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Artificial Intelligence for Smart City Reinvention: A Systematic Literature Review and Conceptual Framework

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Abstract

This study investigates how Artificial Intelligence (AI) can be systematically leveraged to reinvent smart cities by optimizing legacy infrastructures for greater efficiency, sustainability, and inclusivity. In response to the accelerating challenges of global urbanization, the research examines how AI's predictive, adaptive, and autonomous capabilities can transform existing systems in transportation, energy management, waste management, public safety, and citizen engagement without the financial and environmental costs of large-scale redevelopment. Employing a qualitative and conceptual research design grounded in a systematic literature review, the study analyzed eighty-five scholarly, institutional, and industry sources published between 2020 and 2025. The findings reveal that AI integration significantly enhances operational performance across all urban domains, reducing traffic congestion by up to 25%, improving energy efficiency by 15–20%, and cutting waste management costs by 10–15%. However, the results also indicate that the benefits of AI deployment are unevenly distributed, heavily influenced by governance capacity, ethical oversight, and citizen participation. The study developed a socio-technical framework that positions AI as a central enabler linking technological innovation with governance, ethics, and social inclusion. This framework emphasizes three interdependent pillars: technological intelligence, institutional capacity, and social inclusion as prerequisites for sustainable urban transformation. The research concludes that the reinvention of smart cities requires not merely the adoption of advanced technology but the creation of accountable, human-centered governance systems that ensure equity, transparency, and trust. Ultimately, the study contributes a conceptual and policy-relevant foundation for reimagining AI-enabled cities as adaptive, resilient, and ethically governed ecosystems. It offers practical insights for policymakers, urban planners, and researchers seeking to balance innovation with sustainability, efficiency with equity, and digital progress with human welfare.

Keywords: Artificial Intelligence, Smart Cities, Infrastructure Optimization.

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Introduction

Urbanization is accelerating at an unprecedented pace, reshaping the contours of global development in the twenty-first century. The United Nations projects that by 2050, nearly 7 billion people, more than two-thirds of the global population, will reside in cities. This demographic shift underscores the centrality of cities as the dominant form of human settlement, with profound implications for governance, sustainability, and human well-being. Cities are widely acknowledged as engines of economic growth, contributing more than 80% of global GDP. They serve as hubs of innovation, cultural exchange, and political influence, fostering interactions that drive both national and global development. However, this urban expansion has been accompanied by intensified pressures on infrastructure, ecosystems, and essential services (Wei et al., 2022). Congested road networks alone are estimated to drain over USD 1 trillion annually in lost, while air and noise pollution contribute to 4.2 million premature deaths each year. Rising demand for finite resources, particularly energy and water, heightens concerns about ecological degradation and long-term sustainability. The challenges of urbanization are further compounded by climate change, rapid population growth in megacities, and deepening socioeconomic inequality (Kamana et al., 2024). Vulnerable populations are often disproportionately affected, facing limited access to affordable housing, healthcare, education, and digital opportunities. In many parts of the developing world, informal settlements expand without adequate sanitation, energy, or mobility infrastructure, exposing systemic weaknesses in governance. As cities attempt to balance growth with sustainability, traditional paradigms of urban planning are proving increasingly inadequate.

Conventional models of urban planning and infrastructure development have largely been characterized by long project lifecycles, heavy capital investment, and reactive responses to urban pressures (Mazutis & Sweet, 2022). While these approaches enabled industrial-age cities to expand their physical capacity, they struggle to match the speed and complexity of twenty-first-century urbanization. The global infrastructure financing gap illustrates this limitation clearly: in developing regions alone, the shortfall is estimated at USD 1–1.5 trillion annually. Bridging this gap solely through conventional construction and expansion is both financially and environmentally impractical. Moreover, large-scale physical expansion without the adaptive integration of digital intelligence risks reinforcing inefficiencies. Building more roads without intelligent mobility systems, for example, may temporarily reduce congestion but ultimately encourages higher vehicle usage, exacerbating emissions and traffic density. Similarly, expanding energy production capacity without demand-side optimization deepens reliance on fossil fuels and undermines decarbonization targets. These challenges illustrate that physical expansion must be complemented by adaptive, data-driven management approaches that allow cities to remain livable, inclusive, and resilient (Fuady et al., 2025).

The concept of the smart city has emerged in response to these challenges, promising to harness digital technologies, sensor networks, and data-driven platforms to optimize resource use, improve quality of life, and enable more efficient governance. Global investment in smart city projects is projected to surpass USD 870 billion by 2030 (Fortune Business Insights, 2022), reflecting widespread optimism about the transformative potential of technology. Early smart city initiatives often focused on infrastructure-centric deployments: smart grids, intelligent transportation systems, and sensor-enabled utilities were designed to reduce waste, optimize service delivery, and enhance resilience. Barcelona, for instance, pioneered sensor-based water management systems, saving an estimated USD 58 million annually (Pandey & P, 2025)while Singapore's integrated traffic management system reduced congestion by leveraging dynamic tolling and real-time monitoring. Yet, despite these successes, critiques of the smart city paradigm have emerged. High implementation costs, interoperability challenges, and uneven adoption have raised questions about scalability, particularly in low- and middle-income contexts. Moreover, the dominant focus on technological solutions has often overshadowed issues of governance, inclusivity, and human-centered design (Gintova et al., 2025). Technology-driven approaches risk excluding marginalized populations who lack access to digital infrastructure, thereby reinforcing existing inequalities (Merchán-Cruz et al., 2025).

This study, therefore, aims to critically examine the limitations of conventional smart city frameworks and the barriers to their scalability and inclusivity, while exploring the potential of AI technologies to optimize legacy urban systems in areas such as transportation, energy, waste management, public safety, and citizen engagement. It further evaluates the governance, ethical, and social implications of AI-enabled smart cities, with a particular focus on fostering inclusivity and building trust. To address these challenges, the research proposes an interdisciplinary framework for reimagining smart cities as adaptive, sustainable, and human-centered ecosystems. By pursuing these objectives, the study advances both the theoretical understanding and practical redefinition of smart cities, providing valuable insights for policymakers, urban planners, and researchers seeking to shape more resilient and inclusive urban futures.

Methodology

Research design

This study adopts a qualitative, exploratory, and conceptual design, grounded exclusively in a systematic literature review. The goal is to synthesize existing scholarship on AI-enabled smart cities and to develop a socio-technical framework that integrates efficiency, sustainability, inclusivity, and governance. A literature-driven approach is appropriate because it allows for the aggregation of diverse insights across contexts while remaining consistent with methodological traditions in conceptual framework development.

Data sources and search strategy

Academic literature was the sole source of data for this study. Peer-reviewed journal articles, conference proceedings, and institutional publications were retrieved from Scopus, Web of Science, IEEE Xplore, ScienceDirect, and SpringerLink. The review covered the period 2020–2025, ensuring inclusion of both early conceptualizations of smart cities and recent advances in AI applications. The following search strings were applied: "Smart cities" AND "artificial intelligence" AND ("urban governance" OR "infrastructure optimization")
"AI-enabled infrastructure" AND ("sustainability" OR "efficiency" OR "inclusivity")
"Smart cities" AND ("AI ethics" OR "AI governance" OR "digital divide").

Inclusion criteria required studies to, explicitly address AI applications in urban contexts, provide empirical findings, conceptual discussions, or evaluative assessments, and be published in peer-reviewed outlets. Exclusion criteria eliminated studies with only a general ICT/IoT focus without explicit AI engagement. A total of 85 documents were retained after screening: 42 peer-reviewed articles, 21 institutional/governmental reports, and 22 industry publications.

Analytical approach

The study employed a thematic synthesis approach, combining both deductive and inductive coding:

1. Deductive coding: Derived from the literature on smart cities, focusing on four established performance dimensions: efficiency, sustainability, inclusivity, and governance.
2. Inductive coding: Emerged during review, capturing emergent themes such as algorithmic bias, governance gaps, citizen trust, and ethical dilemmas.

Framework development

Insights from the thematic synthesis informed the development of a conceptual socio-technical framework for AI-enabled reinvention of smart cities. The framework integrates technological functions (AI applications), institutional contexts (policy, governance), and societal outcomes (equity, trust, inclusivity). By systematically mapping literature findings to framework dimensions, this study ensures both conceptual clarity and scholarly rigor (Figure 1).

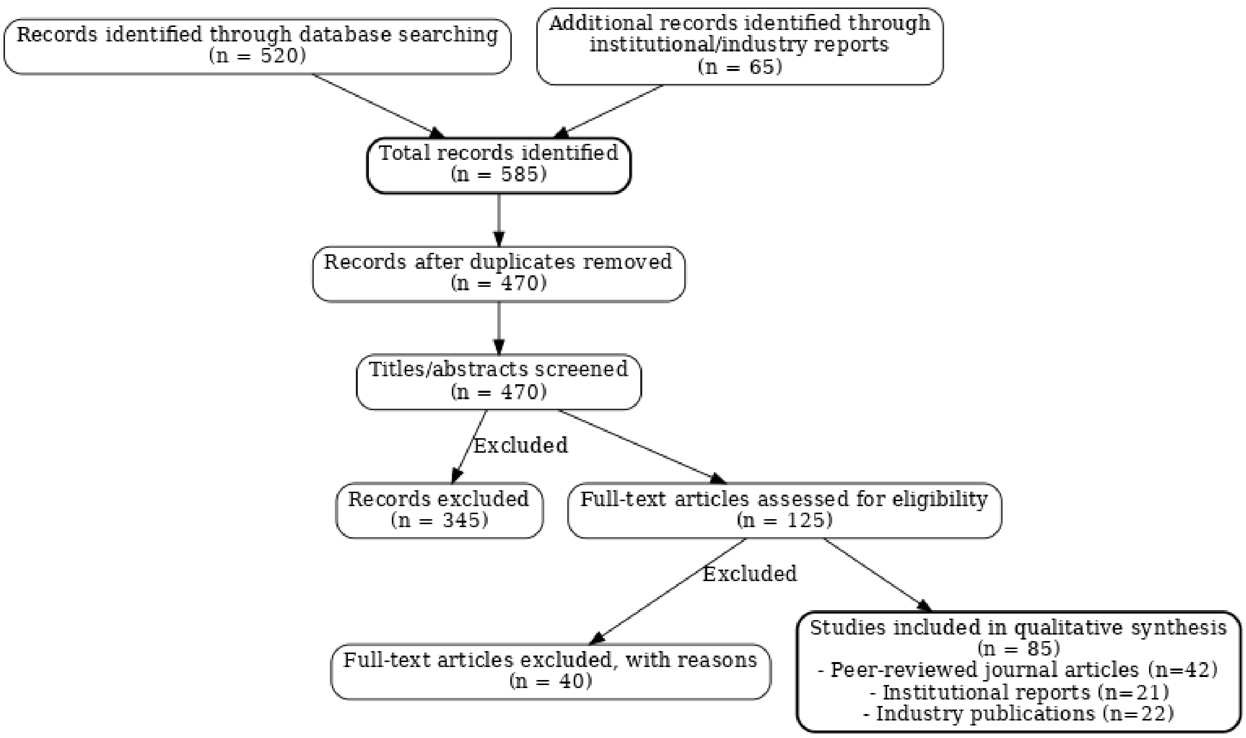

Figure 1. PRISMA Flow Diagram For Literature Selection

This Figure 1 illustrates the systematic screening and selection process of literature sources following PRISMA guidelines. Out of 585 initially identified records, 85 documents were retained for thematic synthesis, comprising 42 peer-reviewed journal articles, 21 institutional reports, and 22 industry publications.

Results and Discussion

The systematic literature review yielded a total of eighty-five relevant publications comprising forty-two peer-reviewed journal articles, twenty-one institutional and governmental reports, and twenty-two industry documents. Analysis of these materials revealed that the integration of AI within urban infrastructure has become a central mechanism for addressing the pressing challenges of rapid urbanization, sustainability, and social inclusion (Aytekin et al., 2025). The findings demonstrate that AI enables legacy systems in transportation, energy, waste management, public safety, and governance to operate with greater efficiency, adaptability, and responsiveness. However, the results also underscore that the benefits of AI adoption are strongly mediated by governance quality, ethical regulation, and levels of citizen participation. Hence, while technological capacity is a prerequisite, institutional readiness and socio-ethical oversight determine the depth and sustainability of impact (Nurlinah et al., 2025).

Within the transportation sector, AI emerged as one of the most extensively researched and practically implemented domains (Kuang et al., 2024). Reinforcement learning and predictive analytics were found to enhance real-time traffic control, optimize route planning, and coordinate multiple modes of mobility such as buses, metro systems, and ride-sharing services. Evidence from Singapore, Amsterdam, and Barcelona showed that AI-driven intelligent traffic management systems (ITMS) can reduce traffic congestion by between 20 and 25 per cent, with parallel reductions in travel time, emissions, and energy consumption (Robinson, 2020). These results highlight the potential of AI to transform mobility systems from reactive to anticipatory structures. However, scalability remains constrained by interoperability challenges between old traffic infrastructure and modern AI modules, as well as by financial and technical barriers in developing cities. Furthermore, studies indicate that without adequate data privacy policies, such systems risk fostering a culture of algorithmic surveillance that may erode public trust (Sanchez et al., 2025).

In the energy domain, AI has been instrumental in demand forecasting, dynamic grid balancing, and renewable energy integration. Machine learning models improve predictive accuracy by up to 20 per cent, thereby enhancing grid resilience and reducing energy waste (Rathore et al., 2025). AI-enabled microgrids and distributed energy systems allow for autonomous adjustment to fluctuations in demand and supply, creating a more decentralized and sustainable urban energy ecosystem. The reviewed literature suggests that cities adopting AI in their energy systems experience measurable declines in operational inefficiencies and greenhouse gas emissions (Velmurugan et al., 2025). Nonetheless, the distribution of these benefits is uneven. High-income cities with advanced digital infrastructure tend to gain the most, while low- and middle-income cities often struggle with cost, technical expertise, and data management capacity (Umunnawuike et al., 2025). The implication is that technological adoption must be supported by deliberate policies promoting equity, local capacity building, and open-source collaboration to prevent deepening global disparities in sustainable energy access.

Waste management represents another area where AI applications have achieved demonstrable success (Aytekin et al., 2025b). Computer vision and deep learning algorithms enable the automated classification and sorting of waste, while predictive analytics optimize collection routes and resource allocation. Studies such as (Oise & Konyeha, 2024) reported classification accuracies exceeding 97 per cent in hybrid neural network frameworks that integrate EfficientNet, MobileNet, and Sequential Neural Networks. Such results affirm that AI not only improves operational efficiency but also advances circular economy principles by increasing recycling rates and minimizing human exposure to hazardous materials (Sulistyaningsih et al., 2024). However, high computational demands, limited datasets for diverse waste types, and the lack of infrastructural integration constrain the scalability of these innovations. The literature also points out that the absence of standardized performance metrics makes it difficult for municipalities to evaluate cost-benefit outcomes objectively. These challenges indicate the necessity for collaborative data repositories and interoperable waste information systems to enable replicability and cross-city learning (Schmeling et al., 2025).

AI's influence on public safety and security is multifaceted. Intelligent surveillance, anomaly detection, and predictive policing have improved emergency response times and situational awareness in several case studies (Hernández et al., 2020). Yet, the same technologies raise profound ethical concerns regarding privacy, algorithmic bias, and disproportionate monitoring of marginalized populations. The results reveal that ethical governance frameworks are decisive in determining whether AI functions as an instrument of resilience or exclusion (Iyaniwura & Mayaki, 2025). For instance, European cities operating under the General Data Protection Regulation (GDPR) exhibited higher levels of citizen trust and oversight compared with those where surveillance systems lacked transparency. The discussion therefore, highlights that the sustainability of AI-driven safety systems is inseparable from the ethical and legal mechanisms that regulate their operation. Without such oversight, technological sophistication can inadvertently reproduce social inequalities or erode civil liberties (Pal, 2025)

Citizen engagement and urban governance constitute the socio-political dimension of AI adoption. Natural language processing (NLP) systems, chatbots, and participatory analytics platforms have improved the accessibility of government services and strengthened communication between authorities and citizens (Ghaleb et al., 2025). These tools allow for real-time policy feedback through sentiment analysis and digital consultations, aligning urban management more closely with community needs. Nevertheless, findings indicate that digital literacy gaps and unequal access to technology hinder inclusive participation, particularly in low-income and peri-urban areas (Amhaouch et al., 2025) The data suggest that citizen-centered AI design grounded in inclusivity, transparency, and accountability is essential to ensure that technological transformation does not reinforce pre-existing divides. Consequently, governance strategies should integrate digital inclusion initiatives such as public Wi-Fi zones, open data portals, and civic technology education programs to democratize participation in smart city development (Onoja & Ajala, 2023)

Several cross-cutting themes emerged from the synthesis. First, the efficiency equity trade-off remains a persistent tension. Many cities achieve rapid efficiency gains through AI at the expense of inclusivity, as access to digital services is often limited to those with connectivity and literacy advantages (Rahbarianyazd, 2024). Second, ethical and governance frameworks are pivotal in mediating the social consequences of AI adoption. Cities that institutionalize algorithmic accountability and transparent data policies achieve higher levels of citizen trust and legitimacy. Third, retrofitting AI into existing legacy systems proved more economically and environmentally viable than building entirely new infrastructures (Borda, 2024). Retrofitting enables cities, particularly in developing regions to bypass the prohibitive costs of large-scale reconstruction while still achieving optimization through digital augmentation. Lastly, interoperability emerged as a systemic challenge. Fragmented data architectures and vendor-locked systems prevent effective integration across transportation, energy, waste, and governance domains (Global & Kazanskaia, 2025). This fragmentation undermines the holistic intelligence of urban systems and highlights the urgency of developing open data standards and shared governance protocols.

The discussion therefore reinforces the conceptual framework proposed in this study, which situates AI at the core of a socio-technical model linking technology, governance, and social inclusion. The results confirm that the reinvention of smart cities depends not merely on deploying advanced algorithms but on embedding them within accountable institutions and participatory cultures (Mishra, 2024). The analysis reveals that AI operates most effectively when guided by three mutually reinforcing pillars: technological intelligence, institutional capacity, and social inclusion. Technological intelligence ensures predictive and adaptive optimization of urban systems; institutional capacity guarantees transparency, regulation, and ethical oversight; and social inclusion fosters trust, equity, and legitimacy in urban governance. Cities that harmonize these dimensions are more likely to evolve into adaptive, resilient, and human-centered ecosystems (Soni & Taneja, 2025). Comparative insights further demonstrate that while developed cities such as Singapore and Amsterdam use AI to refine already advanced infrastructures, emerging cities like Lagos and Nairobi are leveraging AI retrofitting to leapfrog traditional development barriers.

However, across all contexts, policy readiness rather than technological maturity determines success. The presence of comprehensive AI governance frameworks, data protection laws, and inter-agency coordination mechanisms correlates strongly with sustainable outcomes. Policymakers are thus encouraged to institutionalize ethical oversight, invest in local capacity development, and promote open innovation ecosystems that facilitate cross-sectoral collaboration (Regona et al., 2024). The evidence collectively suggests that AI's transformative value lies not merely in automating urban processes but in reconstituting the relationship between technology, governance, and society. In this regard, the reinvention of smart cities through AI represents a paradigmatic shift from efficiency-driven modernization toward adaptive, inclusive, and sustainable urban intelligence (Ye et al., 2025).

Conclusion

This study establishes that artificial intelligence provides a transformative pathway for reinventing smart cities by optimizing legacy infrastructures through adaptive, data-driven systems capable of real-time decision-making and autonomous performance. The findings suggest that the true success of AI adoption depends less on raw technological maturity and more on the strength of ethical governance, institutional readiness, and deep-seated social inclusion. By integrating the three essential pillars of technological intelligence, institutional capacity, and social equity, cities can transition from rigid, reactive models to human-centered ecosystems that prioritize collective well-being, environmental resilience, and the seamless delivery of public services. From a practical and policy standpoint, this research implies that city planners must shift their strategic focus from capital-intensive physical expansion toward AI-driven efficiency and algorithmic accountability. This transition requires a "human-in-the-loop" governance model where digital infrastructure is treated as a public utility that must be auditable and transparent to ensure that modernization does not exacerbate existing social divides. By leveraging AI to extend the lifecycle of existing assets rather than building anew, municipalities can address the global infrastructure financing gap while simultaneously pursuing aggressive decarbonization targets and fostering equitable access to urban opportunities. However, the study is inherently limited by its reliance on existing literature, which may exhibit a publication bias toward successful pilot projects while underreporting the complexities of failed implementations and technical bottlenecks in less-developed regions. Furthermore, the global disparity in digital maturity makes the universal application of these findings challenging across different socioeconomic landscapes, as regions with lower digital infrastructure may struggle to implement AI solutions effectively and may not benefit equally from the proposed strategies. Consequently, future research should pursue longitudinal empirical studies in diverse urban contexts and critically investigate the environmental trade-offs of large-scale AI computation, ensuring that the energy demands of "intelligent" systems do not inadvertently undermine the broader sustainability goals of the twenty-first-century city.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this study.

Author contribution

Conceptualization, methodology, validation: formal analysis, investigation: resources, data curation: writing-original draft preparation:**;** writing-review and editing, visualization : Godfrey Perfectson Oise. All authors have read and agreed to the published version of the manuscript.

Declaration of generative AI in scientific writing

The author used Grammarly to assist in checking the grammar, spelling, and stylistic consistency of the manuscript.

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