INOSR APPLIED SCIENCES 13(2):142-146, 2025
ISSN: 2705-165X

INOSR13.2.000
International Network Organization for Scientific Research
https://doi.org/10.59298/INOSRAS/2025/13.2.142146

Artificial Intelligence in Optimizing Network Design for Smart Cities in Nigeria

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ABSTRACT

The emergence of smart cities represents a paradigm shift in urban planning, driven by the integration of digital technologies to enhance infrastructure, services, and quality of life. In Nigeria, a rapidly urbanizing nation with increasing pressure on urban infrastructure, Artificial Intelligence (AI) has the potential to transform network design for smart cities. This review explores the role of AI in optimizing network design, focusing on transportation systems, energy grids, water management, telecommunication networks, and public safety systems. It discusses the challenges of current urban network infrastructure, outlines AI-driven methodologies such as machine learning, deep learning, reinforcement learning, and evolutionary algorithms, and highlights their applications in intelligent traffic control, predictive maintenance, resource allocation, and decision-making. The review also identifies the specific opportunities and constraints in the Nigerian context, including technological readiness, data availability, policy frameworks, and urban governance. Finally, it presents strategic recommendations for policymakers, urban planners, and technologists to harness AI in building resilient, efficient, and inclusive smart city networks.
Keywords: Artificial Intelligence, smart cities, Nigeria, network design, machine learning.

INTRODUCTION

Urbanization is one of the most powerful transformative forces shaping contemporary societies. In Nigeria, urban growth has accelerated dramatically over the past few decades. The United Nations projects that by 2050, more than 60% of Nigeria's population will reside in urban areas up from just 35% in 1990 [1]. Major urban centers such as Lagos, Abuja, Kano, Ibadan, Port Harcourt, and Enugu are experiencing significant population influx, driven by rural-to-urban migration, economic aspirations, and population growth. While urbanization can drive economic development and innovation, it also brings with it numerous challenges related to infrastructure, resource management, service delivery, and sustainability [2]. Traditional urban planning and management frameworks in Nigeria have proven inadequate in addressing the scale and complexity of these emerging urban challenges. Existing infrastructure networks, such as transportation systems, electricity grids, water distribution, waste management, and telecommunication systems are under immense strain [3]. Many Nigerian cities face recurring issues such as gridlock traffic, electricity blackouts, poor waste disposal, water scarcity, flooding, and increasing security threats. These challenges not only hinder economic productivity but also degrade the quality of life for millions of urban residents. In response to these growing urban pressures, the concept of "smart cities" has emerged globally as a forward-looking approach to sustainable urban development. A smart city integrates Information and Communication Technologies (ICT), the Internet of Things (IoT), and Artificial Intelligence (AI) to enhance the efficiency, resilience, and responsiveness of urban infrastructure and services [4]. AI, in particular, is central to the smart city paradigm because it enables systems to autonomously process vast data inputs, learn from real-time patterns, forecast future states, and optimize operations without constant human intervention.

At the core of smart city development is the optimization of urban networks. These include transportation networks, energy distribution systems, water supply chains, telecommunication frameworks, waste collection systems, and public safety grids. In Nigeria, the effective design, deployment, and management of these interconnected networks is crucial for achieving smart urban functionality [5]. Artificial Intelligence can significantly enhance network

design by enabling predictive analytics, anomaly detection, autonomous decision-making, and adaptive control systems.

For instance, AI algorithms can be used to optimize traffic signal timings in real-time based on vehicle flow patterns, reducing congestion and emissions. Similarly, smart energy grids powered by AI can predict power demand and supply fluctuations, allowing for load balancing and efficient energy distribution [6]. In the realm of public safety, AI-enabled surveillance systems can detect suspicious activities and trigger prompt responses from security agencies. These examples illustrate how AI can serve as a catalyst for transforming Nigerian cities into smarter, safer, and more sustainable environments. Despite the transformative potential of AI in urban network optimization, Nigerian cities are yet to fully leverage these technologies. Many urban centers continue to operate with outdated infrastructure, fragmented data systems, and manual decision-making processes that limit operational efficiency [7]. There is limited implementation of AI-driven solutions in network design and management, largely due to inadequate technical infrastructure, lack of skilled human capital, poor data governance frameworks, and limited government investment in smart city initiatives Moreover, urban planning in Nigeria has often been reactive rather than proactive, with minimal integration of emerging technologies. As a result, cities are left vulnerable to the compounding effects of traffic congestion, energy crises, environmental degradation, and public health threats [8]. If Nigeria is to realize the vision of smart cities, there is an urgent need to explore how AI can be systematically applied to optimize the design and functioning of critical urban networks. The primary objective of this study is to evaluate the transformative role of Artificial Intelligence (AI) in optimizing network design for smart cities in Nigeria, with a focus on addressing the inefficiencies and limitations of current urban infrastructure systems [9]. Specifically, the study aims to analyze the state of existing urban networks such as transportation, energy, water, telecommunications, and public safety in Nigerian cities, and to examine the applicability of AI techniques like machine learning, deep learning, and reinforcement learning in enhancing their performance and integration. Through this lens, it explores practical implementations of AI in smart city systems, drawing on both local case studies and experiences from comparable developing contexts. It also investigates the challenges impeding AI adoption in Nigeria's urban development, including infrastructural gaps, policy inadequacies, limited technical capacity, and financial constraints. Guided by key research questions, the study seeks to uncover the infrastructural, technological, and institutional barriers to AI deployment, and to identify actionable strategies that can support effective AI integration into urban planning and governance. This research is significant because it contributes to the growing body of scholarship on smart city development in Sub-Saharan Africa, where rapid urbanization demands innovative solutions to complex socio-economic and environmental challenges. By centering on Nigeria, the region's most populous and economically influential nation—the study provides scalable insights relevant to other countries experiencing similar transitions. It also emphasizes the urgency for Nigeria to embrace AI-driven, data-centric urban management to remain competitive in a global economy increasingly shaped by digital technologies. Furthermore, it offers a practical framework for stakeholders, ranging from policymakers and urban planners to private sector actors and civil society to engage with AI in a strategic, inclusive, and sustainable manner. Ultimately, the study aligns with global development priorities, particularly SDGs 9 and 11, advocating for resilient, technology-enabled, and future-ready urban systems.

AI Techniques in Network Optimization

Artificial Intelligence (AI) offers a suite of powerful techniques that are revolutionizing network optimization in smart city design, enabling systems to become more adaptive, efficient, and intelligent [10]. Machine Learning (ML) algorithms can analyze vast datasets to uncover patterns in traffic flow, energy usage, and communication behavior, facilitating improved routing strategies, real-time load balancing, and accurate demand forecasting. Deep Learning (DL), particularly through models such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), excels in processing complex visual and temporal data—making it invaluable for tasks such as real-time surveillance analysis and prediction of energy or traffic demand over time. Reinforcement Learning (RL) introduces a dynamic, feedback-driven approach where intelligent agents learn optimal actions through trial and error within simulated or real-world environments, enhancing adaptive control in systems like traffic signal networks and smart power grids. Furthermore, Swarm Intelligence and Evolutionary Algorithms, inspired by natural phenomena like ant colonies and genetic evolution, are increasingly applied to optimize the deployment of sensors, expand wireless network coverage, and enhance energy-efficient routing protocols in smart infrastructure. Together, these AI techniques offer a robust foundation for building responsive, self-optimizing urban networks that can meet the complex demands of modern smart cities, particularly in rapidly growing urban centers such as those in Nigeria [11].

Applications of AI in Smart City Network Design

Artificial Intelligence (AI) plays a pivotal role in optimizing network design across various domains of smart cities in Nigeria, enabling more efficient, responsive, and sustainable urban systems. In smart transportation networks, AI facilitates real-time vehicle detection, congestion forecasting, and dynamic traffic light control, which can significantly improve mobility and reduce carbon emissions in congested cities like Lagos by optimizing Bus Rapid

Transit (BRT) routes [12]. In the energy sector, AI supports load forecasting, fault detection, and the integration of renewable sources, offering potential solutions to Nigeria's erratic power supply and enabling better management of off-grid solar systems. Telecommunication networks also benefit from AI through enhanced Quality of Service (QoS), predictive maintenance, and real-time anomaly detection, which are crucial in supporting reliable mobile and broadband connectivity in rapidly growing urban centers. AI applications in water and waste management include using sensor-based analytics to monitor water quality, detect pipeline leakages, and plan efficient waste collection routes, thereby improving public health outcomes in underserved areas. Additionally, AI enhances public safety through surveillance technologies that support facial recognition, behavioral analytics, crime forecasting, and streamlined emergency response systems. These AI-driven innovations collectively contribute to building smarter, safer, and more livable cities in Nigeria's fast-urbanizing landscape [13].

Challenges in Nigeria's AI-Driven Smart City Development

Despite the promising potential of artificial intelligence (AI) in advancing smart city development in Nigeria, several critical challenges continue to impede progress. One of the foremost obstacles is the lack of high-quality and comprehensive datasets, as urban data in Nigeria is often fragmented, outdated, or inaccessible, limiting the ability of AI systems to generate accurate insights and predictions [14]. This issue is compounded by infrastructural deficits, including limited broadband internet coverage, unreliable power supply, and underdeveloped sensor networks, all of which hinder the real-time data collection and seamless operation of smart city technologies. Additionally, there is a significant shortage of professionals with expertise in AI, data science, and urban informatics, resulting in a skills gap that constrains local innovation and implementation capacity. Nigeria also suffers from policy and regulatory gaps, with no coherent national AI strategy or robust legal frameworks to guide ethical AI deployment and data governance. Furthermore, the rise of AI-driven surveillance and data analytics raises serious ethical and privacy concerns, particularly regarding citizen rights, data security, and government accountability. These multifaceted challenges underscore the urgent need for strategic investments, capacity building, and regulatory reforms to harness the full benefits of AI in shaping inclusive, efficient, and sustainable smart cities across Nigeria [15].

Case Studies and Emerging Initiatives

Several case studies and emerging initiatives in Nigeria illustrate the country's gradual but promising steps toward integrating Artificial Intelligence (AI) into smart city development. The Eko Atlantic project in Lagos, though still under construction, is envisioned as a cutting-edge urban space built on reclaimed land, with potential to serve as a model for AI-driven infrastructure and sustainable smart city planning [16]. It aims to incorporate intelligent energy systems, smart transportation networks, and real-time monitoring systems. Similarly, the Abuja Smart City Project is another ambitious initiative focused on deploying digital infrastructure and intelligent transportation systems to enhance urban mobility and connectivity. However, its implementation remains in early stages, with limited AI integration achieved so far. Beyond government-led projects, Nigeria's startup ecosystem is playing a critical role in driving AI adoption. Organizations such as Data Science Nigeria (DSN) and Robotics and Artificial Intelligence Nigeria (RAIN) are actively building local capacity by training professionals, supporting AI research, and developing context-specific solutions for healthcare, agriculture, and urban development. These startups not only contribute to workforce development but also act as catalysts for technological innovation, ensuring that Nigeria is not left behind in the global movement toward smarter, AI-enabled cities that are resilient, efficient, and inclusive [17].

Future Directions and Recommendations

To fully harness the transformative potential of Artificial Intelligence (AI) in smart city network design, Nigeria must adopt a multi-faceted and strategic approach. A critical first step is substantial investment in infrastructure, particularly in expanding broadband connectivity and ensuring a stable, reliable power supply—both foundational to supporting AI systems and real-time data operations [18]. Equally important is the establishment of robust data governance frameworks that promote open data access, standardization, and interoperability across sectors, enabling seamless data sharing and integration for informed decision-making. Building human capital is also essential; this involves promoting AI research, expanding technical training programs, and incorporating AI and data science into national educational curricula to cultivate a skilled workforce. Moreover, fostering public-private partnerships (PPPs) can accelerate innovation and resource mobilization by encouraging collaboration between government entities, technology companies, universities, and development organizations to co-develop and implement smart solutions. Finally, the adoption and enforcement of ethical guidelines are paramount to ensure the responsible use of AI. This includes instituting measures that promote transparency, protect privacy, prevent algorithmic bias, and uphold accountability—thereby fostering public trust and ensuring that AI-driven smart city innovations are inclusive, fair, and aligned with the rights and needs of all citizens.

CONCLUSION

Artificial Intelligence (AI) offers an unprecedented opportunity to revolutionize network design and service delivery in Nigeria's rapidly urbanizing cities. By enabling data-driven decision-making, adaptive infrastructure

management, and predictive analytics, AI can optimize transportation, energy, water, communication, and public safety systems, paving the way for more efficient, resilient, and inclusive smart cities. However, the full realization of AI's potential is hindered by infrastructural gaps, limited technical expertise, weak data governance, and insufficient policy frameworks. Addressing these challenges will require coordinated efforts across multiple sectors, including sustained investments in digital infrastructure, workforce development, and public-private partnerships. Equally critical is the need to implement ethical guidelines that safeguard privacy, equity, and accountability in AI deployment. As Nigeria positions itself for a technology-driven urban future, integrating AI into smart city design will not only enhance quality of life and urban sustainability but also promote innovation and global competitiveness. The time is ripe for Nigeria to act boldly and strategically in embracing AI for smart urban transformation.

REFERENCES

1. Dodman, D., Leck, H., Rusca, M., Colenbrander, S.: African Urbanisation and Urbanism: Implications for risk accumulation and reduction. International Journal of Disaster Risk Reduction. 26, 7–15 (2017). https://doi.org/10.1016/j.ijdrr.2017.06.029
2. Adedeji, I.: Nigerian Urbanization and the Significance of Affordable Housing. Journal of Service Science and Management. 16, 351 (2023). https://doi.org/10.4236/jssm.2023.163020
3. Zhang, Y., Lin, Y., Zheng, G., Liu, Y., Sukiennik, N., Xu, F., et al.: MetaCity: Data-driven sustainable development of complex cities. The Innovation. 6, 100775 (2025). https://doi.org/10.1016/j.xinn.2024.100775
4. Oyadeyi, O.A., Oyadeyi, O.O.: Towards inclusive and sustainable strategies in smart cities: A comparative analysis of Zurich, Oslo, and Copenhagen. Research in Globalization. 10, 100271 (2025). https://doi.org/10.1016/j.resglo.2025.100271
5. Ghazouani M, Fandi F Z, Zaher N, Ounacer S, Karim Y, Aziza C, Azzouazi M (2024). Enhancing Immersive Virtual Shopping Experiences in the Retail Metaverse Through Visual Analytics, Cognitive Artificial Intelligence Techniques, Blockchain-Based Digital Assets …*Engineering Applications of Artificial Intelligence*, *305-318*.
6. Mahmood, M., Chowdhury, P., Yeassin, R., Hasan, M., Ahmad, T., Chowdhury, N.-U.-R.: Impacts of digitalization on smart grids, renewable energy, and demand response: An updated review of current applications. Energy Conversion and Management: X. 24, 100790 (2024). https://doi.org/10.1016/j.ecmx.2024.100790
7. George U A, Kolawole A O, Ebenezer E (2023). Critical review on the application of artificial intelligence techniques in the production of geopolymer-concrete. *SN Applied Sciences*, *5*, *(8)*, *217*.
8. Shao, Y., Yang, Z., Yan, Y., Yan, Y., Israilova, F., Khan, N., Chang, L.: Navigating Nigeria's path to sustainable energy: Challenges, opportunities, and global insight. Energy Strategy Reviews. 59, 101707 (2025). https://doi.org/10.1016/j.esr.2025.101707
9. Alum, E.U., Ugwu, O.PC. Artificial intelligence in personalized medicine: transforming diagnosis and treatment. *Discov Appl Sci* 7, 193 (2025). https://doi.org/10.1007/s42452-025-06625-x
10. Echegu D. A., Artificial Intelligence (AI) in Customer Service: Revolutionising Support and Engagement. IAA Journal of Scientific Research 11(2):33-39, 2024. https://doi.org/10.59298/IAAJSR/2024/112.3339
11. Elassy, M., Al-Hattab, M., Takruri, M., Badawi, S.: Intelligent transportation systems for sustainable smart cities. Transportation Engineering. 16, 100252 (2024). https://doi.org/10.1016/j.treng.2024.100252
12. Okonta, D.E., Vukovic, V.: Smart cities software applications for sustainability and resilience. Heliyon. 10, e32654 (2024). https://doi.org/10.1016/j.heliyon.2024.e32654
13. Olawade, D.B., Wada, O.J., David-Olawade, A.C., Kunonga, E., Abaire, O., Ling, J.: Using artificial intelligence to improve public health: a narrative review. Front Public Health. 11, 1196397 (2023). https://doi.org/10.3389/fpubh.2023.1196397
14. Ezeonwumelu, J. O. C., Uhama, K. C., Ugwu, O. P. C., Alum, E. U., Ugwuanyi, A. C. and Tambwe, P. R. (2024). The Impact of Artificial Intelligence and Machine Learning on Pharmacy Practice. Research Invention Journal of Research in Medical Sciences 3(1):10-15.
15. Kulal, A., Rahiman, H.U., Suvarna, H., Abhishek, N., Dinesh, S.: Enhancing public service delivery efficiency: Exploring the impact of AI. Journal of Open Innovation: Technology, Market, and Complexity. 10, 100329 (2024). https://doi.org/10.1016/j.joitmc.2024.100329
16. Das, D.K.: Digital Technology and AI for Smart Sustainable Cities in the Global South: A Critical Review of Literature and Case Studies. Urban Science. 9, 72 (2025). https://doi.org/10.3390/urbansci9030072
17. Kennedy C O, Fazal E J, Michael E O, Ifeanyichukwu C O, Alaneme G U, Chidozie I(2021). Artificial intelligence prediction model for swelling potential of soil and quicklime activated rice husk ash blend for sustainable construction. *Jurnal Kejuruteraan*, *33*, *(4)*, *845-852*. *https://doi.org/10.17576/jkukm-2021-33(4)-07*.

18. Aliu, J., Oke, A.E., Jesudaju, O.T., Akanni, P.O., Ehbohimen, T., Dosumu, O.S.: Digital Evolution in Nigerian Heavy-Engineering Projects: A Comprehensive Analysis of Technology Adoption for Competitive Edge. Buildings. 15, 380 (2025). https://doi.org/10.3390/buildings15030380

CITE AS: Mugisha Emmanuel K. (2025). Artificial Intelligence in Optimizing Network Design for Smart Cities in Nigeria. INOSR APPLIED SCIENCES 13(2):142-146. https://doi.org/10.59298/INOSRAS/2025/13.2.142146