

Theoretical Analysis of Artificial Intelligence Integration in Smart City Management Systems

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ABSTRACT

This study aims to theoretically analyze the integration of AI into smart city management systems and identify the mechanisms, benefits, challenges, and conditions required to ensure that its implementation generates sustainable public value. The study employs a qualitative literature review approach by analyzing 25 scientific articles selected from 50 articles identified through the literature search and selection process. The analysis was conducted through the identification, categorization, comparison, and thematic synthesis of findings from previous studies. The synthesis results indicate that AI can function as an enabling technology that strengthens smart city management through data integration, predictive analytics, service automation, resource optimization, and improved decision-making. However, the effectiveness of AI integration is influenced by digital infrastructure readiness, data quality, human resource capabilities, system interoperability, governance, security, privacy, and ethical considerations. Theoretically, AI integration in smart cities should be understood as a socio-technical process that connects technology, organizations, government, and society in the creation of public value.

ABSTRAK

Penelitian ini bertujuan menganalisis secara teoretis integrasi AI dalam sistem pengelolaan smart city serta mengidentifikasi mekanisme, manfaat, tantangan, dan kondisi yang diperlukan agar implementasinya dapat menghasilkan nilai publik secara berkelanjutan. Penelitian menggunakan pendekatan qualitative literature review dengan menganalisis 25 artikel ilmiah yang dipilih dari 50 artikel yang diperoleh melalui proses pencarian dan seleksi literatur. Analisis dilakukan melalui identifikasi, pengelompokan, perbandingan, dan sintesis tematik terhadap temuan penelitian terdahulu. Hasil sintesis menunjukkan bahwa AI dapat berperan sebagai enabling technology yang memperkuat pengelolaan smart city melalui integrasi data, analitik prediktif, otomatisasi layanan, optimalisasi sumber daya, dan peningkatan kualitas pengambilan keputusan. Namun, efektivitas integrasi AI dipengaruhi oleh kesiapan infrastruktur digital, kualitas data, kapasitas sumber daya manusia, interoperabilitas sistem, tata kelola, keamanan, privasi, dan aspek etika. Secara teoretis, integrasi AI dalam smart city perlu dipahami sebagai proses sosio-teknis yang menghubungkan teknologi, organisasi, pemerintahan, dan masyarakat dalam penciptaan nilai publik.

1. INTRODUCTION

Urbanization, population growth, and the increasing complexity of urban challenges have encouraged city governments to develop management systems that are more effective, responsive, and sustainable. In this context, the smart city concept has emerged as an approach that utilizes digital technologies, data, and connectivity to improve the quality of public services, resource efficiency, decision-making, and citizens' quality of life. Allam & Dhunny (2019) explain that the development of the Internet of Things (IoT) in smart cities generates large volumes of data, thereby requiring technologies capable of processing such data rapidly and intelligently. They position Artificial Intelligence (AI) as one of the key technologies for transforming urban big data into smarter systems, while emphasizing that technological orientation needs to remain balanced

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with aspects of livability, resilience, safety, and sustainability.

AI has become increasingly important in smart city systems because of its ability to perform data analysis, pattern recognition, prediction, classification, optimization, and decision-making support. Duan et al. (2019) explain that developments in AI and big data have transformed organizations' ability to utilize information to support increasingly complex decision-making processes. In urban contexts, these capabilities enable data generated from sensors, digital devices, transportation systems, public services, and various other sources to be transformed into more relevant information for urban management. Thus, AI does not merely function as an analytical tool but also has the potential to strengthen governments' capabilities to understand urban conditions and respond to changes more rapidly.

The application of AI in smart cities has expanded across various dimensions of urban management. Wolniak & Stecula (2024), through their literature review, identified six major areas of AI application: smart governance, smart economy, smart mobility, smart environment, smart living, and smart people. These findings indicate that AI has been utilized to support various urban functions, ranging from mobility and environmental management to governance and citizens' quality of life. This development demonstrates that the scope of AI extends beyond automation, as it can support analytical processes, prediction, service delivery, and decision-making across multiple urban sectors.

Nevertheless, the benefits of AI in smart cities depend heavily on the ability to integrate it with existing digital infrastructure and systems. For example, the integration of AI with IoT, cloud computing, big data analytics, and digital twins can create systems capable of collecting, processing, modeling, and analyzing urban conditions more comprehensively. Through such integration, AI can support a shift in urban management from reactive approaches toward more predictive and adaptive approaches. However, these technical capabilities alone are insufficient to ensure successful implementation because urban management systems involve interactions among technology, government, organizations, infrastructure, regulations, and society.

This issue demonstrates that AI integration in smart cities needs to be understood as a socio-technical process rather than merely a technology adoption process. City governments require data quality, system interoperability, digital infrastructure, human resources, organizational capacity, and coordination mechanisms to ensure that the technology can be utilized effectively. Wolniak & Stecula (2024) indicate that AI implementation in smart cities continues to face various barriers, meaning that technological potential does not automatically translate into urban benefits. Therefore, research attention needs to shift from questions concerning what technologies can be used toward how these technologies can be integrated into urban management systems.

In addition to implementation challenges, the use of AI in urban management raises issues related to governance, ethics, and public trust. AI applications in transportation, security, urban planning, public services, and resource allocation can directly affect citizens' lives. Bosco et al. (2026) demonstrate that AI integration into smart city governance needs to consider ethical principles and human-centered approaches to ensure that technological innovation generates sustainable benefits. They developed a framework for assessing the ethical implications of AI projects in smart cities, demonstrating that technological effectiveness needs to be considered alongside ethical dimensions throughout the implementation lifecycle.

The gap between technological potential and integration within government systems is also evident in the study by Lartey & Law (2025). Through a systematic review of AI adoption in urban planning governance, they found that research on AI in this field has increased significantly, while the practical use of AI in decision-making and policymaking remains relatively limited. They also identified issues related to transparency, inclusiveness, ethics, and public trust. These findings indicate the existence of a technology-governance gap, referring to the discrepancy between the theoretical capabilities of AI and the capacity of governance systems to integrate the technology effectively and responsibly.

Based on these developments, research on AI in smart cities requires a synthesis that not only maps technological applications but also explains how AI is integrated into smart city management systems, what factors facilitate or constrain such integration, and how integration relates to urban effectiveness, governance, and sustainability. This is important because the existing literature remains fragmented across studies of AI applications, digital transformation, urban governance, and ethical issues. Therefore, this study employs a qualitative literature review approach to analyze and synthesize relevant literature concerning AI integration into smart city management systems. Specifically, this study aims to develop a more integrated theoretical

understanding of AI as an enabling technology within smart city systems and to identify the conditions required for its implementation to support urban management that is effective, responsible, inclusive, and sustainable.

2. THEORETICAL FRAMEWORK AND HYPOTHESES

2.1 Smart City as an Urban Management System

A smart city has emerged as an approach to urban management that utilizes digital technologies, data, and connectivity to improve service quality, resource efficiency, decision-making, and citizens' quality of life. The concept does not merely refer to the use of technology but also to the ability of governments and stakeholders to integrate technology with organizational processes, institutions, and societal needs. Accordingly, a smart city can be understood as a socio-technical system that connects technology, people, organizations, and institutions in urban management. In its development, the smart city concept encompasses various dimensions, including smart governance, smart mobility, smart environment, smart economy, smart living, and smart people. Wolniak & Stecula (2024) demonstrate that the application of Artificial Intelligence (AI) in smart cities has expanded across these dimensions, including transportation, environmental management, government, the economy, and citizens' quality of life. This perspective indicates that a smart city cannot be understood as a collection of standalone technological applications. Its effectiveness depends on the ability to connect data, digital infrastructure, government processes, human resources, and decision-making mechanisms. Therefore, the development of smart cities creates a need for technologies that are not only capable of collecting data but also of transforming data into information and recommendations that can be utilized for urban management.

2.2 Artificial Intelligence in Smart Cities

Artificial Intelligence is a technology that enables computational systems to perform functions such as learning, pattern recognition, prediction, classification, optimization, and decision-making support. Within smart city systems, these capabilities provide added value because urban data can be processed into information that supports the management of various activities in a faster and more adaptive manner. Duan et al. (2019) explain that developments in AI and big data have enabled organizations to develop new capabilities in data analysis and decision-making. In urban contexts, these capabilities can be applied to analyze traffic conditions, predict energy demand, identify environmental changes, improve public services, and support urban planning. Wolniak & Stecula (2024) demonstrate that AI has been utilized across various smart city functions, including smart governance, smart mobility, smart environment, smart living, and smart economy. This demonstrates that AI has evolved from merely an analytical technology into a component capable of supporting both operational and strategic processes in urban management. However, the presence of AI does not automatically result in better urban management. Lartey & Law (2025) demonstrate that although research on AI in urban planning governance has expanded, the practical integration of AI into decision-making and policymaking continues to face various limitations. Therefore, academic attention needs to shift from merely focusing on AI adoption toward AI integration, namely how AI is connected with data, infrastructure, organizations, people, and governance processes.

2.3 Socio-Technical Systems Perspective on AI Integration

The integration of AI in smart cities needs to be understood as a socio-technical process because urban technologies continuously interact with people, organizations, institutions, and regulations. AI does not operate independently but depends on data, digital infrastructure, human resources, organizational procedures, and decisions made by governments and stakeholders. Within such systems, AI can perform analyses and generate predictions or recommendations, but the implementation of these outputs still requires human interpretation and decision-making. For example, an AI system that predicts traffic congestion requires accurate data, data-processing infrastructure, personnel capable of understanding the analytical results, and policies that determine the appropriate actions to be taken. The socio-technical perspective therefore positions technology and organizational capacity as two complementary components. Advanced technology will not generate optimal benefits if organizations lack the capacity to integrate and utilize it effectively. Lartey & Law (2025) emphasize that AI-related challenges in urban governance are not limited to technological capabilities but also involve inclusiveness, transparency, ethics, and public trust. Accordingly, AI integration needs to be understood as a process of alignment among technology, organizations, institutions, and society.

2.4 AI as an Enabler of Urban Governance

One of the strategic functions of AI in smart cities is to support urban governance. Urban governance encompasses planning, decision-making, public service delivery, resource management, inter-organizational coordination, and policy formulation. AI can strengthen these functions through its capabilities in data analytics, prediction, optimization, and decision support. In urban planning, AI can assist in analyzing land-use patterns and infrastructure needs. In transportation, AI can be used to predict traffic congestion. In public services, AI can help identify citizens' needs and improve the speed of government responses. Xie et al. (2024) demonstrate that research on smart cities and AI is increasingly associated with issues of policy, governance, sustainability, and urban management. This indicates that AI is increasingly positioned as part of decision-making systems rather than merely as an operational technology. Nevertheless, AI is more appropriately positioned as a decision-support technology rather than a replacement for human decision-making. Lartey & Law (2025) demonstrate that AI integration into urban governance still requires strengthening institutional capacity, policy frameworks, transparency, and public participation. Thus, AI can enhance government capabilities, while responsibility for public decisions remains with institutions and human decision-makers.

2.5 Integration of AI with IoT, Big Data, and Digital Infrastructure

AI in smart cities cannot be separated from the technological ecosystem that provides and manages data. The Internet of Things (IoT) provides data through sensors and devices distributed throughout the urban environment, while big data infrastructure enables the storage and processing of large volumes of information. AI subsequently utilizes these data to generate predictions, classifications, optimizations, and recommendations. This relationship forms a management cycle that can be conceptualized as sensing-processing-decision-response. Data concerning urban conditions are collected through sensors and digital systems, processed using AI technologies, utilized to support decision-making, and subsequently translated into responses to identified conditions. Technological developments have also enabled AI to be integrated with urban digital twins. Such systems allow urban conditions to be represented within digital environments, enabling various scenarios to be analyzed before decisions are implemented. This integration expands the function of AI from analyzing current conditions toward simulation and future-oriented planning support. Accordingly, AI should not be analyzed as a standalone technology. Rather, it represents a component of a digital infrastructure ecosystem consisting of data, sensors, connectivity, computing resources, digital platforms, people, and organizations. The quality of relationships among these components is an important factor determining the success of AI integration in smart cities.

2.6 AI, Efficiency, Adaptability, and Sustainability

AI integration has the potential to improve the efficiency of urban resource management through prediction and optimization capabilities. In transportation, energy, water, waste management, and infrastructure, AI can help identify resource utilization patterns and forecast future demand. These capabilities can assist governments in allocating resources more accurately and responding to changing urban conditions more rapidly. Wolniak & Stecula (2024) demonstrate that AI in smart cities has the potential to improve efficiency, optimize resources, support innovation, and enhance citizens' quality of life. However, these benefits coexist with various challenges, including security, ethics, the digital divide, and implementation constraints. AI also has the potential to strengthen urban adaptability and resilience. The ability to process data rapidly enables governments to identify changes and risks before they develop into more serious problems. Consequently, AI can help cities move from reactive approaches toward more predictive and adaptive management. However, smart city sustainability is not solely concerned with technological efficiency. Sustainable urban management must also consider social, environmental, economic, and governance dimensions. Therefore, the benefits of AI should be assessed not only in terms of technical capabilities but also based on its contribution to service effectiveness, quality of life, inclusiveness, resource efficiency, and urban sustainability.

2.7 Responsible AI and Human-Centered Smart Cities

The use of AI in public systems creates a need for responsible technology governance. AI can process large volumes of citizens' data and generate recommendations that may influence public services, security, mobility, planning, and resource distribution. This condition makes transparency, accountability, privacy, fairness,

security, and public trust important components of AI integration. Ahmad et al. (2022) emphasize the importance of a human-centered approach in the development of AI-based smart cities because the use of such technologies may create challenges related to security, interpretability, privacy, and ethics. They position humans as an essential component in the design and management of AI-based smart city systems. This perspective is reinforced by Lartey & Law (2025), who identify transparency, social justice, ethics, and public trust as important issues in the application of AI to urban governance. Thus, the success of AI integration is not determined solely by algorithmic accuracy but also by the ability of systems to produce decisions that can be justified and held accountable. A human-centered approach positions technology as a means of achieving urban management objectives rather than as an end in itself. Therefore, AI integration should be directed toward improving service quality, citizens' well-being, inclusiveness, security, and sustainability.

2.8 Theoretical Synthesis of AI Integration in Smart Cities

Based on the reviewed literature, the integration of Artificial Intelligence (AI) in smart cities can be understood as a multi-level relationship among digital infrastructure and data, AI capabilities, urban functions, and urban management outcomes. Digital infrastructure and data serve as the foundation that provides information resources for the development and implementation of AI. Subsequently, AI expands the capabilities of urban systems in performing analysis, prediction, optimization, and automation, enabling available data to be transformed into more relevant information and decision support for urban management. These AI capabilities are then applied across various urban functions, such as urban governance, mobility, environment, public services, energy, and urban planning. The application of AI across these functions can assist governments and stakeholders in understanding urban conditions, anticipating changes, optimizing resource utilization, improving service quality, and supporting decision-making. Ultimately, such integration is expected to produce urban management that is more efficient, responsive, adaptive, resilient, and sustainable.

However, the relationship between AI capabilities and urban management outcomes does not occur automatically. Human capability, organizational readiness, institutional capacity, governance, ethics, and data governance represent important conditions that determine the extent to which AI technologies can be implemented and generate tangible benefits. Adequate technological infrastructure, for example, will not produce optimal benefits if it is not supported by human resources capable of operating and interpreting AI systems. Similarly, AI's ability to process data needs to be accompanied by governance mechanisms that ensure security, privacy, transparency, accountability, and responsible data use. Therefore, AI integration in smart cities is more appropriately understood as a socio-technical process rather than merely a technology adoption process. AI interacts not only with infrastructure and data but also with people, organizations, institutions, policies, and society. This perspective is important because the success of smart cities is ultimately determined not only by technological sophistication but also by the ability of the urban ecosystem to integrate technology into urban management processes.

Conceptually, this synthesis indicates that digital infrastructure and data constitute the foundation for AI capability, which subsequently strengthens various smart city functions and generates urban outcomes. Throughout this process, governance, human capability, institutional readiness, ethics, and data governance function as enabling conditions that influence the overall integration process. Accordingly, AI is positioned in this study as an enabling technology that strengthens the capacity of smart city management systems. AI is not the ultimate objective of urban development but rather a capability that enables data and digital infrastructure to be utilized more intelligently to support various urban functions. This position is consistent with Wolniak & Stecula (2024), who demonstrate the broad range of AI applications across different dimensions of smart cities. It is also consistent with Lartey & Law (2025), who emphasize that AI implementation in urban planning and governance needs to be connected with implementation contexts, transparency, inclusiveness, fairness, ethics, and societal interests. Based on this synthesis, the conceptual framework for AI integration in smart city management systems is illustrated in Figure 1.

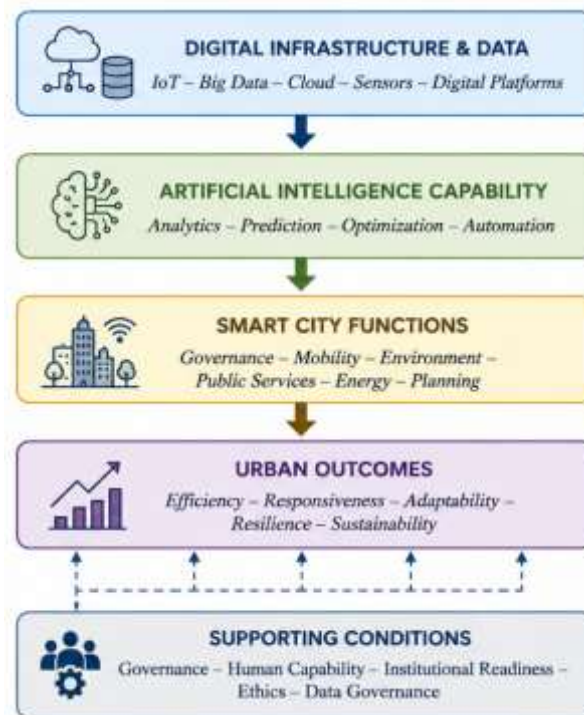


Figure 1. conceptual framework

3. RESEARCH METHOD

3.1 Research Design

This study employs a qualitative literature review approach to theoretically analyze the integration of Artificial Intelligence (AI) into smart city management systems. This approach was selected because the study focuses on identifying, interpreting, comparing, and synthesizing findings from previous research concerning the utilization of AI in urban governance, public services, decision-making, resource management, and the development of smart city systems. The review process was conducted systematically through the stages of literature searching, screening, evaluation, extraction, and synthesis. The article selection process followed the principles of PRISMA 2020 developed by Page et al. (2021), while synthesis was conducted using a thematic synthesis approach to identify patterns, themes, conceptual relationships, enabling factors, barriers, and research gaps. This study does not aim to statistically test relationships among variables but rather to develop a conceptual understanding of how AI is integrated with digital infrastructure, data, people, organizations, governance, and societal needs within smart city management systems.

3.2 Literature Search Strategy

The literature search was conducted using five academic databases: Scopus, Web of Science, ScienceDirect, IEEE Xplore, and SpringerLink. These databases were selected because they provide broad coverage of literature in the fields of artificial intelligence, information technology, information systems, smart cities, governance, and urban management. The search strategy employed a combination of keywords representing three main concepts of the study: Artificial Intelligence, smart city, and urban management/governance. The search string used was: ("Artificial Intelligence" OR "AI" OR "machine learning" OR "deep learning" OR "generative AI") AND ("smart city" OR "smart cities" OR "intelligent city" OR "digital city") AND ("urban management" OR "city management" OR "urban governance" OR "public service" OR "decision making"). The literature was limited to peer-reviewed journal articles published between 2008 and 2026 and written in English. This period was selected to capture the development of research on AI and smart cities in the context of urban digital transformation, including developments in machine learning, deep learning, big data analytics, and generative AI (see Table 1).

Table 1. Literature Search Strategy

No	Element	Criteria
1	Databases	Scopus, Web of Science, ScienceDirect, IEEE Xplore, SpringerLink
2	Keywords	“Artificial Intelligence”, “AI”, “machine learning”, “deep learning”, “generative AI”, “smart city”, “urban management”, “urban governance”, “public service”, “decision making”
3	Publication period	2008–2026
4	Language	English
5	Document type	Peer-reviewed journal articles
6	Research focus	AI integration in <i>smart cities</i> , urban governance, public services, decision-making, resource management, and urban systems
7	Synthesis technique	Thematic synthesis and conceptual synthesis

3.3 Inclusion and Exclusion Criteria

To ensure that the analyzed literature was relevant to the objectives of the study, the selection process was conducted based on predefined inclusion and exclusion criteria. Articles were included when they substantively addressed the use or integration of AI within the contexts of smart cities, urban governance, public services, decision-making, resource management, or urban management systems. Articles were excluded when they focused exclusively on the technical aspects of AI without a connection to urban contexts, were unrelated to the research focus, were duplicate publications, or did not meet the predetermined publication characteristics (see Table 2).

Table 2. Inclusion and Exclusion Criteria

No	Inclusion Criteria	Exclusion Criteria
1	Peer-reviewed journal articles	Duplicate articles
2	Published between 2008–2026	Publications outside the research period
3	Addresses AI in the context of <i>smart cities</i>	AI discussed only from a technical perspective without an urban context
4	Addresses urban governance, public services, decision-making, or urban management	No relationship with urban management systems
5	Articles written in English	Non-English articles
6	Full text available	Full text unavailable
7	Findings relevant to the research objectives	Editorials, opinion pieces, theses, reports, or conference proceedings

3.4 Literature Selection Process

The literature selection process consisted of four main stages: identification, screening, eligibility, and inclusion, following the principles of PRISMA 2020 (Page et al., 2021). During the identification stage, searches using the specified keyword combinations across the five databases produced 50 initially relevant articles. The retrieved records were subsequently examined for duplicate bibliographic information. A total of 7 duplicate articles were removed, leaving 43 articles for the screening stage. During the screening stage, the titles and abstracts of the 43 articles were examined based on their relevance to the research focus. A total of 18 articles were excluded because they did not substantively address AI in the context of smart cities, urban governance, public services, decision-making, or urban management systems. Consequently, 25 articles proceeded to the full-text eligibility assessment. During the eligibility stage, all 25 articles were examined in detail based on the inclusion and exclusion criteria. The assessment considered the research focus, AI context, relevance to smart cities, research methods, and key findings. All 25 articles met the eligibility criteria and were subsequently included as the final literature for synthesis (see Figure 2).

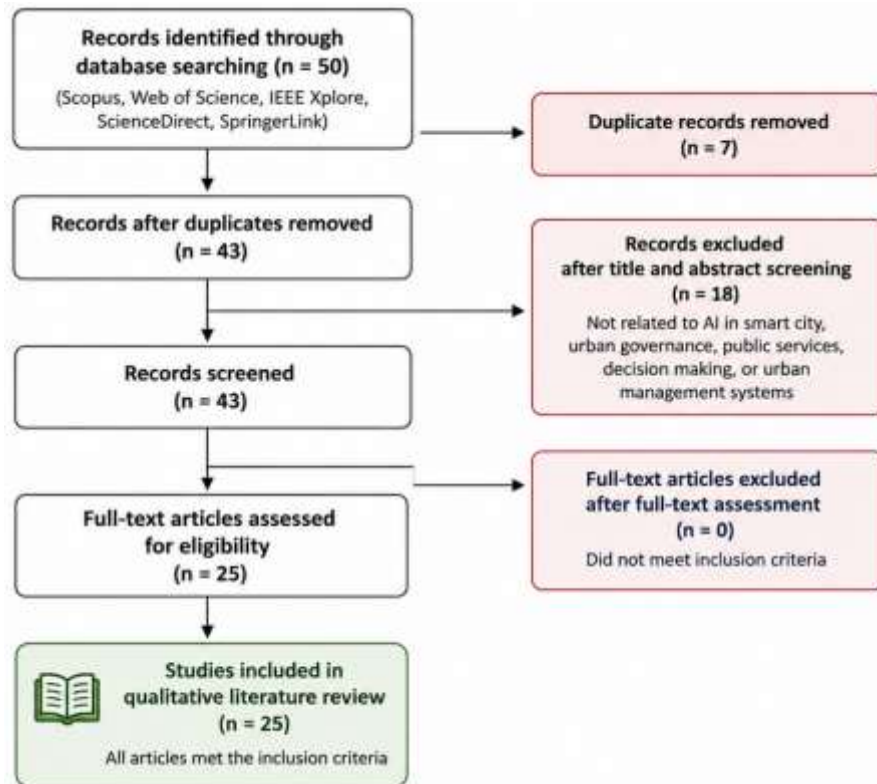


Figure 2. PRISMA Flow Diagram of Literature Selection

3.5 Data Extraction

The selected articles were systematically reviewed and relevant information was extracted to facilitate comparison and synthesis. The extraction process focused on several key elements, including the authors and publication year, research objectives, research context, AI applications, smart city dimensions, research methods, key findings, enabling factors, barriers, and implications for urban management. The extracted information was organized to identify similarities and differences across the selected studies. This process enabled the researchers to establish connections among technological capabilities, organizational factors, governance mechanisms, and urban outcomes.

3.6 Data Analysis and Synthesis

The extracted data were analyzed using a thematic synthesis approach. This approach was employed to identify themes that consistently emerged across the selected articles and subsequently integrate them into a more comprehensive conceptual understanding. The analysis was conducted in three stages. First, the main findings of each article were reviewed and interpreted. Second, findings with similar substantive meanings were coded and grouped into specific themes. Third, the identified themes were compared and integrated to explain the relationships among AI, digital infrastructure, data, smart city functions, governance, and urban management outcomes. Based on the research focus and the results of the literature categorization, the analysis was directed toward six major themes: 1. AI as an enabler of urban management transformation; 2. AI in urban governance and decision-making; 3. AI for improving public service delivery; 4. AI for urban resource efficiency and optimization; 5. Enabling factors and barriers to AI integration; and 6. Responsible AI, ethics, security, privacy, and accountability. Subsequently, the relationships among these themes were analyzed conceptually to explain how AI can function as an enabling capability within smart city management systems. The resulting synthesis provides the foundation for the discussion and for formulating the theoretical and practical implications of the study.

4. DATA ANALYSIS AND DISCUSSION

4.1 Characteristics of the Selected Literature

Based on the selection process described in Chapter 3, this study analyzed 25 articles as the basis for the synthesis. The selected literature addresses the development of smart cities, the application of Artificial Intelligence (AI), urban governance, data management, public services, digital infrastructure, sustainability, citizen participation, and various challenges emerging from the digitalization of urban management.

Table 3. Summary of the Selected Literature

No.	Authors	Research Focus	Context	Main Findings	Relevance
1	Bibri et al. (2024)	AI, AIoT, and urban digital twins	Sustainable smart cities and environmental planning	The integration of AI, AIoT, and <i>digital twins</i> enhances urban environmental modeling, prediction, simulation, and optimization capabilities.	Explains the role of AI in urban planning and sustainability.
2	Bosco et al. (2026)	Ethical assessment of AI projects	Smart city governance	AI projects need to be assessed from ethical perspectives throughout their development and implementation lifecycle.	Reinforces the importance of AI governance and ethics.
3	Rjab et al. (2023)	Barriers to AI adoption	Smart cities	Barriers to AI adoption arise from technological, organizational, and environmental factors.	Explains factors constraining AI integration.
4	Dong & Liu (2023)	AI and smart city governance	Urban governance	AI supports service transformation, participation, sustainability, and data management, while also creating ethical and privacy concerns.	Provides a basis for understanding AI as part of <i>smart governance</i> .
5	Lartey & Law (2025)	AI adoption in urban planning governance	Urban planning and policymaking	AI has the potential to improve decision-making and policymaking, but practical implementation continues to face challenges related to inclusiveness, transparency, fairness, and public trust.	Explains the gap between AI potential and implementation.
6	Allam & Dhunny (2019)	AI and smart cities	Urban development	AI has the potential to improve urban system efficiency and support data-driven urban management.	Provides an early foundation for the relationship between AI and <i>smart cities</i> .
7	Bibri & Krogstie (2019)	Smart sustainable cities	Urban sustainability	Smart technologies can support sustainable urban development through the integration of data and digital systems.	Supports the relationship between AI, smart technologies, and sustainability.
8	Yigitcanlar et al. (2018)	Smart city technology and urban development	Smart city planning	Successful <i>smart cities</i> require a combination of technology, governance, people, and institutions.	Emphasizes an ecosystem-based approach to <i>smart cities</i> .
9	Kitchin (2017)	Data-driven urbanism	Urban data governance	The use of urban data can improve decision-making but also creates issues related to privacy and power.	Highlights the importance of data governance.
10	Calzada (2021)	Smart cities and citizen participation	Urban governance	<i>Smart cities</i> need to consider citizen participation and public interests.	Reinforces the human-centered <i>smart city</i> approach.
11	Cardullo & Kitchin (2019)	Citizen-centered smart city	Urban citizenship	Overly technology-oriented <i>smart city</i> models risk overlooking citizens as key urban actors.	Emphasizes the social dimension of AI integration.
12	Mora et al. (2019)	Smart city implementation	Urban transformation	Successful <i>smart city</i> implementation is influenced by technological, organizational, institutional, and social factors.	Supports the concept of ecosystem readiness.
13	Ruhlandt (2018)	Smart city governance	Municipal governance	Governance is an essential element in the success of <i>smart cities</i> .	Reinforces the relationship between

						technology and governance.
14	Meijer & Bolívar (2016)	Smart city governance	Public governance		<i>Smart cities</i> require the integration of technology with governance and institutional capacity.	Provides a conceptual foundation for technology-government integration.
15	Bibri & Krogstie (2017)	Smart sustainable city	Sustainable urban development		The integration of digital technologies can support urban efficiency and sustainability.	Supports the sustainability dimension.
16	Albino et al. (2015)	Smart city dimensions	Urban development		<i>Smart cities</i> encompass technological, human, institutional, economic, and environmental dimensions.	Provides a foundation for the multidimensionality of <i>smart cities</i> .
17	Batty et al. (2012)	Smart cities and urban systems	Urban complexity	com-	Digital technologies can improve the understanding and management of complex urban systems.	Explains the need for analytics in urban management.
18	Townsend (2013)	Smart cities and digital technology	Urban innovation		Digital technologies transform how cities are managed and how they interact with citizens.	Supports the digital transformation perspective.
19	Hollands (2008)	Critical smart city perspective	Urban governance		<i>Smart cities</i> need to be critically examined to avoid becoming overly oriented toward technological and economic interests.	Reinforces the critical perspective on AI.
20	Nam & Pardo (2011)	Smart city framework	Urban innovation		<i>Smart cities</i> represent a combination of technology, people, and institutions.	Provides a foundation for integrating different smart city elements.
21	Chourabi et al. (2012)	Smart city success factors	Urban governance		Smart city success is influenced by technology, organizations, policies, governance, and citizens.	Supports the framework of factors enabling AI integration.
22	Hashem et al. (2016)	Big data in smart cities	Urban data management		<i>Big data</i> enables improved analytics and decision-making in <i>smart cities</i> .	Explains the importance of data as an input for AI.
23	Zanella et al. (2014)	IoT for smart cities	Urban infrastructure		IoT enables real-time data collection from various urban systems.	Explains the data infrastructure supporting AI.
24	Batty (2018)	Artificial intelligence and urban systems	Urban analytics		AI has the potential to improve the analysis and modeling of urban systems.	Explains AI as an analytical capability.
25	Allam & Jones (2021)	AI and urban development	Smart and sustainable cities		AI can support decision-making, public services, and sustainability but requires strong governance.	Connects AI, <i>smart cities</i> , and sustainable development.

The table demonstrates that the analyzed literature does not examine AI solely from a technological perspective but also from the perspectives of data, people, organizations, institutions, governance, public services, and sustainability. Thus, AI integration in smart cities can be understood as a multidimensional phenomenon. Chronologically, earlier literature provides the conceptual foundation for understanding how digital technologies, data, and governance shape smart city systems. More recent literature, meanwhile, demonstrates the development of AI as an increasingly integrated analytical and predictive capability within urban planning, decision-making, public service delivery, and urban resource management.

4.2 AI as an Enabler in Smart City Management Systems

The synthesis indicates that Artificial Intelligence (AI) can be positioned as a strategic enabler that connects urban data and digital infrastructure with the broader processes of urban management. This interpretation extends the conventional understanding of AI as merely an advanced technological application because its contribution depends fundamentally on how it is embedded within the socio-technical architecture of a city. The early development of the smart city concept provides an important foundation for this argument. Nam

& Pardo (2011) explain that a smart city is formed through the interaction of technology, people, and institutions, suggesting that technological sophistication alone is insufficient to produce meaningful urban transformation. This perspective becomes increasingly relevant with the integration of AI because algorithms require reliable data, competent human actors, organizational routines, and institutional arrangements before their analytical outputs can be translated into public value. Similarly, Batty et al. (2012) conceptualize cities as complex systems characterized by multiple interconnected components, dynamic interactions, and continuous flows of information. Such complexity creates a need for analytical capabilities capable of identifying patterns and relationships that may not be easily detected through conventional urban management approaches. Within this context, AI expands the capacity of city governments to process heterogeneous and rapidly changing urban data, while Batty (2018) further demonstrates how AI can strengthen the modeling and analysis of increasingly complex urban systems.

The enabling role of AI becomes more evident when it is examined in relation to the data infrastructure underlying smart city systems. Hashem et al. (2016) demonstrate that big data provides an important foundation for improving analytical and decision-making capabilities in smart cities, while Zanella et al. (2014) explain that the Internet of Things (IoT) enables continuous and real-time data collection from transportation networks, buildings, environmental sensors, utilities, and other urban infrastructures. However, data availability does not automatically produce better urban management. The strategic value of urban data emerges when data can be transformed into meaningful information and actionable knowledge. AI provides this transformation capability by identifying patterns, detecting anomalies, generating forecasts, classifying conditions, and producing recommendations based on large volumes of urban data. Consequently, the integration of IoT, big data, and AI creates an interconnected analytical ecosystem in which urban conditions can be continuously observed, interpreted, predicted, and managed. Allam & Dhunny (2019) demonstrate that AI has the potential to improve the efficiency of urban systems and strengthen data-driven management, while Allam & Jones (2021) broaden this perspective by linking AI capabilities with urban decision-making, public services, and sustainability. Therefore, the strategic contribution of AI originates not from algorithms in isolation but from their ability to connect data-generating infrastructure with managerial and institutional processes.

Accordingly, AI should be conceptualized as an integrating capability within smart city management systems rather than as a standalone technological component. Its primary contribution lies in transforming fragmented urban data into analysis, predictions, recommendations, and operational actions that can support continuous urban management. This process can be represented as Urban Data → AI Analysis → Prediction/Recommendation → Decision → Action → Evaluation, illustrating that AI occupies an intermediary position between digital information and managerial intervention. More importantly, the evaluation stage creates the possibility of feedback through which previous decisions and outcomes can generate new data for subsequent analysis, thereby producing a continuous learning cycle within urban management systems. This interpretation also changes the way smart city performance should be evaluated. The success of an AI-enabled smart city should not be measured primarily by the number of sensors, algorithms, platforms, or AI applications deployed, but by the extent to which these technologies improve the capacity of urban institutions to understand problems, anticipate change, coordinate interventions, and generate public value. Thus, the synthesis suggests that AI creates strategic value when technological capabilities are effectively integrated with data infrastructure, human expertise, organizational processes, and institutional governance.

4.3 AI in Urban Governance and Decision-Making

One of the strongest patterns emerging from the literature is the increasing role of AI in transforming urban governance and decision-making from predominantly reactive processes toward more data-driven, anticipatory, and evidence-informed approaches. Traditional urban decision-making frequently relies on historical reports, administrative routines, professional experience, and periodic assessments, whereas AI allows governments to process large volumes of continuously generated data and identify emerging conditions more rapidly. Batty (2018) demonstrates the potential of AI for analyzing complex urban systems, while Allam & Jones (2021) emphasize its contribution to decision-making in urban development. These capabilities potentially enable city governments to move beyond simply understanding what has already occurred toward explaining current conditions and anticipating what may occur in the future. Predictive analytics, for example, can support the identification of congestion risks, infrastructure deterioration, environmental hazards,

changes in public service demand, or spatial development patterns before these problems become more difficult or costly to manage. Nevertheless, technological capability does not automatically produce smart governance. Meijer & Bolívar (2016) emphasize that smart city development requires the integration of technological innovation with governance capacity, while Ruhlandt (2018) similarly identifies governance as a fundamental dimension determining the effectiveness of smart city initiatives.

The growing use of AI also changes the nature of governance because algorithms increasingly participate in processes previously dominated by human interpretation and administrative judgment. Dong & Liu (2023) demonstrate that AI in smart city governance is associated not only with efficiency but also with public service transformation, citizen participation, sustainability, data management, ethics, and privacy. This suggests that AI is gradually becoming part of the institutional architecture through which governments understand urban problems, allocate resources, establish priorities, and design policy responses. However, this development simultaneously introduces new governance questions concerning who determines algorithmic objectives, which data are considered relevant, how recommendations are produced, and who remains accountable when AI-assisted decisions generate unintended consequences. Lartey & Law (2025) further demonstrate that the implementation of AI in urban planning and policymaking continues to face challenges related to inclusiveness, transparency, fairness, and public trust. Therefore, improvements in analytical capacity must be accompanied by mechanisms that preserve institutional accountability and democratic legitimacy. The more influential AI becomes in public decision-making, the more important it becomes to ensure that technological recommendations remain understandable, contestable, and subject to appropriate human and institutional oversight.

Based on these findings, the synthesis supports the concept of AI-assisted decision-making rather than fully automated governance. AI can expand the informational and analytical capacity of governments by generating predictions, scenarios, risk assessments, and recommendations, but the interpretation and authorization of consequential public decisions should remain embedded within human judgment and institutional responsibility. This distinction is particularly important because urban decisions frequently involve competing interests, distributive consequences, ethical considerations, and social values that cannot be reduced entirely to optimization problems. An algorithm may identify the technically most efficient allocation of transportation resources, for example, but policymakers must still determine whether the resulting allocation is socially equitable and politically legitimate. Therefore, AI should strengthen rather than replace governmental capacity. The strategic value of AI in governance emerges when computational intelligence is combined with professional expertise, citizen knowledge, institutional rules, and public values. From this perspective, smart governance is not achieved when algorithms make more decisions independently, but when governments become better able to use AI-generated evidence while preserving transparency, accountability, inclusiveness, and human responsibility.

4.4 AI for Improving Public Service Delivery

The synthesis further demonstrates that AI has substantial potential to transform public service delivery by enabling governments to provide services that are faster, more responsive, personalized, and increasingly proactive. Allam & Dhunny (2019) demonstrate the potential of AI to improve the efficiency of urban systems, while Dong & Liu (2023) identify public service transformation as an important theme in the development of AI-based smart city governance. Within public administration, these capabilities can be applied through automated information services, intelligent chatbots, complaint classification systems, administrative document processing, predictive maintenance, transportation management, healthcare support, emergency response, and various forms of digital citizen interaction. The significance of AI in this context extends beyond automation because predictive capabilities can potentially enable governments to anticipate service needs before citizens submit formal requests. For example, patterns in transportation, demographic, environmental, or administrative data can help identify locations or population groups experiencing increasing service demand. Consequently, AI may contribute to a transition from reactive public services, in which governments respond after problems occur, toward more anticipatory service models based on continuous analysis of urban conditions.

However, greater efficiency does not necessarily mean higher-quality public services. A technology-oriented approach may create services that are operationally efficient but socially inaccessible, difficult to understand, or unable to accommodate citizens whose circumstances do not correspond to standardized al-

algorithmic categories. Cardullo & Kitchin (2019) warn that technology-centered smart city models may position citizens merely as users, consumers, or data sources rather than as active participants in urban governance. Calzada (2021) similarly emphasizes the importance of citizen participation and the public interest in smart city development. These arguments are particularly important for AI-enabled public services because automation can unintentionally reduce opportunities for human interaction and discretion. Citizens with limited digital literacy, inadequate internet access, disabilities, language barriers, or unusual administrative circumstances may experience greater difficulties when public services become predominantly automated. Therefore, the evaluation of AI-enabled public services cannot be limited to indicators such as processing time, administrative cost, or transaction volume. Accessibility, inclusiveness, fairness, explainability, privacy, and opportunities for human intervention must also be considered essential dimensions of service quality.

The synthesis therefore suggests that AI-based public service transformation should be guided by a citizen-centered rather than technology-centered logic. Under this perspective, AI functions as a tool for strengthening government responsiveness while human institutions remain responsible for ensuring that services reflect diverse citizen needs and public values. Effective implementation should combine automated processes for routine and high-volume activities with accessible human channels for complex, sensitive, or contested cases. This hybrid approach allows governments to benefit from the scalability and analytical capabilities of AI without eliminating the contextual judgment and empathy required in public administration. Furthermore, AI-generated service data can create feedback mechanisms through which governments continuously identify recurring complaints, service bottlenecks, emerging demands, and underserved communities. Consequently, the strategic contribution of AI lies not simply in digitizing existing public services but in redesigning them around evidence, responsiveness, accessibility, and continuous learning. In this sense, successful AI integration should reduce rather than increase the distance between governments and citizens, while strengthening public value through services that are efficient, inclusive, accountable, and responsive.

4.5 AI for Urban Resource Efficiency and Optimization

The literature also demonstrates that AI plays an increasingly strategic role in improving the efficiency and optimization of urban resources. Modern cities operate through interconnected systems of transportation, energy, water, waste management, buildings, environmental infrastructure, and public facilities, all of which continuously generate operational data. Zanella et al. (2014) demonstrate that IoT technologies enable real-time data generation and collection across urban infrastructures, while Hashem et al. (2016) explain that big data provides cities with enhanced analytical capabilities for decision-making. AI increases the value of these data by enabling governments to identify patterns, predict demand, detect anomalies, and determine more efficient resource allocation strategies. This capability is particularly important because conventional urban management frequently depends on fixed schedules, historical averages, or standardized operating procedures that may not accurately reflect rapidly changing urban conditions. By contrast, AI can enable more dynamic management based on actual and predicted demand. Consequently, resource allocation can potentially become more adaptive, allowing urban systems to respond to changing traffic volumes, energy consumption, water demand, waste generation, environmental conditions, and infrastructure performance.

The emergence of AIoT and urban digital twins further expands this optimization capability. Bibri et al. (2024) demonstrate that the integration of AI, AIoT, and urban digital twins can strengthen environmental modeling, prediction, simulation, and optimization. Digital twins are particularly significant because they enable urban managers to create virtual representations of physical systems and evaluate potential interventions before implementing them in the real environment. In transportation management, for example, different traffic-control scenarios can be simulated to identify strategies that reduce congestion. In energy systems, AI can forecast consumption patterns and support more efficient distribution. Water demand can be predicted to improve supply planning, while waste collection routes can be dynamically adjusted based on actual generation patterns. Similarly, infrastructure data can be analyzed to detect early indications of deterioration and enable predictive maintenance before failure occurs. These applications demonstrate that AI contributes not merely to operational automation but also to a more fundamental transformation in how urban resources are understood and managed. Urban management gradually shifts from static planning toward continuous monitoring, prediction, simulation, and adaptive optimization.

Accordingly, the synthesis identifies a progression from descriptive management toward predictive and prescriptive urban management. Descriptive analytics explains what is happening, predictive analytics estimates what is likely to happen, while optimization and prescriptive analytics help determine what actions

should be taken under different conditions. This progression represents one of the most strategically important contributions of AI to smart city management because urban governments are increasingly required to manage limited resources under conditions of population growth, climate uncertainty, infrastructure pressure, and rapidly changing demand. Nevertheless, optimization should not be interpreted exclusively in technical or economic terms. A mathematically efficient allocation of resources may not necessarily be socially equitable or environmentally sustainable. Therefore, AI-generated optimization needs to be interpreted within broader policy objectives, including accessibility, social inclusion, environmental protection, resilience, and quality of life. AI provides the analytical capacity to identify more efficient alternatives, but governments remain responsible for determining which alternatives are consistent with public values and long-term urban objectives.

4.6 AI, Smart Cities, and Urban Sustainability

Sustainability emerges as another major theme connecting AI with smart city development. Bibri & Krogstie (2017) and Bibri & Krogstie (2019) explain that digital technologies can contribute to sustainable urban development by improving efficiency, information processing, coordination, and the management of urban systems. From this perspective, technology is not merely an instrument of modernization but a potential mechanism through which cities can pursue economic, social, and environmental objectives simultaneously. AI strengthens this potential by enabling cities to analyze complex relationships among resource consumption, mobility patterns, environmental conditions, infrastructure utilization, and human activities. Allam & Jones (2021) similarly connect AI with urban decision-making, public services, and sustainable development, suggesting that AI can support governments in managing the increasingly complex trade-offs associated with urban growth. This is particularly important because sustainability challenges are characterized by interdependence: transportation policies influence emissions, land use affects mobility, energy consumption influences environmental performance, and infrastructure investment affects both economic development and social accessibility. AI can help reveal these relationships and provide analytical support for more integrated sustainability strategies.

The development of AIoT and digital twins provides additional opportunities for strengthening sustainability-oriented urban management. Bibri et al. (2024) demonstrate that AI, AIoT, and urban digital twins can support environmental planning through modeling, prediction, simulation, and optimization. These capabilities enable policymakers to evaluate potential environmental consequences before interventions are implemented and to continuously adjust policies as new data become available. For instance, AI can support the optimization of energy consumption, identification of pollution patterns, prediction of environmental risks, improvement of waste management, and evaluation of alternative transportation or land-use scenarios. Nevertheless, technological capability should not be equated automatically with sustainability. Yigitcanlar et al. (2018) emphasize that successful smart city development requires the integration of technology with people, governance, institutions, and broader urban objectives. An AI system that improves energy efficiency but excludes vulnerable communities, increases surveillance, or generates significant institutional dependence on opaque technological systems cannot necessarily be considered sustainable. Sustainability therefore requires a broader assessment of how technological benefits and risks are distributed across society.

The synthesis consequently positions AI as an enabling mechanism for sustainability rather than sustainability itself. Its contribution depends on the objectives embedded in AI applications and the institutional capacity to align technological optimization with environmental protection, social equity, economic viability, resilience, and quality of life. This distinction prevents technological determinism – the assumption that more advanced technology will automatically produce more sustainable cities. Instead, AI should be understood as increasing the capacity of governments to observe environmental conditions, anticipate risks, evaluate alternatives, and optimize interventions. Human institutions must still determine which sustainability objectives are prioritized and how trade-offs among efficiency, equity, growth, and environmental protection are resolved. Therefore, sustainable smart city development requires the alignment of AI capability, sustainability objectives, institutional governance, and citizen interests. When these dimensions are effectively integrated, AI can contribute not only to reducing resource inefficiencies but also to strengthening cities' adaptive capacity and resilience in responding to long-term environmental and socioeconomic challenges.

4.7 Enabling Factors for AI Integration in Smart Cities

The synthesis of the 25 selected articles demonstrates that successful AI integration requires substantially broader readiness than technological readiness alone. Nam & Pardo (2011) identify technology, people, and institutions as fundamental components of smart city development, while Chourabi et al. (2012) demonstrate that smart city initiatives are shaped by multiple dimensions, including technology, organizations, policies, governance, and citizens. Mora et al. (2019) similarly demonstrate that smart city implementation depends on the interaction of technological, organizational, institutional, and social factors, while Yigitcanlar et al. (2018) emphasize the importance of an ecosystem-based approach. These perspectives challenge the assumption that AI integration can be achieved simply by purchasing advanced software, deploying sensors, or establishing data platforms. Instead, AI adoption should be understood as an organizational and institutional transformation in which technological systems must be integrated with administrative processes, human competencies, governance structures, and public policy. Rjab et al. (2023) reinforce this interpretation by categorizing barriers to AI adoption into technological, organizational, and environmental dimensions, demonstrating that the effectiveness of AI depends substantially on the readiness of the surrounding ecosystem.

Several interdependent enabling conditions can be identified from the synthesis. First, data quality and integration are fundamental because AI systems require accurate, relevant, timely, representative, and interoperable data. Second, digital infrastructure—including IoT systems, communication networks, cloud computing, data platforms, and computing capacity—provides the technical foundation for collecting and processing urban information. Third, human resource capability is necessary because government personnel must be able not only to operate AI applications but also to interpret outputs, recognize limitations, question recommendations, and translate analytical results into administrative actions. Fourth, organizational and institutional readiness is required to align leadership, budgets, structures, procurement processes, standard operating procedures, and interdepartmental coordination with AI implementation. Fifth, interoperability becomes critical because transportation, energy, healthcare, environmental, security, and public service systems frequently operate through separate institutional and technological architectures. Without interoperability, AI may reproduce existing organizational silos rather than create integrated smart city management. Sixth, policy and regulatory support is necessary to establish legitimate rules concerning data access, privacy, security, algorithmic accountability, and institutional responsibility.

More importantly, these enabling conditions should not be treated as independent variables but as mutually reinforcing components of an AI readiness ecosystem. High-quality data provide limited value without adequate infrastructure, while advanced infrastructure provides limited benefits if public officials lack the capacity to interpret AI-generated information. Similarly, technically sophisticated AI systems may fail to create public value when institutional responsibilities are unclear or regulations prevent responsible data sharing. This interdependence explains why similar technologies may produce different outcomes across cities with different organizational and governance capacities. Therefore, the synthesis suggests a transition from the concept of technology readiness toward ecosystem readiness, in which AI implementation depends on the alignment of data, infrastructure, people, organizations, institutions, interoperability, and policy. This finding has important implications for city governments because investment strategies should not concentrate exclusively on acquiring technology. Sustainable AI integration requires parallel investment in institutional reform, human capital development, data governance, interorganizational coordination, and regulatory capacity.

4.8 Barriers and Risks of AI Integration in Smart Cities

Despite its potential benefits, the integration of AI into smart city systems generates substantial technological, institutional, ethical, and social risks that require systematic management. Cardullo & Kitchin (2019) demonstrate that data-intensive urban governance may enhance analytical capacity while simultaneously generating concerns regarding privacy, surveillance, and control over urban data. These concerns become increasingly significant when data are processed through AI because algorithmic systems can combine multiple datasets, infer behavioral patterns, and produce classifications or predictions that may affect individuals and communities. Dong & Liu (2023) similarly identify ethics, risk management, and data privacy as important dimensions of AI-based smart city governance, while Rjab et al. (2023) demonstrate that barriers to AI adoption extend beyond technical limitations to organizational and environmental conditions. The synthesis therefore identifies several interconnected risks, including data privacy violations, algorithmic bias, limited transparency, unclear accountability, cybersecurity vulnerabilities, digital exclusion, inadequate institutional

capability, and excessive reliance on technological systems. These risks indicate that the same capabilities that make AI powerful for urban management can also generate new vulnerabilities when implementation occurs without adequate governance.

A deeper concern relates to the possibility that AI may reproduce or intensify existing social and institutional inequalities. Algorithms learn from data generated within existing social systems; consequently, historical inequalities or underrepresentation within datasets may influence AI-generated recommendations. The critical perspective developed by Hollands (2008) remains highly relevant because smart cities should not be reduced to technologically sophisticated or economically competitive urban projects while neglecting broader societal interests. Cardullo & Kitchin (2019) similarly emphasize that citizens should be positioned as active urban actors rather than passive data subjects. If AI systems are primarily designed around efficiency objectives without sufficient attention to accessibility, rights, and representation, certain populations may benefit disproportionately while others experience exclusion or increased surveillance. Lartey & Law (2025) reinforce this concern by emphasizing equity, transparency, inclusiveness, and public trust in AI-based urban governance. Therefore, algorithmic performance alone cannot serve as the primary criterion for evaluating AI systems in the public sector; their distributive and societal consequences must also be considered.

The central challenge of AI integration is therefore not simply whether an algorithm works technically, but whether it operates fairly, transparently, securely, accountably, and legitimately within the public sphere. This distinction is critical because urban governance involves decisions that affect citizens' rights, opportunities, mobility, access to services, and quality of life. Risk management should consequently be embedded throughout the AI lifecycle rather than introduced only after problems emerge. Governments need mechanisms for data protection, cybersecurity, bias assessment, algorithmic auditing, transparency, public communication, human oversight, and channels through which citizens can question or contest AI-assisted decisions. Furthermore, excessive dependence on automated systems may create institutional vulnerability if governments gradually lose internal expertise or become dependent on external technology providers. Thus, responsible AI integration requires not only technical risk mitigation but also institutional capability, democratic oversight, and continuous evaluation of social consequences. The synthesis ultimately suggests that managing AI risks is not an obstacle to smart city innovation; rather, responsible risk governance is itself a prerequisite for sustainable and publicly legitimate innovation.

4.9 AI Governance as a Key Element of Smart Cities

As AI becomes increasingly embedded within urban management, AI governance emerges as a critical institutional requirement for ensuring that technological capabilities remain aligned with public objectives and societal values. Meijer & Bolívar (2016) emphasize that smart city technologies must be integrated with institutional and governance capacity, while Ruhlandt (2018) similarly demonstrates that governance is fundamental to the successful implementation of smart city initiatives. These arguments become even more important when applied to AI because algorithmic systems can influence public decisions, service allocation, risk assessment, and resource prioritization. AI governance can therefore be understood as an extension of smart governance that specifically addresses how algorithms, data, models, and automated recommendations are designed, implemented, monitored, and controlled within public institutions. The objective is not merely to regulate technology but to clarify institutional responsibilities, define acceptable uses, protect citizen rights, and establish mechanisms through which technological performance and societal consequences can be continuously evaluated.

Bosco et al. (2026) strengthen this perspective by demonstrating that AI projects in smart cities should be evaluated ethically throughout their development and implementation lifecycle. This lifecycle perspective is particularly important because ethical and governance problems may originate long before an AI system becomes operational. Decisions concerning which data are collected, which variables are selected, how models are trained, which performance indicators are prioritized, and how automated outputs are presented can shape subsequent social outcomes. Consequently, governance should operate throughout the cycle of Data Collection → Model Development → Deployment → Decision Support → Monitoring → Evaluation. At the data-collection stage, privacy, consent, representativeness, and data security become central concerns. During model development, attention should be directed toward data quality, bias, explainability, and model validity. Deployment requires clear institutional responsibilities and human oversight, while monitoring and evaluation should examine not only technical accuracy but also fairness, public impact, cybersecurity, and

unintended consequences. This lifecycle approach shifts AI governance from reactive regulation toward continuous institutional oversight.

The synthesis therefore indicates that mature smart city development requires the simultaneous advancement of smart technology and smart governance. Technology provides the capacity to analyze complex urban data, generate predictions, automate processes, and optimize resources, while governance determines whether these capabilities are deployed responsibly and legitimately. This relationship is complementary rather than restrictive: effective governance can increase public trust, reduce implementation risks, clarify accountability, and thereby support the sustainable scaling of AI applications. In this sense, privacy, transparency, accountability, fairness, security, and human oversight should not be viewed merely as compliance requirements but as dimensions of institutional capability. A city with advanced AI systems but weak governance may be technologically sophisticated while remaining institutionally vulnerable. Conversely, a city that combines technological innovation with strong governance mechanisms is more capable of converting AI capabilities into sustainable public value. AI governance should therefore be treated as a core component of smart city management rather than as an additional regulatory layer imposed after technological implementation.

4.10 Conceptual Synthesis of AI Integration in Smart City Management Systems

Based on the synthesis of the 25 selected articles, AI integration in smart cities can be conceptualized as a multi-stage socio-technical process connecting digital infrastructure and urban data with AI capabilities, smart city functions, governance mechanisms, and urban management outcomes. The conceptual foundation originates from the broader smart city literature. Nam & Pardo (2011) emphasize the interaction among technology, people, and institutions, while Chourabi et al. (2012) demonstrate that smart city development is influenced by technology, organizations, policies, governance, and citizens. These perspectives indicate that AI should not be positioned as an autonomous technological layer operating independently from urban institutions. Rather, AI represents a capability that increases the capacity of urban systems to transform increasingly large, heterogeneous, and dynamic datasets into actionable knowledge. Batty (2018) demonstrates how AI expands analytical capabilities for understanding complex urban systems, while Allam & Jones (2021) connect these capabilities with urban decision-making, public service delivery, and sustainable development. Thus, the conceptual role of AI is fundamentally transformational: it converts digital resources into analytical capabilities that can subsequently influence urban management processes.

The synthesis identifies three primary mechanisms through which this transformation occurs: intelligent decision-making, public service transformation, and urban resource optimization. Intelligent decision-making refers to the ability of AI to generate predictions, scenarios, risk assessments, and recommendations that strengthen the evidence base available to policymakers and urban managers. Public service transformation involves the use of AI to improve service responsiveness, automate routine administrative processes, anticipate demand, and create more adaptive interactions between governments and citizens. Resource optimization involves applying AI to transportation, energy, water, waste, environmental management, infrastructure, and other urban systems to improve allocation, prediction, simulation, and operational efficiency. Bibri et al. (2024) demonstrate that AI, AIoT, and urban digital twins can significantly strengthen modeling, prediction, simulation, and optimization capabilities, illustrating the growing sophistication of these mechanisms. However, the synthesis also demonstrates that these relationships are conditional. Data quality, digital infrastructure, human capability, organizational readiness, interoperability, and policy support function as enabling factors that determine whether technological capabilities can actually be translated into effective urban management.

Accordingly, the conceptual synthesis can be summarized through four interconnected stages: (1) Digital Infrastructure and Urban Data → (2) AI Capability → (3) Smart City Functions and Decision Support → (4) Urban Management Outcomes. AI capability transforms urban data through analysis, prediction, automation, and optimization; these capabilities subsequently support governance, public service transformation, and resource management, ultimately contributing to urban systems that are more efficient, responsive, adaptive, resilient, and sustainable. However, this relationship is not linear or technologically deterministic. Governance mechanisms—including privacy, transparency, accountability, fairness, security, and human oversight—operate across the entire process and determine whether technological benefits can be converted into legitimate public value. This interpretation is reinforced by Bosco et al. (2026), who emphasize the importance of integrating ethical considerations throughout the AI development and implementation

lifecycle. Therefore, AI integration should ultimately be understood as capability integration rather than technology adoption. Its success depends on the capacity of the smart city ecosystem to align technology, data, people, organizations, institutions, and governance around clearly defined urban and public objectives.

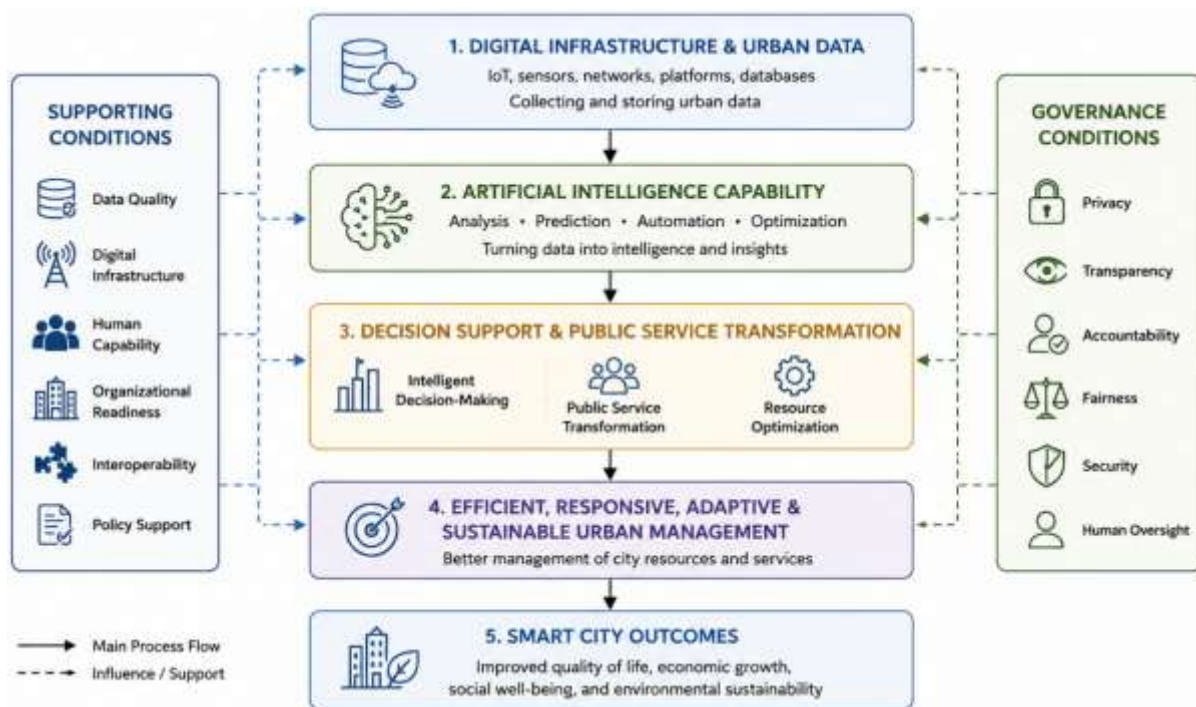


Figure 3. Conceptual Synthesis of Artificial Intelligence Integration in Smart City Management

The conceptual model developed from this synthesis demonstrates that AI occupies an intermediary enabling position between digital resources and urban management outcomes. Digital infrastructure and urban data constitute the input layer, while AI provides the analytical capability required to transform these inputs into predictions, automation, recommendations, simulations, and optimization. These capabilities subsequently operate through three principal mechanisms – intelligent decision-making, public service transformation, and resource optimization – which represent the primary pathways through which AI contributes to urban management. The model therefore distinguishes technological capability from managerial outcomes and avoids assuming that AI adoption automatically produces a smarter city. Instead, technological capabilities must first be embedded within operational and institutional processes before they can generate meaningful improvements in urban management.

The second important implication of the model is that enabling factors operate as foundational conditions across the entire AI integration process. Data quality determines the reliability of analytical outputs; digital infrastructure determines the capacity to collect and process urban information; human capability determines whether AI outputs can be critically interpreted; organizational readiness determines whether recommendations can be incorporated into administrative processes; interoperability determines whether fragmented urban systems can exchange information; and policy support provides the institutional legitimacy required for responsible implementation. Consequently, differences in these enabling conditions may explain why cities adopting similar AI technologies can experience substantially different outcomes. The model therefore emphasizes that technological investment should be accompanied by organizational, institutional, and human-capital development if AI is expected to generate sustainable urban value.

Finally, governance functions as a cross-cutting mechanism surrounding all stages of the conceptual model. Privacy, transparency, accountability, fairness, cybersecurity, and human oversight should not be treated as separate outcomes but as conditions shaping how AI capabilities are developed and applied. This leads to the central conclusion of the synthesis: AI does not make a city smart by itself; rather, AI strengthens the capacity of an already developing smart city ecosystem to understand, anticipate, coordinate, and respond to urban challenges. The ultimate contribution of AI therefore depends on the quality of integration

between technological intelligence and institutional intelligence. When these dimensions are effectively aligned, AI can contribute to urban management that is more efficient, responsive, adaptive, resilient, and sustainable. When they are poorly aligned, technological sophistication may instead generate fragmentation, inequality, institutional dependency, and declining public trust. This socio-technical interpretation provides a more comprehensive foundation for understanding AI integration in smart city management systems and constitutes the central conceptual contribution derived from the 25 selected articles.

4.11 Research Gap

The synthesis of the 25 selected articles reveals several important research gaps that indicate that the development of AI in smart cities remains conceptually advanced but empirically and institutionally incomplete. The first gap concerns the distance between the technological potential of AI and its practical implementation within government structures. Lartey & Law (2025) demonstrate that research on AI in urban planning and governance has expanded considerably, yet the translation of AI capabilities into actual governmental processes continues to face challenges related to institutional readiness, organizational routines, policy structures, and public acceptance. This indicates that the literature has been more successful in explaining what AI is technically capable of doing than in explaining how these capabilities can be sustainably embedded within public-sector organizations. A second gap relates to the sectoral fragmentation of existing research. AI applications are frequently examined separately in transportation, energy, environmental management, healthcare, security, infrastructure, or public services, even though these functions operate as interconnected components of the same urban system. Such fragmentation limits understanding of how AI-generated information from one sector can influence decisions in another. For example, transportation data may have implications for energy consumption, environmental quality, land-use planning, and public health. Therefore, future research needs to move beyond isolated sectoral applications toward integrated models that conceptualize AI as part of a cross-sector urban management architecture in which data, analytical capabilities, and decisions circulate between different governmental functions.

A third major gap concerns the imbalance between technological development and governance-oriented research. Much of the existing literature emphasizes analytical capabilities, automation, prediction, optimization, and technological efficiency, while comparatively less attention has been given to the institutional mechanisms required to ensure that AI operates transparently, fairly, accountably, and in accordance with the public interest. Bosco et al. (2026) demonstrate the importance of incorporating ethical considerations throughout the AI development and implementation lifecycle, while Cardullo & Kitchin (2019) and Hollands (2008) provide critical perspectives on technology-centered models of smart cities that may marginalize citizens or prioritize technological efficiency over broader societal objectives. This imbalance is closely connected with a fourth gap concerning the need for a stronger human-centered smart city perspective. Calzada (2021) emphasizes citizen participation as a fundamental element of smart urban development, while Cardullo & Kitchin (2019) demonstrate the risks of positioning citizens merely as technology users or data subjects. Consequently, future research should examine not only whether AI increases operational efficiency but also whether AI-supported urban systems improve accessibility, equity, trust, participation, and quality of life. This requires research designs capable of incorporating citizen perceptions, public trust, digital inclusion, institutional legitimacy, and human oversight alongside conventional measures of technological performance. The effectiveness of AI in smart cities should therefore be evaluated through both technical and societal outcomes rather than through efficiency indicators alone.

A fifth research gap concerns the integration of AI with the broader digital technology ecosystem underlying smart cities. Emerging developments increasingly combine AI with the Internet of Things, big data analytics, cloud infrastructure, and urban digital twins, yet the mechanisms through which these technologies collectively create integrated urban management capabilities remain insufficiently understood. Bibri et al. (2024) demonstrate the potential of AI, AIoT, and digital twins to strengthen urban modeling, prediction, simulation, and optimization, but further empirical investigation is required to determine how such technologies interact across different institutional and urban contexts. A sixth gap relates to the empirical relationship between AI integration and urban sustainability. Bibri & Krogstie (2017), Bibri & Krogstie (2019), and Allam & Jones (2021) provide important conceptual foundations regarding the contribution of digital technologies and AI to sustainable urban development, but stronger empirical evidence is required to establish how AI capabilities translate into measurable environmental, social, economic, resilience, and quality-of-life outcomes. Based on these gaps, the most significant opportunity for future research lies in developing

and empirically testing an integrative socio-technical framework that explains the relationships among digital infrastructure, urban data, AI capability, organizational capability, governance, intelligent decision-making, public service transformation, resource optimization, citizen-centered outcomes, and urban sustainability within a unified smart city management system. Such a framework would move the literature beyond the question of whether AI can improve cities toward a more important question: under what technological, organizational, institutional, governance, and social conditions can AI capabilities be transformed into sustainable public value? This represents a critical direction for future research because AI integration in smart cities should ultimately be understood not as isolated technology adoption, but as the coordinated integration of digital capabilities into the broader urban management ecosystem.

5. CONCLUSION, IMPLICATION, SUGGESTION, AND LIMITATIONS

This study aimed to theoretically analyze the integration of Artificial Intelligence (AI) into smart city management systems through a qualitative literature review of 25 scientific articles selected through a literature screening process based on the principles of PRISMA 2020. The synthesis of the literature shows that AI has evolved from merely a supporting technology into a strategic capability that connects data, digital infrastructure, decision-making processes, public services, and resource management within the smart city ecosystem. The findings indicate that the primary role of AI in smart cities lies not only in automation capabilities but, more importantly, in its ability to analyze data, identify patterns, make predictions, provide recommendations, optimize resources, and support decision-making. Thus, AI functions as an enabler that transforms urban data into information and analytical capabilities that can be used to improve the quality of urban management. AI integration also makes an important contribution to urban governance and decision-making. AI enables city governments to move toward more data-driven, predictive, and adaptive decision-making. However, the synthesis indicates that AI is more appropriately positioned as a decision-support capability rather than a replacement for human decision-makers. The complexity of urban challenges continues to require human judgment, institutional capacity, social values, and consideration of public interests. In terms of public services, AI has the potential to improve service speed, efficiency, responsiveness, and personalization. Meanwhile, in resource management, AI can help optimize transportation, energy, water, waste, infrastructure, and various other urban systems. Ultimately, these applications can contribute to more efficient, responsive, adaptive, and sustainable urban management.

Nevertheless, AI integration does not occur automatically simply because the technology is available. Its effectiveness depends heavily on data quality, digital infrastructure, human resource capabilities, organizational readiness, system interoperability, and policy and regulatory support. Furthermore, as the role of AI in urban systems expands, the implementation of AI governance becomes increasingly important, particularly with regard to privacy, security, transparency, accountability, fairness, and human oversight. Based on the overall synthesis, this study conceptualizes AI integration in smart cities as the following process: Urban Data & Digital Infrastructure → AI Capability → Analysis, Prediction, Automation & Optimization → Decision Support & Service Transformation → Efficient, Adaptive & Sustainable Urban Management. However, this relationship operates within an environment shaped by two main conditions: enabling conditions, including infrastructure, data quality, human resources, organizational readiness, interoperability, and policies; and governance conditions, including privacy, transparency, accountability, fairness, security, and human oversight. Therefore, the central finding of this study is that AI should not be viewed as the ultimate goal of smart city development, but rather as a capability that enables the integration of various urban resources, systems, and management processes to produce smarter, more responsive, adaptive, and sustainable governance and public services.

Conceptually, this study contributes by positioning AI not as a standalone technology, but as a bridging capability within the smart city ecosystem. The resulting synthesis demonstrates that the success of AI depends on the interconnectedness of technology, data, people, organizations, and governance. This contribution extends the understanding of smart cities, which has traditionally emphasized digital technologies, IoT, and data as fundamental foundations. From the perspective developed in this study, AI provides an additional layer of capability that enables urban data to be used not only to understand current urban conditions, but also to predict future conditions, optimize resources, support decision-making, and design more adaptive responses. This study also emphasizes that the governance dimension should be positioned as an integral component of AI integration. Accordingly, the success of a smart city should not be assessed solely based on the level of technology adoption, but also on the ability of governments and stakeholders to ensure

that AI is used in a responsible, transparent, inclusive, secure, and human-centered manner.

This study has several limitations. First, the analysis was based on 25 articles selected according to specific search strategies and inclusion criteria and therefore does not encompass the entire body of literature on AI and smart cities. Differences in databases, keywords, publication periods, and selection criteria may produce different literature compositions. Second, this study employed a qualitative literature review approach, meaning that the findings are primarily interpretive and conceptual. The study did not conduct a meta-analysis or statistical testing of the magnitude of AI's effects on urban management performance. Third, AI is developing rapidly, particularly with the emergence of generative AI. Consequently, some of the latest technological developments and implementation practices still require further empirical investigation. Therefore, the findings should be viewed as a conceptual synthesis that can continue to evolve alongside developments in AI technology and governance.

Based on the identified research gaps, future research could focus on empirically testing the AI integration model within specific urban contexts. Empirical studies are needed to determine how data quality, digital infrastructure, human resource capabilities, organizational readiness, and AI governance influence the successful implementation of AI in urban management systems. Future research should also place greater emphasis on human-centered AI. The success of a smart city should not be determined solely by improvements in system efficiency, but also by the ability of technology to enhance service quality, inclusiveness, public trust, citizen participation, and residents' quality of life. Furthermore, the development of generative AI creates new research opportunities in urban management, particularly in supporting citizen–government interaction, policy analysis, urban planning, knowledge management, and public services. However, its application requires further investigation concerning accuracy, transparency, privacy, security, hallucination, and accountability. Therefore, the future research agenda should not only ask “To what extent can AI enhance urban intelligence?”, but also “How can AI be responsibly integrated into urban systems so that the benefits of technology can be delivered inclusively and sustainably?”.

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