban governance, creating conditions for local communities to participate in co-creating smart solutions and shaping the urban environment.

The Digital Maturity Assessment Model for Smart Cities (DMAM-SC), developed by Topuz et al. (2022), was created as an innovative tool for assessing the digital maturity of cities using the multicriteria decision-making method Best-Worst Method (BWM). The authors aimed to develop a measurable and adaptable evaluation system that enables cities to identify their strengths and weaknesses in deploying digital technologies and to plan strategic actions toward smart development. The model includes five main dimensions: society, mobility, administration, resources, and technology management. Each dimension is evaluated through weighted criteria derived using BWM, which helps objectify the assessment process and reduce expert subjectivity. The model defines six levels of digital maturity: Outsider, Beginner, Intermediate, Experienced, Expert, and Top Performer, which describe the degree of integration of digital solutions in urban management. Empirical validation was conducted through a case study of Istanbul (Turkey). The results indicated that the city is at an advanced level, with the highest scores in technology and management, and the lowest in the social dimension. The study confirmed the model's practical usefulness for strategic analysis and its flexibility for adaptation to local conditions.

The Maturity Model-Based Service Evaluation (MMSE) developed by Sheng et al. (2022) is the first Chinese maturity model appearing in the literature that was designed to establish a standardized system for assessing and comparing the development level of smart city services. MMSE is intended to enable municipal authorities and researchers to conduct an integrated assessment of the quality, efficiency, and effectiveness of public services while accounting for social and technological factors. The structure of the MMSE is based on a three-level evaluation system: the Performance Layer, which measures the efficiency of municipal services (e.g., transportation, healthcare, education, emergency management); the Process Layer, which assesses management processes, data openness, innovation, and cross-sector collaboration; and the Input-Output Layer, which focuses on resources, technological infrastructure, and implementation outcomes. The model defines five evaluation principles (data consistency, integration of subjective and objective indicators, dynamic development, regional flexibility, and empirical verifiability) and a hierarchical set of indicators comprising more than 100 variables describing the efficiency of municipal services. The model was applied in a study of 10 Chinese cities, for which a comparative evaluation was conducted for the years 2016-2018 using objective and subjective data.

In 2023, Aragão and his team aimed to create a model that would allow a quantitative measurement of a city's "smartness" level and enable comparison and development planning in accordance with ISO standards. Nineteen dimensions and 111 indicators were extracted from ISO standards and assigned to six smart axes according to the classical Giffinger model, forming the Multicriteria Smart City Maturity Model (MSCMM). The model uses a five-level maturity scale, evaluating indicators within ranges from "poor" to "great". The model was empirically tested using London (United Kingdom) as a case study.

Ajowder, Alego and Kurnia (2023) proposed the Focus Area Smart City Maturity Model (FAMM), which can be applied globally regardless of regional context. The model consists of seven domain groups (ICT, economy, environment, society, resources, services, governance) and 18 focus areas within these groups. Five maturity levels were identified, including level 0, representing the absence of actions or initiatives. The model was empirically validated using the Delphi method with 60 experts from 12 countries, representing stakeholders from public administration, academia, international organizations (including UN Agencies), and the private sector.

The Smart Circular City Maturity Model, developed by Damianou et al. (2023), extends smart city maturity concepts by incorporating the circular economy dimension. The purpose of the model is to support city decision-makers in planning and assessing the transition toward a data-driven circular economy by identifying the balance between technological investments, citizen participation, and resource efficiency. The model describes four maturity levels: (1) Instrumented City – infrastructure equipped with basic sensors and measurement devices; (2) Connected City – limited data exchange among entities; (3) Smart City – full integration of data and digital infrastructure; and (4) Responsive City – the highest level, in which the city operates adaptively, automatically reconfiguring resources in real time. The model encompasses areas such as technological infrastructure (IoT, 5G, data centers), data and service management, citizen participation (prosumers), governance and security (including cybersecurity), as well as environmental and economic dimensions related to circularity. Empirical validation was conducted using a cybersecurity use case concerning the application of crowdsourcing in incident response. The study confirmed that introducing crowdsourcing mechanisms increases a city's maturity in data management and security, providing proof of concept for the model's practical effectiveness.

The Smart City Maturity Model for Small and Medium-Sized Cities (SMC-MM), developed by Anschütz, Ebner and Smolnik (2024), is one of the latest and most context-sensitive tools for assessing smart city maturity. It was designed with the needs and capabilities (financial, human, and infrastructural) of small and medium-sized cities in mind, which had been previously overlooked in maturity models. The SMC-MM aims to enable diagnosis of a city's digital advancement level, identification of development priorities, comparison with peer cities, and planning of further transformation stages toward a smart city. The model incorporates five maturity levels—from the absence of smart city initiatives through the initial phase, early implementation, strategic planning, and up to full maturity. The model analyzes city development across the six Giffinger (2010) domains with weighted importance: smart governance and smart people at 26% each, and smart economy, environment, living, and mobility at 12% each. The model was empirically tested using expert interviews in two small cities (approx. 30,000-40,000 inhabitants) – Bad Hersfeld and Lemgo (Germany) – and two medium-sized cities (approx. 100,000-150,000 inhabitants) – Guimarães (Portugal) and Tartu (Estonia).

Ajoudanian and Aboutalebi (2025) proposed a maturity model combining multicriteria decision-making (MCDM) methods with classical concepts of organizational and urban maturity. The goal is to develop a hybrid evaluation system that integrates technological, social, economic, and environmental aspects, enables quantitative classification of city maturity levels, and provides a tool supporting strategic decision-making in public administration. The model focuses on analyzing city functioning across five domains with differentiated weights: governance – 0.27, economy – 0.21, environment – 0.20, mobility – 0.18, and living and people – 0.14. The maturity levels range from the initiation of smart solutions, through fragmented ICT implementation, establishment of integrated urban projects, advanced data-driven strategic management, and innovation and full data integration, to adaptive management and sustainable decision-making. The model was tested on four medium-sized Iranian cities (including Mashhad, Isfahan, Yazd, and Shiraz), using data from public documents, municipal portals, and expert interviews.

Jacques et al. (2025) highlighted the need to develop an assessment of cities' technological readiness for implementing smart city solutions using a quantitative method tailored to the context of developing countries. The Smart City Technology Maturity Model (SCTMM) includes five maturity levels: at the Initial level, there is a lack of strategic smart city actions; the second level (In Evolution) introduces basic ideas and actions toward smart solutions; the third level (Intermediate) involves the preliminary identification of technologies used in the urban environment; the fourth level (In Improvement) reflects technological development, where mature implementations of smart city initiatives are verified; and the fifth level (Advanced) encompasses near-complete data integration, automation, and decision-making based on predictive analysis. SCTMM evaluates 11 assessment areas, and for the first time compared to previously described models, includes entrepreneurship as a separate element, as well as economy and sustainable consumption, coexistence, and reciprocity, indicating a shift toward sustainable urban development. The authors developed a set of quantitative indicators for each area and applied factor analysis to validate the model's structure. Empirical validation was conducted in Santa Maria, Brazil, where the city's smart city maturity was identified at an intermediate level.

Finally, Kalaldeh and Tarawneh (2025) presented a quantitative dynamic model, empirically applied in Amman, Jordan, which enables real-time monitoring of progress and calibration of urban policies. The core of the model is the Holistic Key Performance Indicator (H-KPI), which integrates indicators from multiple areas of urban management, including infrastructure and spatial planning, environment and energy, economy and investment, mobility and transport, quality of life and citizen engagement, and governance and participation. The model does not classify cities into predefined stages; instead, maturity is treated as a continuous variable that can increase over time as indicators improve. The researchers propose creating a digital twin of Amman based on real-time data.

Among the common features of the analyzed models, most incorporate elements of Giffinger's concept for organizing indicators and capabilities. A similar trajectory of smart city development is also observable – regardless of terminology – progressing from fragmented initiatives through data-driven management to continuous improvement.

It can be concluded that in the analyzed set of 33 smart city maturity models, three main streams are clearly visible: progressive models, indicator-normative models, and framework models. Progressive models are based on five-level or similar maturity scales (e.g., IDC 2013, national variants such as Br-SCMM, FAMM, SMC-MM), mapping development from initiation/fragmentation to optimization and continuous improvement. Indicator-normative models are based on ISO/ITU standards (e.g., ISO 37122/37123, national solutions such as MMSSCB in Brazil, or continuous 0-1 models like SCMAM in Turkey), where maturity is perceived as a numerical result or standard compliance rather than a named rank. Framework (diagnostic) models, which do not contain rigid levels and are used for mapping capabilities and gaps, include SCGMF and CityDNA/USCM.

The analysis of national and regional contexts in which smart city maturity models emerge indicates that their structure, measurement logic, and thematic scope are neither random nor neutral. Instead, they reflect the level of institutional development of states, the dominant culture of public administration, and the actual administrative capacities of cities. Consequently, maturity models not only measure the degree of advancement of smart city development but also constitute a projection of the systemic conditions within which they are created and implemented.

In countries characterized by high institutional capacity, stable legal frameworks, and advanced systems of public data collection and integration, normative and continuous models grounded in indicators and international standards prevail. This is exemplified by approaches inspired by ISO and ITU standards, as well as by models developed in Western European countries such as Germany and the United Kingdom. In these contexts, urban maturity is perceived as a measurable level of compliance with established standards, where data interoperability, international benchmarking, and long-term coherence of public policies play a central role. Such models presuppose the existence of competent public administrations capable of conducting advanced monitoring, reporting, and organizational learning processes.

A different logic underlies models developed in developing countries or in states undergoing intensive institutional transformation, such as India, Brazil, and Indonesia. In these cases, stage-based models, often of a compensatory nature, dominate. Their objective is not precise measurement of compliance with predefined standards, but rather the identification of a realistic development pathway—from fragmented and pilot initiatives toward more integrated forms of urban governance. Staged progression thus serves a pedagogical and strategic function, enabling cities with limited resources to gradually build technological, organizational, and social capacities. In such models, particular emphasis is placed on social inequalities, accessibility of public services, and the provision of basic digital infrastructure.

Another important differentiating factor in the construction of maturity models is the degree of centralization of the public governance system. In highly centralized contexts, the state plays a prominent role in defining the smart city maturity framework, resulting in models that function as national standards or official public policy instruments. These models are often linked to national digitalization strategies and serve to coordinate public investment. In contrast, decentralized systems tend to produce framework-based and diagnostic models that do not impose rigid maturity levels but instead allow cities to independently identify competency gaps, development priorities, and areas requiring intervention.

These observations demonstrate that smart city maturity models are inherently context-embedded instruments, and that their design reflects not only developmental ambitions but also real institutional and cultural constraints. The transition from simple stage-based models to more complex, adaptive, and data-driven maturity assessment frameworks becomes possible only when cities possess adequate organizational, competency, and informational foundations. Accordingly, smart city maturity should not be interpreted solely as a function of implemented technologies, but rather as the outcome of the co-evolution of technology, institutions, and public governance culture.

The conducted systematic literature review makes it possible to identify a common conceptual architecture underlying existing smart city maturity models. This architecture does not constitute a new measurement model; rather, it synthesizes the key components and analytical logics recurring across the reviewed approaches, regardless of their geographical and institutional contexts.

From a synthetic perspective, this architecture consists of three interrelated analytical domains and differentiated conceptualization logics of maturity that determine how smart city development trajectories are interpreted (Table 2).

Table 2.
Preliminary conceptual architecture of smart city maturity models (result of literature review synthesis)

Architecture component	Role in smart city maturity models	Dominant logics of maturity
Structural layer (governance, data, institutional capacity)	They create boundary conditions for the development of smart cities; determine the ability to integrate technology, the scalability of solutions and the ability to learn organizationally.	Stage-based Continuous
Operational layer (urban services, technologies, interoperability)	It is the area of implementation of intelligent solutions and the main subject of maturity measurement in most empirical models.	Continuous
Result layer (sustainability, resilience, inclusiveness)	It defines the meaning and goals of smart city development; shifts the focus from technology to social, environmental and institutional effects.	Adaptive

The identified maturity logics – stage-based, continuous, and adaptive – do not represent separate dimensions of the architecture, but rather alternative interpretative lenses for understanding the smart city development process. Their application depends on the level of institutional maturity, data availability, and the analytical and decision-making objectives assigned to maturity models within a given context.

4. Discussion

A systematic review of smart city maturity models reveals a clear evolution in the paradigm for assessing urban development – from simple, stage-based structures describing the levels of technological implementation to complex, multidimensional and integrated assessment systems based on data management, sustainability and resilience.

In the first generation of models, the perspective of linear technological and institutional progress predominated – from the initial phase to full optimization. These models had high educational and communicative value, facilitating strategic planning and progress comparison for cities. However, their limitations include low measurement precision and limited flexibility in the context of dynamic technological changes.

The next generation of models, based on ISO standards (37120, 37122, 37123) and ITU-T guidelines, introduced the dimension of normative comparability and continuous scales. This allowed for more precise monitoring of progress over time and linking maturity assessment with sustainable development goals. The advantage of this approach is alignment with international reporting systems, while its drawback is the risk of excessive standardization, which may hinder consideration of local socio-economic conditions.

In recent years, framework (diagnostic) models have also emerged. These models are characterized by the absence of formal maturity levels and a focus on management quality, data interoperability, institutional openness, and service co-creation. They provide in-depth functional diagnostics, serving as valuable strategic tools for policymakers, but they make direct quantitative comparisons between cities more difficult.

It can be observed that all identified models share a common structural core: governance, technology and data (ICT/data governance), and social participation. These three dimensions appear to be the key determinants of smart city maturity development. However, we agree with Torrinha and Machado (2017) and Mohsin et al. (2020) that existing models focus primarily on measuring the current state of smart cities but do not provide guidance on transitioning between maturity levels, nor do they include indicators covering all activities across the value chain of impact (Santosa et al., 2024).

The findings of this review demonstrate that smart city maturity models are inherently context-dependent instruments rather than neutral or universally applicable frameworks. Their design consistently reflects the institutional maturity, governance culture, and development priorities of the environments in which they are produced. Variations among models therefore arise not merely from academic traditions but from adaptive responses to concrete systemic constraints, including data fragmentation, limited interoperability, social trust deficits, regulatory pressures, and administrative capacity. Models developed in data-rich, institutionally mature settings tend to adopt continuous, indicator-based and normative structures aligned with international standards, while models originating in resource-constrained contexts more frequently employ stage-based architectures that simplify transformation through discrete development levels. Consequently, maturity models function as translational mechanisms that operationalize abstract smart city objectives into governance tools calibrated to local institutional and socio-organizational conditions. This perspective enables a shift from descriptive model cataloguing toward an explanatory understanding of the structural forces shaping the evolution and differentiation of smart city maturity frameworks.

We also believe that smart city development is not based solely on advanced technologies. Implemented solutions must benefit residents, enable barrier removal, prevent emerging problems, and eliminate bottlenecks (Tundys et al., 2022). The differences we identified between models mainly concern the representation of maturity (stage-based vs. continuous), the scope of standardization (normative vs. adaptive), and the functional orientation (technological, organizational, or environmental).

Ghazinoory et al. (2024), based on a systematic analysis and synthesis of smart city maturity models, suggest giving greater consideration during the assessment of a city's maturity to the local context, adaptability, and modularity. We also agree with Hajduk (2020) that there is no single exemplary or ideal model of urban development leading to a smart city, given the individuality of each city in terms of economic, social, and environmental conditions. Nevertheless, we believe it is possible to develop a universal maturity model that would allow for comparative analysis and provide guidance on further steps toward smart city development.

5. Conclusions

Smart city maturity models today constitute an important tool for both researchers and practitioners, allowing the diagnosis of a city's current state, identification of development pathways, and support for strategic decision-making and resource allocation. Based on the conducted literature review, it can be concluded that the evolution of smart city maturity models reflects a paradigm shift – from a technological perspective, viewing the smart city as a set of ICT solutions, toward an integrated, systemic approach in which governance, data, participation, and resilience are mutually interlinked pillars.

In light of the analysis, several scientific and practical recommendations appear warranted. First, harmonization of terminology and measurement methodology is necessary to enable comparison of results across different models and countries. Second, further research should focus on integrating the data perspective (data quality, interoperability) with governance and social dimensions, as this represents a current key knowledge gap. Third, future models should incorporate resilience and social inclusivity as integral components of maturity, in line with the direction indicated by ISO 37123 standards.

Finally, empirical and longitudinal validation is recommended, allowing not only the assessment of a static maturity level but also the tracking of urban development dynamics over time. Additionally, research indicates that following the conceptual phase (earlier years), there is currently an intensification of constructive and validation studies of maturity models, yet a greater unification of language and research tools is still needed.

There is a need for further development of maturity models that holistically integrate digital, social, environmental, and institutional components. In practice, this implies a transition from the "smart = technology" model toward the "smart = sustainable + resilient + inclusive" model. Standardization of comparability between cities should be promoted, potentially supported by common indicators, frameworks, and databases. Models must possess flexibility and adaptability, as cities differ in terms of size, resources, organizational culture, and local policy; hence, a universal model requires a modular structure and the capacity to adapt to local contexts.

Empirical validation of models should be expanded, including more case studies in countries and cities at varying levels of development and across different geographic regions, as well as longitudinal studies showing how cities transition between maturity levels. New research directions should include, among others: integration of urban digital twins, continual learning in city AI systems, cybersecurity issues, digital equity, and the relationship between maturity models and sustainable development outcomes (e.g., alignment with the SDGs).

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