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Review Article

Synergizing Artificial Intelligence and Smart Cities: Paving the Way for Inclusive and Sustainable Urban Futures

Sharqa Arif[1], Aqeeb Hussain[2] and Zeenat Khan[3]*

[1]Department of Software Engineering, Capital University of Science & Technology, Pakistan

[2]Department of Software Engineering, Capital University of Science & Technology, Pakistan

[3]Department of Bioinformatics and Biosciences, Capital University of Science & Technology, Pakistan

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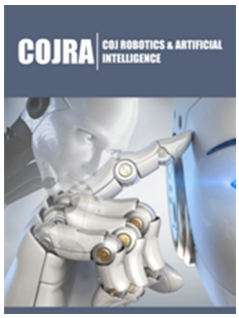

***Corresponding author:** Zeenat Khan, Department of Bioinformatics and Biosciences, Capital University of Science & Technology, Pakistan

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Abstract

Smart cities, driven by Artificial Intelligence (AI), are transforming urban living by enhancing efficiency, sustainability, and human well-being. This review explores the integration of AI in six key smart city domains: governance, economy, mobility, environment, living, and people. AI enables real-time decision-making, predictive analytics, and improved public services through interconnected digital systems. Drawing on scholarly research from the past two decades, the paper examines AI's role in optimizing urban infrastructure and addressing socio-environmental challenges. Case studies from different regions are also reported, demonstrating practical applications of AI in shaping sustainable urban development. It highlights the potential of AI to promote inclusive and resilient cities, while also addressing ethical, infrastructural, and policy-related challenges essential for sustainable urban development.

Keywords: Artificial intelligence; Smart cities; Urban sustainability; Digital governance; Smart infrastructure

Introduction

Smart cities are technologically advanced urban areas designed to enhance sustainability, efficiency, and citizen well-being. They rely on integrated systems sup-ported by ICTs and the Internet of Things (IoT) for real-time monitoring and data-driven governance [1]. The framework of smart cities is built on six key dimensions: smart economy, smart people, smart governance, smart mobility, smart environment, and smart living [2]. These dimensions promote innovation, human development, transparency, and ecological balance [3]. Smart economy drives competitiveness and innovation. Smart people emphasize education and civic engagement [4]. Smart governance ensures accountability and participation. Smart mobility supports efficient and safe transport. Smart environment addresses sustainability and pollution control [5]. Smart living improves quality of life through better healthcare, housing, and education. Together, these pillars enable adaptive, inclusive, and future-ready urban ecosystems.

Artificial intelligence (AI) plays a pivotal role in the development of smart cities by enabling data-driven decision-making, automation, and adaptive urban services. Evolving from basic machine intelligence to advanced cognitive technologies, AI sup-ports real-time analytics, sustainable infrastructure management, intelligent mobility, and personalized living environments [6]. With the global AI market projected to reach $190 billion, its integration into urban systems-especially in countries like China-has enhanced service efficiency through smart sensors and predictive platforms [7]. Pro-jects such as Kenya's

Twende-Twende illustrate AI's practical impact on traffic and safety [8]. However, ethical considerations, digital equity, and context-specific implementation remain critical to ensuring that AI-driven smart cities are not only innovative but also inclusive, resilient, and sustainable.

Artificial Intelligence (AI) is revolutionizing smart cities by enhancing six key domains: smart governance, smart economy, smart mobility, smart environment, smart living, and smart people. In smart governance, AI improves administrative efficiency, transparency, and civic engagement through automation and predictive tools [8]. The smart economy harnesses AI for innovation, financial analytics, and sustainable growth [9]. Smart mobility benefits from intelligent traffic systems, autonomous transport, and integrated transit networks [10]. AI also contributes to the smart environment by enabling real-time monitoring of pollution, energy optimization, and waste management. In smart living, AI enhances healthcare, housing, and safety through telemedicine and smart home technologies [11]. The smart people domain promotes digital literacy, inclusive education, and participatory governance. These interconnected domains work together to create responsive, data-driven urban systems [12]. Despite significant advancements, issues such as ethical concerns, data privacy, and infrastructure limitations remain [13]. Overall, AI integration across these domains is key to building sustainable, inclusive, and future-ready smart cities.

The integration of Artificial Intelligence (AI) into smart cities presents multifaceted challenges, including ethical concerns over data privacy, surveillance, and algorithmic bias; infrastructural gaps in connectivity and real-time processing; and socio-economic disparities that exacerbate digital exclusion [14]. Addressing these issues necessitates a comprehensive approach rooted in ethical AI design, public accountability, and inclusive governance [15]. Strategic recommendations emphasize the importance of explainable AI, citizen engagement, and infrastructure modernization-particularly through the adoption of IoT, 5G, and renewable energy systems [16]. Promoting digital literacy and equitable access to technology is essential to narrowing the digital divide and fostering civic empowerment [17]. Moreover, integrating complementary technologies like block chain can enhance security and responsiveness in critical sectors [18]. Ultimately, a collaborative effort among policymakers, industry leaders, researchers, and communities is vital to ensure that AI in smart cities advances not only efficiency and innovation but also sustainability, resilience, and social equity.

Smart cities

The municipal landscape is shifting promptly with the advent of smart cities, which aim to improve urban livability through the use of strapping technologies and advancements. Such cities are designed to use intelligent and interconnected systems. As such, smart cities rely on Information and Tele-Communication Technologies (ICTs) for automation and data-supported governance [4]. By embedding digital infrastructure across various sectors such as healthcare, smart transportation and energy, education, and public safety, smart cities improve the service to citizen ratio and optimize resource allocation [7]. These systems are further reinforced through the pervasive use of the Internet of Things (IoT) which permits real-time data monitoring and sophisticated analytics for ongoing refinement [19]. At last, smart cities are crafted to be adaptive, resilient, and dynamic, evolving with urban citizen demands as well as prospective developmental goals.

All urban innovations and sustainable development are influenced by these six essential dimensions of smart cities. These core pillars: smart economy, smart people, smart governance, smart mobility, smart environment, and smart living, create the framework for the use of technologies to advance the functionalities of a city and the well-being of its citizens (Figure 1). A smart economy fosters innovation, entrepreneurship, and global competitiveness. Smart people prioritize a well-educated populace, creativity, and civic participation, while smart governance fosters transparency, accountability, and public participation [20]. Smart mobility is concerned with the development of safe, efficient, and digitized transport systems, while smart environment emphasizes ecological sustainability, pollution reduction, and responsible use of resources [2]. Smart living includes healthcare, housing, education, cultural enrichment and any other services that enhance the quality of life of citizens [10]. Integrated with AI and other emerging technologies, these dimensions can create intelligent urban ecosystems that are capable of adaptive and data-driven decision making (Figure 1) [20].

Figure 1: Concept and tools of smart city [20].

Artificial intelligence and smart cities

The role of Artificial Intelligence (AI) in the development of smart cities is significant. AI technologies help improve the efficiency of urban systems. Traditionally, AI was regarded as the science concerning the development of intelligent machines, but it now includes technologies that can mimic human thinking and actions [21]. AI can now enable autonomous decision making of

systems as a result of problem solving and information analysis [16]. New advancements in AI technologies are predicted to increase the value of the global market to 190 billion dollars by the end of the year [7]. Countries such as China are leading the market by using AI technologies such as sensors, smart meters, and other embedded systems to improve city management efficiency [22]. The application of such technologies makes use of data mining, machine learning, as well as real time analytics to improve the effectiveness of operations as well as the delivery of services [13]. The application of AI technologies is witnessed in various fields such as robotics, computer vision, natural language processing and the ever-growing urban life. The use of AI is vital in the development of smart cities as they improve the cities' responsiveness to the challenges they face while making the cities more sustainable.

The utilization of AI in smart cities goes beyond automation, providing unconventional solutions to intricate socio-environmental issues. AI enables sustainable building management systems, where intelligent systems determine and adjust to optimize building operations for better performance and energy savings [17, 23]. In urban mobility, AI is applied to traffic management, route optimization and public safety through real-time data processing, as seen in Kenya's Twende-Twende that supplies real-time traffic updates and guidance [24]. Extreme Computing and AI in Smart Home AI in smart homes makes context-aware and ambient assisted living more personalized and energy saving [20]. These developments echo the vision of a stack of ICT infrastructures driven by AI and the Internet of Things (IoT) that enable pervasive services in sec-tors like (Table 1) [24-29] energy, environment, governance, public health and safety [15]. While the attention to AI has waxed and waned over time there has been a resurgence of interest due in part to the rise of Big Data and the proliferation of the smart city agenda [23]. But successful implementation of "smart city of the future" should be about more than just technological utopianism-it requires socially responsible contextualization that goes beyond boosting the adoption of advanced technology and transforms smart cities into sustainable, inclusive, and smart resilient cities.

Table 1: Sub types of AI proposed Smart City [24-29].

Domain	Description
Smart Governance	Utilizes AI to streamline public administration, promote transparency, deliver real-time services, and enhance civic engagement through data-driven platforms, automation, and predictive analytics.
Smart Economy	Leverages AI for economic modernization by driving innovation, enhancing entrepreneurship, optimizing financial operations, and supporting the digital transformation of market systems.
Smart Mobility	Applies AI in transportation to improve efficiency, reduce congestion, and facilitate autonomous and shared mobility solutions through intelligent traffic systems and predictive maintenance.
Smart Environment	Employs AI to manage and enhance environmental quality, including air and water monitoring, energy efficiency, waste management, and ecological sustainability.
Smart Living	Enhances urban life through AI-driven solutions in health, education, housing, and safety, such as smart homes, telemedicine, and personalized digital services.
Smart People	Focuses on empowering citizens by fostering digital skills, inclusive learning, and participatory governance, ensuring active engagement in smart urban development.

AI integrated domains of smart cities

The integration of Artificial Intelligence (AI) into smart city models is becoming more structured around six major domains as urban development progresses: smart governance, smart economy, smart mobility, smart environment, smart living, and smart people (Table 1) [25]. This thorough framework provides an organized lens for analyzing AI-driven innovations across important urban sectors, and it is backed by academic literature and the McKinsey Global Institute [8]. With the use of technologies like intelligent chatbots, predictive policing, and automated decision-making systems, Artificial Intelligence (AI) improves administrative procedures and public participation in smart governance [26]. In order to promote innovation, enhance financial operations, and use predictive analytics that aid in economic growth and adaptability, the smart economy makes use of artificial intelligence [11]. Meanwhile, to build more sustainable and effective urban transit networks, smart mobility uses AI technologies in integrated transportation systems, traffic management, and autonomous vehicles [27]. When taken as a whole, these AI applications are changing how cities operate, making them more responsive, intelligent, and future-ready.

The fields of smart living, smart environments, and smart people in smart city ecosystems are all being advanced by Artificial Intelligence (AI). AI is used in the smart environment space to manage waste systems, optimize energy use, and monitor the quality of the air and water, all of which contribute to ecological sustainability [28]. By using innovations like home automation, telemedicine, and intelligent safety solutions, smart living aims to improve the quality of urban life [6]. By utilizing AI in educational technologies and participatory governance platforms, the smart people domain encourages civic engagement and digital inclusion [29]. Nevertheless, ethical issues, data privacy, insufficient infrastructure and fragmented regulations remain challenges [4]. In future, there will be urgent demand for "transparent AI algorithms," "integrated data systems" and "inclusive development strategies" [30]. In the end, these initiatives are a reminder of AI's key role in creating smart cities that are not only tech forward but better environmentally, socially and for people.

Smart governance and smart cities: Smart governance plays a pivotal role in shaping the development and sustainability of smart cities by integrating advanced technologies, administrative efficiency, and participatory mechanisms into governance

structures (Figure 2) [31]. It is an evolution from traditional governance frameworks, where ICTs form the backbone to ensure efficiency, transparency, and inclusivity in government operations [32]. The components of smart governance include the deployment of advanced tools such as artificial intelligence, machine learning, blockchain, big data analytics, and the Internet of Things, which enhance real-time decision-making and streamline public service delivery [33]. These technologies provide governments with the ability to manage vast datasets efficiently, predict future needs, and implement policies that directly improve citizen services [34]. However, the role of smart governance is not restricted only to technological adoption but also to ensuring citizen participation, inclusivity, and accountability in governance processes [35]. By embedding principles (Figure 2) of transparency, accountability, and democratic engagement, smart governance ensures that the transformation of cities does not remain a purely technological endeavor but also fulfills social, economic, and ethical objectives [36]. It acts as a mechanism that bridges the gap between citizens and governments through both one-way and two-way communication channels, fostering collaborative approaches in policy-making and governance [37]. In this context, governance becomes more dynamic, adaptive, and responsive to urban challenges, addressing not only efficiency but also the broader goal of equitable growth and sustainable development in smart cities.

Figure 2: Smart governance of smart city [31].

The smart governance model conceptualizes governance as an interconnected system of inputs, outputs, and outcomes, providing a comprehensive framework to measure preparedness, challenges, and achievements in smart cities. Inputs include reforms in laws, adjustments in policies, institutional restructuring, and resource reallocation, which create the foundation for governance transformation [38]. Outputs are the tangible results of these reforms, encompassing digital innovation, open data systems, collaborative practices, financial strategies, and enhanced citizen engagement mechanisms [39]. Outcomes, in turn, reflect the long-term impacts of these changes, seen in the improvement of services, greater inclusivity, enhanced trust between governments and citizens, and strengthened policy frameworks [40]. The model emphasizes that effective governance does not solely depend on technological implementation but also on the integration of social, legal, and ethical standards to balance innovation with privacy, security, and equal accessibility [41]. Furthermore, it highlights the risks associated with over-reliance on technology, such as cybersecurity threats, maintenance costs, and potential exclusion of marginalized populations due to digital divides [42]. Thus, the model positions smart governance as a multidimensional construct where technology, citizen participation, and institutional frameworks converge to produce adaptive, resilient, and citizen-centric governance systems that are essential for the sustainable development of smart cities and nations.

Smart mobility in smart cities: Smart mobility is a central element of the smart city concept, designed to address urban challenges such as congestion, pollution, limited public spaces, and inefficient transport systems [43]. It relies on the use of past and real-time data, together with advanced information and communication technologies, to optimize travel times, reduce traffic, prevent accidents, and cut down harmful emissions [44]. The concept emphasizes sustainable urban mobility, promoting environmentally friendly transport options and social inclusivity [45]. Electromobility is a key component, involving the integration of electric and hybrid vehicles, supported by local and national policies [46]. Additionally, smart mobility encourages efficient management of urban spaces, the promotion of non-motorized traffic, and the strengthening of public transportation [47]. These measures collectively aim to reduce the dominance of private cars, increase safety, and ensure more sustainable and accessible urban environments for citizens.

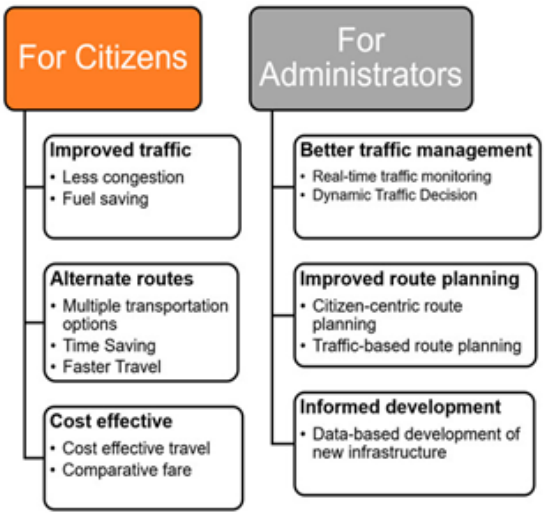

Figure 3: Need for smart mobility [48].

The scope of smart mobility extends beyond immediate efficiency to long-term sustainability, aligning closely with global low-carbon and circular economy goals (Figure 3) [48]. The growth of electric vehicles highlights the need for supportive infrastructure

such as charging stations and smart energy grids [49]. At the same time, emerging paradigms like mobility-as-a-service aim to replace private vehicle ownership with shared, lighter, and autonomous options [50]. Technologies such as the Internet of Things, Big Data, and Artificial Intelligence enhance traffic management, logistics efficiency, and predictive planning in mobility systems [51]. Moreover, smart mobility seeks to advance broader societal objectives, including reducing inequality in access to transport, improving urban safety, and fostering economic growth [52]. By combining innovation with sustainability, it becomes a critical driver for transforming cities into resilient, efficient, and citizen-focused spaces (Figure 3) [48].

Smart life in smart cities: Smart life in smart cities revolves around the integration of technology, infrastructure, and human needs to enhance quality of living for citizens [53]. It emphasizes the role of intelligent networks, digitalized services, and automated systems in creating efficient, inclusive, and sustainable urban lifestyles [54]. The focus is not solely on technological innovation but also on improving livability, well-being, and social equity through accessible and secure ICT infrastructures, resilient environments, and participatory governance [53]. Smart living highlights the interactivity between people, services, and communities, where citizens are central to the functioning of the system [55]. However, challenges such as unequal access, digital divides, and lack of citizen engagement limit the inclusivity of smart living, raising questions about its sustainability and fairness.

At the same time, smart life is positioned as a user-centric outcome of smart urbanism, requiring citizens' adoption and participation in digital services and systems [56]. It is not defined merely by technological capabilities but by the extent to which smart infrastructures improve everyday living conditions across mobility, governance, economy, and the environment [57]. A truly sustainable smart life depends on bridging inequalities and ensuring that vulnerable groups are not excluded from opportunities provided by smart infrastructures [57]. The effectiveness of smart life is measured not just by innovation but by its contribution to equitable access, enhanced liveability, and improved quality of life [58]. Therefore, smart life is the intersection of technology, sustainability, and citizen inclusion within the broader framework of smart cities.

Case studies of smart cities: Several countries across the Global South (Table 2) and the MENA region are adopting digital technologies and AI to promote sustainability and improve urban living [59]. India has focused on digital identity, financial transactions, and AI-enabled traffic systems, while Kenya applies AI across multiple sectors, including energy and fintech, though challenges remain in regulation and ethics [60]. Rwanda has advanced in digital registries, transport systems, and IoT for urban management, yet struggles with skill shortages and data ecosystems [61]. Brazil leverages AI in both public and private sectors but faces infrastructure gaps, inequality, and data security concerns [62]. In the MENA region, Sharjah Sustainable City in the UAE highlights solar-powered communities with smart housing and mobility; Lusail in Qatar emphasizes ICT integration and GSAS-based sustainability standards; and SEKEM in Egypt focuses on sustainable agriculture, cultural development, and ecological integration [63].

These cases highlight diverse approaches to building smart sustainable cities, shaped by local contexts and priorities [64]. While India, Kenya, Rwanda, and Brazil prioritize AI and ICT-driven urban solutions, the MENA region emphasizes sustainability rooted in cultural, social, and environmental adaptations [65]. The findings reveal common challenges such as digital divides, regulatory gaps, and (Table 2) [59-66] socio-economic inequality, but also showcase successful models like Rwanda's digital land registry, Kenya's smart grids, India's Aadhaar and UPI, and the UAE's walkable solar-powered communities [66]. Collectively, these examples demonstrate both the transformative potential of digital technologies and the persistent barriers to ensuring inclusivity, equity, and long-term sustainability in smart city development.

Table 2: Previous researches on smart cities in smart world [61-68].

Country	Description	Findings
India	Aadhaar digital identity, UPI payments, AI in traffic and waste management	Improved governance and financial access; challenges include digital divide and data privacy
Kenya	AI in agriculture, health, fintech, smart grids	Growth in tech innovation; hindered by lack of AI policies and privacy concerns
Rwanda	Digital land registry, Tap&Go transport, IoT parking	Increased transparency and efficiency; limited by skill shortages and weak data ecosystems
Brazil	AI in urban planning, e-commerce, finance, EBIA strategy	Boost in digitalization; obstacles include inequality, broadband gaps, and weak data protection
UAE (Sharjah)	Net-zero solar-powered community with smart housing and clean transport	Alignment with SDGs; promotes walkability, affordability, and mixed-use planning
Qatar (Lusail)	38 sq km smart city with ICT, GSAS rating, smart governance	Large-scale sustainable design; strong ICT integration for services and mobility
Egypt (SEKEM)	Sustainable agriculture, cultural and ecological integration, 16 Vision Goals	Strong focus on SDGs; combines economy, society, culture, and ecology for holistic development

Challenges, future directions, and strategic recommendations

The integration of Artificial Intelligence (AI) into smart cities brings forth a range of complex challenges spanning ethical, infrastructural, socio-economic, and operational domains [27]. Privacy and ethical issues are at the forefront, particularly due to the use of surveillance technologies like facial recognition and predictive policing, which raise concerns about data misuse, social bias, and lack of accountability stemming from opaque AI decision-making processes [21]. Infrastructure limitations, especially in less developed regions, restrict the implementation of AI by limiting access to IoT networks, reliable connectivity, and real-time data processing systems [67]. Socio-economic disparities further widen the digital divide, as marginalized communities often face barriers to digital access and literacy. Operational challenges include fragmented systems that lack interoperability, scalability issues, and outdated or insufficient legal and policy frameworks [68]. Additionally, public resistance fueled by fears of surveillance and job displacement presents a social barrier to adoption [17]. Ad-dressing these multifaceted issues is crucial to ensure the ethical, equitable, and sustainable deployment of AI in smart urban environments.

Overcoming the challenges associated with AI adoption in smart cities demands a proactive and holistic approach that prioritizes ethics, infrastructure, and inclusivity [13]. Ethical AI must be anchored in principles of fairness, transparency, and accountability, with explainable AI (XAI) playing a key role in building public trust through clear and interpretable decision-making [69]. Incorporating citizen feedback into the design and governance of AI systems ensures alignment with community values and societal needs. Infrastructure modernization-through investments in IoT, 5G, edge computing, and renewable energy-powered smart grids is crucial for enabling efficient and resilient urban operations [70]. Promoting digital inclusion by expanding access to affordable technologies and digital education helps bridge the digital divide and empower underserved populations [16]. The integration of complementary technologies such as block chain and 5G can further enhance real-time, secure, and coordinated responses in critical areas like disaster management and energy distribution [24]. Ultimately, sustained collaboration among governments, industry, academia, and civil society is vital to ensure that AI solutions are locally relevant, widely accepted, and effectively contribute to the creation of inclusive and sustainable smart cities.

Effective implementation of Artificial Intelligence (AI) in smart cities requires strategic planning grounded in ethical, inclusive, and forward-looking principles. Central to this is the establishment of strong governance frameworks that promote transparency, equity, and public participation [71]. Developing future-ready infrastructure and standardizing interoperability protocols are essential for seamless data integration and operational efficiency across urban systems [18]. Policymakers should prioritize bridging the digital divide through widespread access to technology and digital literacy initiatives, ensuring that all citizens can benefit from AI advancements [25]. Additionally, AI-driven research on climate resilience can support predictive modeling and risk mitigation, aligning urban development with sustainability goals [36]. Collectively, these strategic recommendations are designed to harness the full potential of AI, enabling the creation of smart cities that are not only technologically advanced but also inclusive, resilient, and prepared for both current and future urban challenges.

Conclusion

Smart cities represent a shift towards integrating ICT, IoT, and AI to enhance governance, mobility, economy, environment, and living standards. They aim to ensure efficiency, sustainability, and resilience while keeping citizens at the center of development. AI and big data help in managing urban challenges through automation, predictive models, and smart decision-making. The six core dimensions-smart economy, people, governance, mobility, environment, and living-define the framework for building sustainable and inclusive cities. Smart life emerges as the outcome of this integration, where technology not only improves services but also supports quality of life, accessibility, and sustainability. Case studies highlight different global approaches. India's Smart Cities Mission focuses on digital identity and e-governance; Kenya and Rwanda emphasize smart infrastructure and connectivity; while Brazil applies AI in planning and monitoring. In the MENA region, Sharjah Sustainable City reflects renewable energy and ecological design, Lusail City highlights advanced infrastructure, and Egypt's SEKEM focuses on sustainable community-based development. These examples underline how smart cities adapt to local needs, yet challenges such as unequal access, high costs, and gaps in regulation remain significant.

The concept of smart life in smart cities emphasizes digital services, sustainable infrastructure, and citizen inclusion. It reflects how urban innovation must move beyond technology towards improving livability, equity, and well-being. Challenges such as digital divides, privacy concerns, and lack of citizen engagement remain obstacles. However, the integration of AI with sustainability goals and inclusive frameworks ensures that smart cities can progress toward resilience and fairness.

At last, smart cities are not defined only by advanced technologies but by their ability to combine AI, ICT, and governance for sustainable, inclusive, and citizen-focused development. The reviewed cases and data show that while smart cities hold transformative potential, their success depends on bridging inequalities, ensuring participation, and maintaining sustainability. Smart life thus becomes the central outcome, where technology and human needs converge to build cities that are both innovative and equitable.

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