



## Harnessing AI and IoT for Secure and Sustainable Urban Development: A Smart Cities Perspective

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### Abstract

Artificial Intelligence (AI) and the Internet of Things (IoT) are reshaping smart cities areas into intelligent, interconnected ecosystems. This study examines how AI-driven technologies can boost security, promote sustainability, also increase the efficiency of city operations. A qualitative content analysis of peer-reviewed journal articles and academic publications was conducted, focusing on AI technologies considered to aid in sustainable smart city solutions in the era of internet. Through AI, systems like traffic control, waste disposal, and environmental monitoring can be significantly improved, eventually enhancing residents' quality of life. However, the extensive deployment of AI and IoT also brings obstacles, particularly in the areas of cybersecurity, data protection, and environmental consequences. The study highlights the importance of establishing strong regulatory frameworks to address these risks and fully harness the benefits of AI and IoT in urban development. It concludes that countries adopt ethical AI guidelines, encourage collaboration across sectors, invest in environmentally sustainable (Green AI) technologies, and enforce robust data privacy and security policies.

**Keywords:** AI, IoTs, Smart Cities, Sustainability, Security

### Introduction

With the rapid pace of urbanization, cities worldwide are increasingly turning to digital technologies to enhance their functionality. The concept of smart cities has gained prominence as a strategy to improve living standards, optimize service delivery, and promote environmental sustainability through data-driven solutions. Central to smart city development are the Internet of Things (IoT) and Artificial Intelligence (AI), which enable interconnected urban systems to function cohesively. However, urbanization also presents significant obstacles, such as overburdened infrastructure, severe pollution, depletion of natural resources, and a deepening of existing social inequalities (Weiwei & Guifeng 2024). To address the above issues, a transition towards a new paradigm of sustainable urban management, which is hallmarked by efficient utilization of resources, protection of the environment, and a better quality of life for the citizens, has become imperative (Xia & Rezaei, 2023).

Sustainable development involves striking a balance between economic growth and environmental restoration (Tan, 2024). It ensures that the future needs of cities can be met without jeopardising the well-being of society, the quality of life, or the health of the planet (Yan et al., 2018). Wang et al. (2024) define achieving sustainable urban development as means aligning economic progress with social involvement and preservation of the environment. As stated, many cities around the world have adopted a technology-focused approach to urban planning, aiming to meet the aims of smart and sustainable development (Su & Fan, 2023). While the integration of technology in urban governance dates back to the late 1950s and early 1960s, its full potential is only now being more effectively realized.

Weiwei and Guifeng (2024) emphasize that IoT allows cities to collect real-time data through sensors integrated into infrastructure such as traffic lights. AI then analyzes this data to streamline city functions, forecast trends, and improve decision-making. Combining Internet of Things (IoT) technologies with image processing offers a groundbreaking approach to urban monitoring by enabling advanced real-time data collection, analysis, and informed decision-making. Despite their significant potential, these technologies also raise critical issues related to protection of personal data, cybersecurity, and the environmental footprint of increasingly connected urban systems (Weiwei and Guifeng (2024) Smart cities offer answers to some of the time-old issues like traffic, garbage disposal, and power usage. But with increased connectivity via IoT and AI, cities also face new vulnerabilities (Ondiviela & Ondiviela, 2021). Smart cities face several significant challenges, including the exposure of critical infrastructure to cyber threats, the complexity of handling massive data streams generated by IoT devices, and the environmental consequences of increased resource consumption (Islam et al., 2025). Moreover, AI offers substantial efficiency gains, it also Highlights the importance of well-established framework to ensure data security, user privacy, and environmental sustainability. The swift implementation of IoT and AI technologies in urban environments underscores the urgent need to develop comprehensive knowledge on their secure and responsible implementation (Bibri & Jagatheesaperumal, 2023). Without proper safeguards, these technologies can introduce risks that undermine the benefits they are meant to deliver. Therefore, it is crucial to integrate AI in a manner that is secure, scalable, and aligned with the long-term goals of sustainable urban development. The application of AI in smart cities promotes safety and sustainability by exploring both the benefits and the possible risks associated with these technological innovations. It encompasses the need to balance technological advancement with considerations for protecting systems and promoting sustainability to build lasting urban resilience.

### Objective of the Study

The main objective of this study is to explore how AI-driven solutions capable of supporting secure, sustainable, and efficient smart city ecosystems. Specifically, the goal is to:

1. explore the role of Artificial Intelligence (AI) in enhancing the functionality of smart cities through IoT integration.
2. identify and review AI-driven solutions that promote sustainability in smart city infrastructure and services.
3. examine the security challenges associated with IoT devices and networks in smart cities and how AI addresses them.
4. evaluate existing AI-IoT models and frameworks used in smart city applications for the sustainable urban development

The integration of Artificial Intelligence (AI) and the Internet of Things (IoT) has particularly reshaped urban development, enabling smarter, more sustainable city systems. AI is instrumental in streamlining resource distribution, boost system performance, and addressing urban challenges through informed, data-centric decisions (Wolniak & Stecula, 2024).

Vasudevan (2024) AI contributes to urban sustainability by improving energy usage, streamlining waste management, and enabling real-time ecological observation. For instance, smart grid algorithms can predict electricity demand, adjust supply accordingly, reduce waste, and facilitate the adoption of renewable energy. Similarly, Gupta & Ragala (2024) notes that IoT sensors combined with AI analytics are vital for tracking air quality and optimizing the handling of city waste. Security plays a crucial role in the development of smart cities. Artificial Intelligence increase cybersecurity by enabling real-time threat detection and response. It also supports data privacy through sophisticated encryption methods and AI-driven anomaly detection systems that safeguard information shared across IoT networks. In addition, AI-based surveillance tools contribute to public safety by spotting potential threats and facilitating swift action (Hussain, 2024). However, despite these innovations, several challenges persist. The implementation of AI and IoT into urban infrastructure is hindered by concerns over privacy, significant financial costs, and the necessity for comprehensive regulatory policies (Wolniak & Stecula, 2024). Addressing these issues demands coordinated efforts from government officials, technology experts, and city planners to promote equitable and responsible development.

### Artificial Intelligence and its Urban Development

The use of AI in urban development has brought major improvements, especially in how efficiently cities operate. As noted by Zhou et al. (2022) AI can boost services like traffic control, waste management, and energy use by analyzing huge amounts of data from IoT devices and making quick, informed decisions. For example, AI can adjust traffic lights in real time to ease traffic jams, cut down on pollution, and make it easier for people to get around (Liu et al.,

2021). Presently, AI is being applied in different regions across the globe. Such as Europe, America, and Asia, particularly in Amsterdam, London, Vienna, Stockholm, Toronto, Singapore, and Hong Kong, have been utilising AI to achieve sustainable outcomes in their smart city transformation objectives (Son et al., 2023). Son et al. (2023) further stated that AI enhanced analysis capabilities, planning, awareness, and recovery operations in urban disaster management Likewise, urban planning systems have employed, amongst other things, AI in traffic system management, crime detection, air quality monitoring, efficient energy management, and water leakage detection systems (Son et al., 2023).

Manish (2025) points out that a city like Lagos aims to become a smart city, incidents like this highlight its gaps in implementing advanced governance technologies. Incorporating AI-powered analytics, predictive modelling, and IoT-based traffic monitoring could significantly transform how the city oversees and executes infrastructure projects.



**Fig 1: Transportation Gridlock and Its Implications in Lagos  
Future Direction**

As described by Manish (2025) the crisis should act as a critical warning to both the Lagos State Government and the Federal Ministry of Works. Going forward, road maintenance initiatives must incorporate technologies such as AI, big data, and machine learning to avoid similar breakdowns. For a fast-expanding city, investing in intelligent infrastructure management is no longer optional, it is essential (Manish, 2025). As reported by Manish (2025) residents of Lagos deserve proactive planning, not crisis-driven responses. It's time for the authorities to adopt technology-based governance to prevent situations where the closure of a single bridge paralyzes an entire city (Manish, 2025). In an era defined by data, analytics, and artificial intelligence, such a preventable disruption is unacceptable. Manish (2025) stated that the key question is why wasn't there a comprehensive traffic flow analysis before the closure was implemented? With proper planning, the chaos could have been avoided, ensuring a smoother transition and minimal impact on daily life.

**Artificial Intelligence and the Transformation of Traffic Management in Africa**

Urbanization in Africa is accelerating rapidly, with projections indicating that by 2050, half of the continent's population will reside in cities. This swift expansion is straining already limited urban infrastructure, resulting in inefficient traffic management and increased road congestion (Kumareswaran & Jayasinghe 2023)



### Fig 2: traffic congestion in Lagos State

Conventional navigation systems often fail to effectively manage the complexities of traffic congestion in metropolitan areas due to these limitations. The increase in vehicle numbers, limited access to live data, and the lack of detailed street maps for informal settlements are among the key factors contributing to these inefficiencies (Optimus AI Labs, 2025). AI is taking over by providing a range of intelligent navigation and traffic management solutions to help with these issues. The drawbacks of this extend beyond passenger annoyance; according to Optimus AI Labs (2025), traffic jams hinder economic production and interfere with necessary services.

### Ensuring Security and Privacy in IoT-Based Smart City Infrastructures

Cybersecurity is the most critical concerns in IoT-driven smart cities. According to Sharma and Arya (2023) the growing number of connected devices in urban settings heightens the risk of data leakage and hacking on critical infrastructure. To address these vulnerabilities, AI-powered cybersecurity solutions such as anomaly detection, threat intelligence, and intrusion prevention systems have been recommended (Botezatu & Ciupercă, 2025). The integration of IoT devices into urban infrastructure introduces new entry points for hacking, making it critical to address security issues to ensure the safety and resilience of smart city systems. Goudarzi et al. (2022) emphasize the vulnerabilities that stem from the interconnected nature of IoT networks, noting that many smart city systems lack essential security features like encryption and authentication protocols. As a result, these systems are exposed to threats such as hacking, data breaches, and service disruption attacks.

In addition, Khalil et al. (2022) pointed out the necessity of safeguarding the data privacy of citizens. AI technologies will be able to maintain the data privacy through methods such as data anonymization, encryption, and blockchain-based distributed ledger technologies. However, there have to be well-defined policies and ethical principles to ensure AI is used responsibly and effectively in smart cities (Wolniak & Stecula, 2024).

### Environmental Sustainability through AI and IoT

Ecological sustainability is currently a major global concern shaping the 21st century. With the advancement of urbanization, the pressure on resources and ecosystems from the environment increases, leading to such widespread problems as resource depletion, pollution, and climate change (Martine & Alves, 2015). AI and IoT technologies are widely applied in managing urban natural resources such as energy, water, and waste contribute a significant role in promoting environmental sustainability. Kumar et al. (2023) describe how IoT sensors are incorporated into smart water management systems. These sensors track water usage, detect leaks, and monitor pollution levels, while AI algorithms forecast water demand and help optimize its distribution. This can reduce water wastage, as well as improve the utilization of resources, particularly in water-scarce regions.



**Fig 4: illustration of water pollution with plastic bags**

The position of AI in promoting sustainability in smart cities is an emerging body of study. AI technologies have the capacity to reduce the consumption of resources, lower emissions, and facilitate the circular economy. Wolniak and Stecula, (2024) highlight how AI-assisted smart grids become more energy efficient, while Gupta et al. (2025) highlight AI's ability to optimize waste management systems, e.g., routes for collection and recycling processes. Although the use of technology in urban governance began as early as the late 1950s and 1960s, it is only in recent years that its full potential is being widely recognized and realized by individuals (Huang, 2021).



**Fig 3: isomeric garbage flowchat with garbage factory truck processing sorting and packaging**

Additionally, Zhou et al. (2022) discuss the AI has the potential to continuously track environmental factors such as air and water quality in real time, providing critical insights that enable timely and informed responses. AI can forecast environmental hazards like surges in pollution or natural disasters, enabling cities to prevent them.

### Challenges in Balancing AI, Security, and Sustainability

The hasty growth of artificial intelligence (AI) has been accompanied by cautionary concerns about how it is being integrated in different areas, including security and sustainability. All these challenges, in addition to the ethical, technological, and societal consequences, demand a strategic balance between harnessing AI’s benefits and mitigating its harms. AI has been very promising in supplementing cybersecurity as a method of predicting, sensing, and defending against cyber-attacks. While both security and AI have undeniable potential, the intersection with sustainability involves the unique problems. AI may be used to optimize energy systems, automate waste reduction, and predict ecological changes, but these uses must ensure their implementation is not causing security weaknesses as a side effect. Suggesting AI-based systems in energy grids can maximize efficiency but simultaneously expose them to potential cyber-attacks, as seen in recent power facilities attacks (Marr, 2020).

Sustainability even in AI systems themselves is also a problem. As pointed out earlier, computing expense in training advanced AI models has significant environmental consequences, posing a dilemma of the benefits of AI-based innovations against their environmental price tag (Wu et al., 2022). Therefore, it is essential to guarantee that developing AI to achieve sustainability and security goals does not come at the expense of environmental well-being (Truby, 2020).

Another approach to address such a challenge is the concept of Eco-friendly AI with a focus on reducing the environmental degradation of AI models by optimizing energy use during training and inference. Aside from that, cybersecurity practices need to be incorporated in AI systems to assure not to make critical infrastructures exposed to new vulnerabilities as efforts toward sustainability are made. AI and IoT have enormous potential to restructure cities but also pose questions of balancing innovation with security and sustainability. Yigitcanlar and Cugurullo (2020) point out that the use of AI for smart cities must be closely controlled to avoid having ethical consequences, like decision-making bias and unequal access to smart city technology. Furthermore, the increased energy consumption of AI systems themselves raises questions about the net sustainability of AI solutions (Zhou et al., 2022). The challenge is to develop AI systems that not only work well, but also are secure, transparent, and aligned with sustainability goals. Kanellopoulos et al. (2022) provide frameworks to integrate AI in planning smart cities with a focus on mitigating environmental impact without affecting robust data privacy and security.

### Methodology

This study employed a systematic literature review to harnessing AI and IOT solutions capable of supporting secure, sustainable, and efficient smart city ecosystems. A qualitative content analysis of peer-reviewed journal articles and academic publications was conducted, focusing on AI technologies considered to aid in sustainable smart city solutions in the era of internet are emerging and intersecting, and the themes become clearer with developing progress of the research with time. Carrying out a systematic review of literature on a novel body of research involving new topics and issues performs a number of functions. One of them is a very significant reason to become aware of both the advantages and risk of such technologies knowledge within the field that helps researchers understand current findings, innovations, and outcomes. It becomes a basis for further investigation and exploration.

## Conclusion

The integration of AI and IoT provides a revolutionary opportunity for smart cities with the possibility of promoting efficiency, sustainability, and urban living quality. However, the rapid innovation of these technologies also provides serious challenges, particularly with regards to cybersecurity, data privacy, and environment sustainability. AI can be a vital solution to overcome these challenges but must be embraced carefully keeping in mind the ethical, security, and sustainability aspects.

## Recommendations

Based on the research findings the researcher made the following recommendations:

- African countries should develop ethical AI frameworks.
- Countries should promote cross-sector collaborations.
- Government should invest in Green AI technologies.
- Government should strengthen policies on data privacy and security.

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