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Harnessing Artificial Intelligence for Smart City Development: Benefits and Challenges in Lagos State, Nigeria

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Abstract
This study investigates the role of Artificial Intelligence (AI) in the development of smart cities in Lagos State, Nigeria, with a particular focus on its potential benefits and implementation challenges. Employing a descriptive survey research design, the study collected quantitative data from 250 purposively selected respondents across five local government areas—Apapa, Ibeju-Lekki, Surulere, Lagos Island, and Lagos Mainland. The participants, comprising residents, urban planners, policymakers, and other stakeholders, completed structured questionnaires designed to evaluate perceptions of AI's contributions to urban mobility, energy efficiency, public safety, waste management, healthcare, and governance.Data were gathered using a validated four-point Likert scale instrument, with a Cronbach's Alpha reliability coefficient of 0.82. Descriptive statistics revealed strong agreement among respondents regarding the positive impact of AI on efficient urban planning, traffic management, resource optimization, and quality of life. One-sample t-tests further confirmed the statistical significance of these perceptions, with all items yielding p-values below 0.05 when compared to the baseline value of 2.0. However, challenges such as high implementation costs, limited access to reliable infrastructure, and a shortage of technical expertise were also significantly acknowledged.The findings underscore AI's transformative potential in urban development while highlighting the need for strategic investments in infrastructure and human capital. The study concludes with policy-oriented recommendations to facilitate the successful integration of AI technologies in the pursuit of sustainable and inclusive smart city initiatives.

Keywords: Smart Cities, Artificial Intelligence, Energy Efficiency, Public Safety, Waste Management

Introduction

The continuous growth of urban populations worldwide has driven a need for cities to transition into smart, sustainable environments capable of efficiently managing resources, delivering essential services, and improving the overall quality of life for residents. The global population appears to be moving towards urban areas. This trend has placed immense pressure on city infrastructures, demanding innovative solutions to address the challenges of urbanisation, such as traffic congestion, energy consumption, waste management, and public safety. Smart cities, which integrate advanced technologies such as the Internet of Things (IoT), big data analytics, and Artificial Intelligence (AI), offer promising solutions to these challenges. Among these technologies, AI has emerged as a pivotal tool in the development of smart cities, enabling real-time data processing, predictive analytics, and automated decision-making. AI is being leveraged to optimize urban mobility, enhance energy efficiency, improve public safety, and streamline waste management, making cities more efficient and sustainable. The ability of AI to process vast amounts of data, detect patterns, and make informed decisions positions it as a key driver in the evolution of smart cities (Hammoumi et al., 2024). Moreover, AI's role extends to healthcare systems within smart cities, where it supports predictive health analytics, enhances diagnostic accuracy, and enables personalised healthcare delivery. In the realm of governance, AI-driven systems allow for data-based policy decisions and improved resource allocation, leading to more efficient urban management. As cities continue to grow and their challenges become more complex, AI's potential to foster resilience, adaptability, and sustainability becomes increasingly evident. (Mehta et al., 2022)

Artificial Intelligence as a Veritable Tool for Building Smart Cities

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The rapid urbanization witnessed globally has necessitated the evolution of urban centers into smart cities, leveraging advanced technologies to enhance the quality of life, optimize resource utilization, and ensure sustainable development. Central to this transformation is Artificial Intelligence (AI), which offers innovative solutions across various urban sectors. This literature review delves into the multifaceted applications of AI in smart cities, examining its role in urban planning, infrastructure management, public safety, environmental monitoring, and citizen engagement (Herath& Mittal, 2022). Smart cities represent the future of urban living, where technology and data-driven insights enhance the quality of life for residents, optimize resource management, and create sustainable environments. Artificial Intelligence (AI) plays a crucial role in realizing these goals by enabling cities to operate efficiently, make informed decisions, and adapt to the changing needs of their populations. Below are the ways AI is contributing to the development of smart cities: Optimizing Urban Mobility and Smart Transportation Systems**:** Transportation is a vital component of urban life, and AI enhances its efficiency through intelligent traffic management and autonomous mobility solutions. AI-driven traffic light systems, for instance, adjust signal timings based on real-time traffic data, reducing congestion and emissions. Furthermore, AI facilitates the development of autonomous vehicles, which promise to revolutionize urban mobility by providing safer and more efficient transportation options. AI algorithms can analyze traffic patterns in real-time to manage congestion, reduce travel times, and lower emissions. Smart traffic lights, for example, use AI to adjust signal timings dynamically based on current traffic conditions. In public transportation, AI helps optimize routes, schedules, and vehicle dispatch, improving service efficiency and reducing overcrowding. For instance, cities like Singapore and Amsterdam use AI-based traffic management systems to reduce congestion and manage public transportation more efficiently (Zamponi & Barbierato, 2022). Energy Efficiency and Resource Management:AI enhances energy efficiency by predicting demand and managing supply in real-time. Smart grids, powered by AI, can balance electricity supply with consumption, leading to reduced energy waste. AI also enables smart meters, which monitor household and commercial energy use, providing recommendations to minimize waste and promote energy conservation. For instance, AI systems in smart grids, such as those in cities like Barcelona, manage the distribution of renewable energy to homes and industries, reducing reliance on fossil fuels (Cugurullo, 2020).

AI enables smart waste management systems, optimizing the collection and recycling processes. AI-powered sensors installed in waste bins monitor fill levels and predict the best collection routes. This reduces fuel consumption and operational costs. Additionally, AI helps in environmental monitoring, analyzing air and water quality data to prevent pollution and ensure sustainability. For example, Seoul has implemented AI in its waste management system, significantly reducing unnecessary waste collections and contributing to a cleaner city environment (Wolniak&Stecula, 2024). AI is revolutionizing healthcare in smart cities through telemedicine, predictive analytics, and AI-assisted diagnostics. AI-driven healthcare platforms can monitor patients remotely, predict health issues based on data analysis, and improve the overall healthcare delivery system. This is especially useful in cities where hospitals may face high demand or during public health crises. For instance, AI-enabled systems in Toronto's smart city framework have been integrated with local healthcare providers, offering predictive insights into healthcare needs and optimizing resource allocation (Cugurullo, 2020). AI facilitates better decision-making for city administrators by providing insights through the analysis of massive datasets collected from various urban sources, such as public services, transportation, and citizen feedback. This enables data-driven governance, ensuring that policies and resources are effectively managed. For example, New York City's government uses AI to analyze data across city services, helping authorities allocate resources where they are most needed (Luckey et al., 2021). AI technology is increasingly used in building management to improve energy efficiency, security, and comfort for occupants. Smart buildings equipped with AI can control lighting, heating, ventilation, and air conditioning (HVAC) systems based on occupancy and environmental conditions. For instance, in smart cities like Copenhagen, AI-powered buildings adapt energy consumption based on real-time data, reducing operational costs and environmental impact (Hammoumi et al., 2024). AI has emerged as a pivotal tool in urban planning, offering new methods for analyzing, modelling, and simulating complex urban systems. By processing vast amounts of data, AI enables city planners to make informed decisions that promote sustainability and resilience. For instance, AI-driven digital twins—virtual replicas of physical urban environments—facilitate scenario testing and predictive analysis, aiding in efficient resource allocation and infrastructure development. highlight the integration of generative AI techniques with urban digital twins to automate data generation, scenario planning, and urban design, thereby enhancing the scalability and reliability of smart city management. (Kumar et al., 2024).

Public safety is a critical concern in urban environments, and AI contributes significantly to its enhancement. Advanced surveillance systems equipped with AI-powered cameras and facial recognition technologies enable real-time monitoring, threat detection and aid in tracking missing persons or detecting suspicious activities.. Additionally, AI algorithms analyze crime data to predict potential hotspots, allowing law enforcement agencies to allocate resources proactively. The integration of AI in emergency response systems ensures rapid identification and assessment of incidents, facilitating timely interventions and minimizing risks to citizens. A report by S&P Global (2024) emphasizes that AI-powered smart cities can enhance safety by utilizing data analytics to predict and mitigate potential threats. For example, in cities like Dubai, AI-driven facial recognition systems have been integrated into public safety infrastructures to enhance security (Herath & Mittal., 2022). AI enhances citizen engagement by streamlining service delivery and fostering participatory governance. Chatbots and virtual assistants powered by AI provide residents with instant access to information and services, improving user experience and operational efficiency. For instance, AI can process applications and respond to inquiries, freeing up staff to handle more complex tasks. (Kaiser, 2024) highlights that AI can greatly ease citizen service delivery through smart conversations and efficient processing of applications. Artificial Intelligence (AI) serves as a pivotal tool in the development of smart cities, offering innovative solutions to urban challenges. In Lagos State, Nigeria, integrating AI can significantly enhance urban management and improve residents' quality of life.

Key Components of an AI-Driven Smart City Model for Lagos State:

Smart Traffic Management: Implement AI algorithms to analyze real-time traffic data, optimizing traffic flow, reducing congestion, and minimizing travel times. This approach can lead to more efficient transportation systems and improved air quality (Nikitas et al., 2020). Utilize AI to monitor waste levels in bins, predict collection schedules, and optimize routes for waste collection vehicles. This system can enhance sanitation services and promote environmental sustainability. Deploy AI to manage energy consumption across the city, balancing supply and demand, and integrating renewable energy sources. This strategy can lead to cost savings and a reduced carbon footprint (Camacho et al., 2024). Employ AI-powered surveillance systems to detect and respond to security threats in real-time, improving public safety and emergency response times. Implement AI in healthcare facilities to analyze patient data, predict health trends, and optimize resource allocation, thereby enhancing the quality and accessibility of healthcare services. Use AI to analyze demographic and environmental data, informing sustainable urban planning decisions and infrastructure development. Develop AI-driven platforms to facilitate communication between residents and local authorities, enabling efficient service delivery and fostering community participation. (Yigitcanlar et al., 2020).

Challenges and Considerations:

1. Data Privacy and Security: Ensure robust measures are in place to protect citizens' data privacy and prevent unauthorized access.
2. Infrastructure Development**:** Invest in the necessary technological infrastructure to support AI applications, including reliable internet connectivity and data storage solutions.
3. Public Awareness and Education: Conduct programs to educate residents about AI technologies and their benefits, fostering acceptance and active participation.
4. Policy and Regulation**:** Develop clear policies and regulations governing the use of AI in public services to ensure ethical standards and accountability (Bokhari & Myeong, 2022).

By addressing these challenges and leveraging AI technologies, Lagos State can advance towards becoming a more efficient, sustainable, and livable smart city. To conceptualize the architecture of Artificial Intelligence (AI) as a tool for building smart cities, such as Lagos State, we can break it down into several key components. Here's an outline of how AI can be integrated into a smart city, focusing on the infrastructure, data management, and intelligent decision-making systems that drive improvements in urban living:

AI Architecture for Smart Cities such as Lagos State:

In a smart city framework, the Data Collection Layer serves as the foundational component, where smart sensors are deployed to gather vital information on traffic patterns, weather conditions, air quality, and energy consumption. This is complemented by a diverse range of IoT devices, including smart meters, surveillance cameras, and RFID sensors, all working in tandem to facilitate real-time data acquisition. Public engagement tools, such as interactive kiosks and citizen feedback systems, further enrich this layer by capturing the perspectives and experiences of city residents.

At the Communication Layer, connectivity is paramount. Technologies such as 5G and Wi-Fi networks enable high-speed, low-latency transmission of data, ensuring seamless interaction between devices and systems. A crucial component here is the data bus, composed of APIs that use standardized communication protocols to allow interoperability across the entire smart city ecosystem. Furthermore, edge computing capabilities allow for the pre-processing of data close to the source, significantly reducing latency and enabling timely, intelligent decision-making.

The Data Processing and Analysis Layer handles the aggregation and storage of the immense volumes of data generated. This is achieved through robust cloud infrastructure, including platforms like AWS, Microsoft Azure, or proprietary servers. To manage and process large datasets, big data tools such as Hadoop and Spark are employed. Layered atop these tools are AI and machine learning algorithms—spanning supervised, unsupervised, and reinforcement learning—that analyze traffic patterns, optimize energy consumption, and predict equipment maintenance requirements.At the heart of intelligent urban systems lies the Artificial Intelligence Layer, dedicated to decision-making and automation. This layer utilizes diverse AI models, including neural networks, decision trees, and clustering algorithms, to identify anomalies, forecast trends, and recommend context-specific solutions. Optimization algorithms are instrumental in refining the allocation of city resources, from public transport to water and electricity distribution. Additionally, autonomous systems, such as self-driving vehicles, drones, and robotic waste collectors, operate based on AI guidance to perform essential city functions.The Visualization Layer translates complex datasets into accessible, actionable insights. Through AI-powered dashboards, city officials can monitor key metrics like traffic density, pollution levels, and energy use in real time. Citizens also benefit from public interfaces such as mobile applications that provide updates on traffic, smart parking availability, and more. Control centers serve as centralized hubs where administrators oversee and coordinate various city services.

In the Action Layer, intelligent infrastructure systems come to life. Smart traffic management systems use AI to control traffic signals dynamically, reducing congestion and suggesting alternative routes. Energy optimization is realized through AI-enabled smart grids that enhance distribution efficiency and minimize waste. In the same vein, waste management systems utilize sensors and AI to track bin fill levels and automate collection routes. Smart healthcare solutions, including emergency response coordination, predictive diagnostics, and telemedicine, are integrated into urban health frameworks.Security and trust are upheld in the Security and Governance Layer, where AI-based cybersecurity systems detect and prevent digital threats, protecting sensitive data. Alongside these, privacy and data governance mechanisms ensure adherence to legal frameworks such as GDPR, maintaining citizen trust and regulatory compliance. Finally, the Feedback Loop and Continuous Improvement Layer ensures that the smart city remains adaptive and responsive. AI feedback systems continually learn from operational data, refining predictive models and enhancing urban planning efforts. Moreover, public participation is actively encouraged; AI analyzes citizen feedback to guide service improvement and infrastructure development, fostering a truly inclusive and evolving smart city environment (Bokhari&Myeong, 2022).

Statement of the Problem

Lagos State, the commercial nerve center of Nigeria, continues to experience exponential urban growth, with rising challenges in areas such as transportation, waste management, energy distribution, security, and public service delivery. Despite various efforts by the government and stakeholders to address these issues, the absence of an integrated and intelligent approach has limited the effectiveness of urban management strategies. Traditional systems are often reactive, inefficient, and unable to cope with the dynamic demands of a rapidly expanding population. Artificial Intelligence (AI) has emerged globally as a transformative tool for developing smart cities by enabling data-driven decision-making, real-time monitoring, predictive analytics, and automation of urban systems. However, the application of AI in Lagos State remains largely untapped, fragmented, or in nascent stages, with limited empirical research examining its potential, current usage, or implementation barriers within the local context. There exists a critical knowledge gap in understanding how AI technologies can be systematically harnessed to build sustainable, resilient, and efficient urban ecosystems in Lagos. Without a clear roadmap and evidence-based analysis, the state risks falling behind in leveraging AI innovations that could enhance service delivery, improve quality of life, and drive socio-economic development. This paper, therefore, seeks to investigate the role of AI as a strategic tool for building smart cities in Lagos State, identify existing limitations, and propose actionable insights for effective integration (Gupta et al., 2022).

Aim and Objectives of the Study

The study aims to explore the role of AI in smart city development. The primary objectives of this study are as follows:

1. Investigate the potential benefits of AI adoption in smart cities (e.g., efficient urban planning, traffic management, energy consumption, water and waste management, healthcare delivery, and improved quality of life).
2. Identify challenges and drawbacks to AI adoption in smart cities (e.g., high costs, limited access to reliable electricity and internet, and lack of technical expertise).

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Hypothesis
H01: Artificial Intelligence does not significantly contribute to the development and efficiency of smart cities in terms of infrastructure management, resource optimization, and quality of life improvement.

Methodology
This study adopts a descriptive survey research design to explore the role of Artificial Intelligence (AI) in the development of smart cities in Lagos State, Nigeria. The design facilitates the collection of quantitative data through structured questionnaires, enabling the assessment of perceptions and attitudes toward AI-driven smart city initiatives. The study focuses on five selected local government areas (LGAs) in Lagos State: Apapa, Ibeju-Lekki, Surulere, Lagos Island, and Lagos Mainland. The target population comprises residents, urban planners, policymakers, and other stakeholders in the selected LGAs of Lagos State. A purposive sampling technique was employed to ensure the inclusion of respondents with relevant knowledge or experience in urban development and technology adoption. A total of 250 respondents were selected, with 50 respondents from each of the five LGAs, ensuring equal representation across the study areas.

Data were collected using a structured questionnaire designed to evaluate respondents' perceptions of AI's contributions to smart city development, including its impact on urban mobility, energy efficiency, public safety, waste management, healthcare, and governance. The questionnaire consisted of closed-ended questions using a four-point Likert scale (Strongly Disagree = 1, Disagree = 2, Agree = 3, Strongly Agree = 4). The instrument was validated through a pilot test conducted with 20 respondents outside the study sample, and reliability was assessed using Cronbach’s Alpha, yielding a coefficient of 0.82, indicating high reliability. The questionnaires were administered directly to respondents in the selected LGAs by trained research assistants. The process involved obtaining informed consent from participants and ensuring anonymity to encourage honest responses. The data collection spanned two weeks, with follow-up visits to retrieve completed questionnaires. A total of 250 questionnaires were distributed, and all were returned, resulting in a 100% response rate.

The collected data were analyzed using both descriptive and inferential statistical methods. Descriptive statistics, including frequency distributions and percentages, were used to summarize respondents' perceptions of AI's role in smart city development. Inferential statistics, specifically the one-sample t-test, was employed to test the significance of the hypotheses and assessed the association between AI adoption and smart city efficiency, while the t-test compared mean responses against a test value of 2.0 to determine the significance of AI's perceived contributions. Data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 26.0.

Results

Table 1: Summary of descriptive statistics on the potential benefits of AI adoption in smart cities (e.g., efficient urban planning, traffic management, energy consumption, water and waste management, healthcare delivery, and improved quality of life).

SN	Item	SD	D	A	SA
1	AI can play a significant role in the development of smart cities	3 (1.2)	17 (6.8)	109 (43.8)	120 (48.2)
2	An AI-powered system can enhance efficient urban planning and decision-making in smart cities	5 (2)	22 (8.8)	119 (47.8)	103 (41.4)
3	Adoption of AI can lead to efficient management of traffic in our cities	5 (2)	22 (8.8)	88 (35.3)	134 (53.8)
4	Adoption of AI can lead to efficient management of energy consumption in our cities	9 (3.6)	26 (10.4)	98 (39.4)	116 (46.6)
5	Adoption of AI can lead to efficient water and waste management in our cities	4 (1.6)	17 (6.8)	71 (28.5)	157 (63.1)
6	Adoption of AI can lead to efficient management of health care delivery in our cities	4 (1.6)	28 (11.2)	137 (55.0)	80 (32.1)

Source: Field Survey 2025

The data presented in Table 1 provides a compelling insight into stakeholders' perceptions regarding the potential benefits of artificial intelligence (AI) adoption in the development and management of smart cities. The descriptive statistics reveal a predominantly positive outlook, with the majority of respondents agreeing or strongly agreeing with

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the various assertions about AI's transformative role in urban systems. A significant 92% of respondents either agreed or strongly agreed that AI can play a vital role in the overall development of smart cities. This high level of consensus underscores a strong recognition of AI as a foundational enabler of intelligent urban systems. Similarly, 89.2% of respondents believed that AI-powered systems can enhance efficient urban planning and decision-making, reflecting confidence in AI's ability to process complex datasets and support evidence-based policy and infrastructure planning. In the area of traffic management, a substantial 89.1% expressed agreement that AI adoption could lead to more efficient handling of vehicular movement and congestion. Notably, 53.8% strongly agreed, suggesting heightened public expectation for AI-driven traffic solutions, such as adaptive traffic signal systems and real-time routing algorithms. AI's potential in energy management also received strong endorsement, with 86% of respondents indicating that its adoption could enhance efficiency in energy consumption. This suggests awareness of AI's capability to support the operation of smart grids, monitor consumption patterns, and reduce energy waste.

The most pronounced support was observed in the domain of water and waste management, where 91.6% of respondents agreed or strongly agreed with the statement. The 63.1% strong agreement indicates a clear perception that AI could address longstanding inefficiencies in municipal services, likely due to its application in predictive maintenance, automated scheduling, and sensor-driven monitoring systems.In the field of healthcare delivery, while still highly rated, the strength of agreement was slightly lower. Nonetheless, 87.1% of participants recognized the potential of AI in improving health systems, including emergency response coordination, predictive diagnostics, and telemedicine services. The lower percentage of strong agreement (32.1%) may reflect cautious optimism, possibly due to concerns surrounding data privacy, ethical considerations, or the complexity of healthcare systems. The findings suggest a broad and optimistic consensus on the utility of AI in enhancing smart city functions. The positive perception across multiple sectors—urban planning, traffic, energy, waste, and healthcare—indicates that stakeholders are not only aware of AI's potential but also ready to embrace its implementation. As such, this data provides a strong empirical basis for further investments in AI-driven solutions and for formulating policies that support intelligent urban development

Table 2: Summary of descriptive statistics on challenges and drawbacks to AI adoption in smart cities (e.g., high costs, limited access to reliable electricity and internet, and lack of technical expertise).

SN	Item	SD	D	A	SA
7	There are high costs associated with deploying smart technologies	9 (3.6)	41 (16.5)	113 (45.4)	86 (34.5)
8	There is limited access to reliable electricity and internet connectivity, and a lack of technical expertise are the major drawbacks in the adoption of AI-powered systems for smart cities	14 (5.6)	38 (15.3)	73 (29.3)	124 (49.8)
9	The adoption of an AI-powered system can bring about improved public safety and security in our urban centers	16 (6.4)	33 (13.3)	97 (39)	103 (41.4)

Table 2 presents descriptive statistics that illuminate stakeholders' perceptions regarding the challenges and potential limitations of adopting artificial intelligence (AI) in smart city development. The data highlights key concerns related to cost, infrastructure, technical capacity, and public safety, which are critical for policymakers and urban planners to consider when planning AI integration. A significant 79.9% of respondents (those who agreed or strongly agreed) acknowledged that high costs are a major barrier to deploying smart technologies. Specifically, 45.4% agreed and 34.5% strongly agreed, indicating that financial constraints are a common and widely acknowledged impediment to the widespread implementation of AI-driven solutions in urban environments. This suggests that, despite awareness of AI's potential benefits, economic feasibility remains a critical concern, particularly in developing regions. Furthermore, 79.1% of respondents also identified limited access to reliable electricity, internet connectivity, and a shortage of technical expertise as major obstacles to the successful adoption of AI in smart cities. With 49.8% strongly agreeing, these finding underscores systemic infrastructural deficiencies that could hinder the operationalization and sustainability of smart technologies.

These challenges are especially pertinent in regions where digital infrastructure and power supply remain unreliable or underdeveloped, suggesting a need for foundational investments in these areas before AI initiatives can be effectively deployed. Interestingly, while the first two items focused on constraints, the third statement explores a

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perceived benefit of AI adoption—its potential to enhance public safety and security in urban centers. Here, 80.4% of respondents expressed agreement, with 41.4% strongly agreeing, indicating that despite the identified drawbacks, there remains strong belief in AI's ability to deliver tangible improvements in urban security, such as through surveillance systems, predictive policing, and emergency response management. The findings from Table 2 reflect a dual perspective: while there is clear recognition of AI's value in improving urban life, there is also an acute awareness of the real-world barriers that could stall or complicate its implementation. These insights point to the necessity for targeted policy interventions—such as financial subsidies, infrastructure development, and capacity-building initiatives—to address these foundational challenges and pave the way for inclusive and sustainable AI integration in smart cities.

Table 3: On-sample t-test on the potential benefits of AI adoption in smart cities (e.g., efficient urban planning, traffic management, energy consumption, water and waste management, healthcare delivery, and improved quality of life).

SN	Item	t	df	p-value	MD
1	AI can play a significant role in the development of smart cities	32.743	248	.000	1.38956
2	An AI-powered system can enhance efficient urban planning and decision-making in smart cities	28.592	248	.000	1.28514
3	Adoption of AI can lead to efficient management of traffic in our cities	30.236	248	.000	1.40964
4	Adoption of AI can lead to efficient management of energy consumption in our cities	25.552	248	.000	1.28916
5	Adoption of AI can lead to efficient water and waste management in our cities	34.707	248	.000	1.53012
6	Adoption of AI can lead to efficient management of health care delivery in our cities	27.123	248	.000	1.17671
7	Adoption of AI can lead to improved quality of life in our cities	26.365	248	.000	1.30120

All items under Table 3 yielded highly significant results ($p < .001$), with positive mean differences (MDs) ranging from 1.17 to 1.53. These results suggest that participants overwhelmingly agree on the potential of AI to transform urban systems positively. The highest mean difference (MD = 1.53012, *t* = 34.707) was recorded for the item *"Adoption of AI can lead to efficient water and waste management in our cities"*. This reflects the strongest consensus among respondents regarding AI's ability to optimize critical municipal services. Similarly, substantial support was observed for statements regarding traffic management (*MD = 1.40964*), urban planning (*MD = 1.28514*), energy consumption (*MD = 1.28916*), and healthcare delivery (*MD = 1.17671*), all of which had very high t-values and statistically significant p-values. The overall perception that AI can play a significant role in the development of smart cities (*t* = 32.743, *MD = 1.38956*) reinforces the overarching optimism about AI's transformative potential in urban governance and service delivery. These results provide strong empirical support for the proposition that stakeholders perceive AI as a catalyst for enhanced efficiency, improved infrastructure management, and better quality of life in smart cities.

Table 4: Summary of one-sample t-test on challenges and drawbacks to AI adoption in smart cities (e.g., high costs, limited access to reliable electricity and internet, and lack of technical expertise).

Item

SN		t	df	p-value	MD
7	There are high costs associated with deploying smart technologies	21.771	248	.000	1.10843
8	There is limited access to reliable electricity and internet connectivity, and a lack of technical expertise are the major drawbacks in the adoption of AI-powered systems for smart cities	21.425	248	.000	1.23293
9	The adoption of an AI-powered system can bring about improved public safety and security in our urban centres	20.553	248	.000	1.15261

Key: using a test value of 2.0 as a baseline for comparison

Similar to Table 3, the results in Table 4 also showed statistically significant deviations from the baseline test value of 2.0 ($p < .001$ for all items), indicating strong agreement among respondents about the existence of key challenges hindering AI adoption. The greatest concern was around *"limited access to reliable electricity, internet connectivity, and lack of technical expertise"* ($MD = 1.23293$, $t = 21.425$), which underscores the infrastructural and capacity deficits that must be addressed for successful AI deployment.*High costs associated with deploying smart technologies"* also emerged as a major concern ($MD = 1.10843$, $t = 21.771$), reflecting financial barriers as a recurrent issue in smart city development initiatives.Interestingly, respondents still showed positive attitudes towards AI's impact on public safety and security, with an MD of 1.15261 ($t = 20.553$), suggesting a belief in AI's dual role in both advancing urban functionality and enhancing safety outcomes.

Discussion

This study aimed to explore both the potential benefits and challenges of adopting AI technologies in the context of smart cities. The results, based on descriptive statistics and one-sample t-tests, reveal strong support for the role of AI in enhancing urban living, yet also underscore significant barriers to its widespread adoption. Below is a detailed interpretation of the findings:

Potential Benefits of AI in Smart Cities

The analysis indicates that participants overwhelmingly recognize the potential of AI to transform urban environments. Specifically, AI's role in the development of smart cities was highly endorsed, with 48.2% of respondents strongly agreeing and 43.8% agreeing that AI can play a significant role in urban development. This aligns with the growing global trend of utilizing AI for urban planning, resource management, and service delivery.

Similarly, the application of AI in urban planning and decision-making received substantial support, with 41.4% strongly agreeing that AI-powered systems can enhance efficient planning and decision-making processes. This indicates a broad acknowledgment of AI's ability to optimize urban systems through predictive modeling, data analysis, and automated decision-making, essential components for smart city development.Participants were also positive about AI's impact on traffic management, energy consumption, and healthcare delivery. For example, a significant proportion (53.8%) strongly agreed that AI could facilitate efficient traffic management, a crucial area for improving urban mobility and reducing congestion. Similarly, 46.6% strongly agreed that AI could contribute to energy optimization, supporting sustainable urban living. Notably, AI's potential to improve healthcare delivery was endorsed by 32.1% of participants, indicating a recognition of AI's role in predictive healthcare systems, telemedicine, and patient management.AI's impact on water and waste management received the highest agreement (63.1% strongly agreeing), which emphasizes the increasing relevance of AI in optimizing resource allocation and ensuring sustainable environmental practices in rapidly urbanizing areas.

Challenges to AI Adoption

While the benefits of AI adoption were widely acknowledged, the study also highlighted several significant challenges to its implementation. Cost remains a critical barrier, with 34.5% of respondents strongly agreeing that the high costs associated with deploying smart technologies could impede AI adoption in smart cities. The financial constraints associated with the infrastructure needed for AI-powered systems—such as sensor networks, AI hardware, and data processing capabilities—are a major concern for cities, particularly in developing regions.Another key challenge identified was the limited access to reliable electricity and internet connectivity, which 49.8% of participants strongly agreed could hinder the adoption of AI technologies. This concern is particularly pertinent in many urban areas where infrastructure limitations and technological gaps remain persistent. As AI technologies often require high-speed internet and constant power supply for real-time data processing, this lack of foundational infrastructure poses a significant challenge. Additionally, the lack of technical expertise in implementing AI systems was highlighted by respondents as another barrier to adoption. The ability of cities to recruit and retain a skilled workforce capable of managing AI systems and data analytics platforms is critical. This challenge reflects broader global issues related to digital skill gaps, especially in developing regions where AI adoption is still in nascent stages.

Interestingly, while cost and infrastructure limitations were identified as major barriers, a notable proportion of respondents (41.4%) agreed that AI could also enhance public safety and security in urban centers. This suggests an increasing recognition of AI's role in surveillance systems, predictive policing, and emergency response coordination. AI can improve crime detection, disaster management, and public safety protocols through the analysis of vast datasets and the use of machine learning algorithms to predict and mitigate security threats.

The one-sample t-tests conducted on the potential benefits and challenges of AI adoption provided statistically significant results for all items, with p-values less than 0.001 across all aspects. The mean differences (MD) for each item were all notably above the test value of 2.0, further reinforcing the respondents' strong positive outlook on AI's potential benefits. The highest mean differences were observed for AI's role in water and waste management (MD = 1.53012), indicating particularly strong agreement on its potential to optimize resource use in smart cities. Conversely, the challenges associated with AI adoption—specifically high costs, infrastructure limitations, and lack of expertise—also produced statistically significant mean differences, highlighting their importance as barriers to AI integration.

The findings suggest that while the potential benefits of AI adoption in smart cities are widely recognized, significant barriers must be addressed to ensure successful implementation. The challenges of **cost**, infrastructure limitations, and technical expertise highlight the need for targeted investments in smart city infrastructure, skilling initiatives, and cost-effective AI solutions.
To overcome these barriers, it is recommended that cities prioritize:

- Public-private partnerships to fund AI infrastructure.
- Capacity building programs to develop the necessary technical skills for AI deployment and maintenance.
- Investments in reliable connectivity and energy sources to support the technological backbone required for AI systems.

Furthermore, AI's role in public safety and resource optimization should be further explored, with pilot projects that focus on improving security, traffic flow, and environmental sustainability. Ensuring that these systems are accessible, efficient, and equitably distributed across urban populations will be essential for fostering inclusive and resilient smart cities.

Conclusion

This study reveals a strong consensus on the potential benefits of AI adoption in smart cities, particularly in improving urban planning, traffic management, energy use, and public services. However, the successful deployment of AI is contingent upon overcoming critical challenges related to cost, infrastructure, and technical expertise. Addressing these challenges through strategic investments and targeted initiatives will be key to unlocking the full potential of AI in transforming urban environments into smart cities that are efficient, sustainable, and secure.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. To overcome the challenge of limited access to reliable electricity and internet connectivity, it is crucial for governments and urban planners to prioritize investments in foundational infrastructure. This includes upgrading power grids and expanding high-speed internet access to ensure that AI technologies can operate efficiently in smart cities. Public-private partnerships could be an effective model for securing the necessary resources.
2. The study highlighted a significant gap in technical expertise. To address this, cities should implement capacity-building programs to train both current and future employees in AI technologies, data analytics, and smart city management. Collaborations between universities, research institutions, and local governments could facilitate this, ensuring that the workforce is prepared to manage and maintain AI systems.
3. To build confidence and demonstrate the effectiveness of AI, pilot projects should focus on high-impact areas such as public safety, traffic management, and resource optimization (e.g., waste and energy management).

By starting with manageable, targeted initiatives, cities can refine AI systems before scaling up, ensuring they meet the unique needs of the urban environment and gain public trust.

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