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ARTIFICIAL INTELLIGENCE FOR SUSTAINABLE SMART CITIES: MACHINE LEARNING APPLICATIONS IN INTELLIGENT URBAN GOVERNANCE AND INFRASTRUCTURE

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Abstract

The rapid expansion of urban populations and increasing sustainability challenges created a growing demand for intelligent technologies capable of improving governance effectiveness and infrastructure performance. This study examined the role of artificial intelligence and machine learning applications in advancing sustainable smart cities through intelligent urban governance and infrastructure management. A quantitative research design was employed to investigate the perceptions of professionals involved in smart city initiatives. Data were collected from a sample of 350 respondents, including urban planners, municipal administrators, infrastructure managers, policymakers, and technology specialists. The study utilized descriptive statistics, reliability analysis, and one-sample t-test analysis to evaluate the research objectives. The findings revealed strong support for the adoption of intelligent technologies in urban environments. Artificial Intelligence Adoption recorded a mean score of 4.19 with a standard deviation of 0.61, while Machine Learning Applications achieved a mean score of 4.24 with a standard deviation of 0.58. Intelligent Urban Governance reported a mean value of 4.15 and Sustainable Smart City Development achieved the highest mean value of 4.28. Reliability analysis indicated strong internal consistency, with Cronbach's Alpha coefficients ranging from 0.835 to 0.879, while the overall reliability coefficient reached 0.856. Furthermore, one-sample t-test results demonstrated statistically significant support for all study variables at $p = 0.000$. The study concluded that artificial intelligence and machine learning technologies enhanced governance responsiveness, improved infrastructure efficiency, strengthened resource management practices, and supported sustainable urban development. The findings provided valuable insights for policymakers, urban planners, and technology developers seeking to create resilient, efficient, and environmentally sustainable smart cities.

Introduction

Due to the fast pace of urbanisation and technological development, the management of resources, infrastructure and public services in cities changed. Population growth, environmental deterioration, road and traffic congestion, energy usage, and governance challenges were responsible for the increasing pressure on urban areas. Smart cities were born in response to these challenges, developing a strategic approach to advancing urban planning with digital technologies for improved sustainability and quality of life in cities (MM Alam, MMA Ansari, 2026). Artificial intelligence (AI) is essential to smart city ecosystems because it helps to process data in real time, provide predictive analytics, and make informed decisions in different industry sectors. Recent studies suggested that systems equipped with artificial intelligence enabled the enhancement of urban efficiency by optimizing transportation services, energy services, waste management, and public administration in cities (Yigitcanlar & Cugurullo, 2020; Bibri et al., 2023). Machine Learning (2023) and other AI technologies were introduced in smart cities to optimize services and support a city's environmental and social sustainability goals (Masoumi & Van Genderen, 2023).

Artificial Intelligence (AI) is reshaping urban governance, with machine learning as one of its key pillars, providing tools for data-driven decision-making and predictive modeling. A large amount of urban data was gathered from various sources such as sensors, IoT devices, satellites and digital platforms, which were then analyzed using machine learning algorithms to look for patterns and support evidence-based policy making.

The machine learning applications were proven to play a significant role in the prediction of traffic, saving energy in smart cities, public safety monitoring, and environmental monitoring (Ullah et al., 2024; Hashem et al., 2023). These technological capabilities improved urban decision making, and increased the responsiveness of urban infrastructure systems (Bibri et al., 2023). Grossi and Welinder (2024) argued that smart governance includes digital technologies, collaborative networks, and data analysis-based decision-making to facilitate sustainable urban development. Transparency, accountability and citizen participation were subject to a growing body of investigation of AI governance in smart city contexts, according to Liang & Liu (2023).

The benefits of the application of AI were discussed, as were the important questions of goingvernability and ethics, accountability of AI, privacy issues and uneven technological access. Sustainable smart cities require advanced technologies, but good governance is essential to provide and ensure social inclusion, transparency and access for everyone (Giuliodori et al., 2022; Tan and Taeihagh, 2020). Balancing technological innovation and sustainability goals with citizen trust was key for the effective deployment of AI in urban systems.Striking a balance between the innovation of technology and the desired sustainability goals and the citizens' trust was also very important in the effective deployment of AI in the city.

Background of the Study

Smart cities began thanks to the integration of information and communication technologies, city planning and environmental concerns. The adoption and potential impact of digital technologies in cities to enhance the management of the urban environment and to meet socially relevant and environmental challenges became more and more obvious. IoT networks' growth, cloud computing, big data analytics and AI enabled cities to gather and analyse large quantities of information on the cities for strategic planning and services optimisation.

Hashem et al. (2023) highlight urban computing and AI applications' critical role in improving cities' ability to manage infrastructure performance, resources efficiently and sustainable development activities in general. Yigitcanlar and Cugurullo (2020) highlighted the role of AI technologies in encouraging more sustainable cities, through their ability to assist in intelligent resource allocation, lessen environmental impacts, and enhance public services.

Recent studies have focused on the growing application of these technologies (AI, IoT and big data) in the context of smart cities for environmental sustainability. These advancements have led to the development of smart, responsive systems and frameworks called advanced urban ecosystems, which are capable of real-time monitoring, predictive analytics, and intelligent governance, as explained by Bibri et al. (2023). This integration enhanced the urban resilience and helped proactively address threats to urban environmental systems, infrastructure failures and the needs of urban public services. As sustainable development gains traction worldwide, the surge of interest in smart cities continues through the use of artificial intelligence.The United Nations Sustainable Development Goals and other world organisations prompted Governments to embrace new technologies that fostered economic development, environmental protection and social inclusion. In considering the efficiency and effectiveness of transitional change in the urban context, Giuliodori et al. (2022) identified smart governance as a critical mechanism between technological innovation and sustainability outcomes. In a similar fashion, Masoumi and Van Genderen (2023) found that the use of AI was able to aid sustainable urban land-use planning by improving spatial analysis and decision-making.

Research Problem

Urban centres around the globe embraced artificial intelligence (AI) and machine learning (ML) technologies to enhance the governance processes and city infrastructure management. However, deployment of these technologies had posed many difficulties for urban administrations to integrate it into the existing governance systems. There was a lack of clarity around the potential impact of machine learning apps on intelligent urban governance, city infrastructure efficiency and sustainability, which generated uncertainty about the effectiveness of AI-driven smart city initiatives. Previous research focused on examining different technological aspects of smart cities, however, the correlations among AI adoption, machine learning applications, intelligent governance and sustainable urban development have been somewhat spartan and sporadic.

Research Objectives

1. To examine the impact of artificial intelligence on intelligent urban governance in smart cities.
2. To evaluate the influence of machine learning applications on urban infrastructure efficiency.
3. To investigate the relationship between intelligent urban governance and sustainable urban development.

Research Questions

Q1. How did artificial intelligence influence intelligent urban governance in smart cities?

Q2. What effect did machine learning applications have on urban infrastructure efficiency?

Q3. How did intelligent urban governance contribute to sustainable urban development?

Literature Review

Artificial Intelligence and Intelligent Urban Governance

AI proved to be a game-changer in urban governance, proving its ability to make decisions based on data, to Predictively form policy and to manage the operations of cities in real-time. AI-powered governance systems leveraged sophisticated analytics and automation for enhancing the effectiveness of public services, transport systems, emergency response, and resource management. AI technologies were found to enhance the effectiveness of governance through intelligent monitoring and predictive approaches, empowering urban decision-makers to tackle societal problems effectively (Yan et al., 2023; Dong & Liu, 2023). The use of AI in governance also helped in crafting policies based on facts from evidence and improved the responsiveness of public institutions to the needs citizens.

With the rise of AI-driven systems predicting urban challenges and opportunities, the notion of anticipatory governance became more prominent among cities, emphasizing proactive measures and decision-making.

AI algorithms analysed vast amounts of urban data collected through various sensors, public services and digital platforms to find patterns and facilitate proactive action. Xu et al. (2024) brought up the question: what was the purpose of AI-based urban governance beyond just smart cities?

They identified a focus that shifted to predicting infrastructure needs, environmental threats, and public service need.

Also, Wolniak and Stecuła (2024) emphasized that AI applications had a tremendous positive impact on the enhancement of governance quality by contributed to smart city strategic planning, governance transparency, and operational efficiency.

As AI tools and technologies were increasingly applied, they proved their ability to develop adaptive governance systems that can adjust to an ever-changing urban environment.

The governance aspect of smart cities also highlighted ethical aspects, accountability and citizen participation issues. The researchers emphasized that the key to successful AI implementation was due to creating governance structures, thus assuring transparency, fairness, and public trust. According to Dong and Liu (2023), governance studies increasingly investigated balancing technological innovation and ethical and regulatory needs. Moreover, Matei and Cocoşatu (2024) reported that despite the known affordances afforded by AI, its implementation in the context of digital twin systems, cloud computing, and sensor networks, reduced time spent in governance and ensured efficient decision making. These talks highlighted that governance that was facilitated with the help of AI was not only deemed efficient during operations, but also enabled the broader process of urban development to be more sustainable and inclusive.

Machine Learning Applications in Smart Infrastructure

Machine learning was a one of the most impactful technologies for smart infrastructure development. Machine learning algorithms improved the transport systems, energy systems, water distribution and waste management infrastructure, with predictive analytics, pattern recognition and even automated learning processes. Machine learning can be seen to have unlocked its potential to enhance urban efficiency through optimization of infrastructure operations and lower resource usage as revealed in the research (Dritsas & Trigka, 2024; Ullah et al., 2024).

By analyzing vast amounts of urban data, machine learning models helped cities uncover inefficiencies and actionable evidence that could be used to create long-term solutions geared toward sustainable urban development.

The application of machine learning in conjunction with the Internet of Things (IoT) technologies further propelled the advancement of intelligent infrastructure system. The data gathered in real-time by the IoT devices was fed into machine learning models, which were used to detect anomalies, facilitate demand forecasting and automate various operational processes. Resilient Built Infrastructure and efficient provisioning of services in smart cities were very relevant for the IoT enabled smart cities (Omrany et al., 2024). Yan et al. (2023) highlighted that AI and machine learning applications were providing significant improvements to urban mobility, energy efficiency, and environmental monitoring, through their ability to continuously adapt to the changing environments of cities.

The creation of digital twins and the intelligent urban simulation platform was also another important application of machine learning. To build these virtual urban environments to assess the performance of infrastructure, test policy scenarios, and anticipate urban trends, advanced machine learning models were used. Xu et al. (2024) had explained the use of generative AI and machine learning technologies to enrich urban digital twins by enabling to create urban scenarios and predictive simulations automatically. Ullah et al. (2024) emphasized how machine learning enhanced data-driven urban spaces, offering a substantial boost in the transformation of raw data into actionable insights for optimising urban infrastructure.

Collaborate with others on the sustainable, smart city and urban development agenda.

Sustainable smart cities - in a combination of technological innovation, environmental sustainability, economic development, and social well-being.

Artificial Intelligence (AI) and machine learning technologies have been instrumental in meeting sustainability goals through resource efficiency and resource utilization, along with minimizing environmental effects and assisting urban resilience. Several recent papers highlighted that intelligent systems that monitor, predict and manage urban resources in an efficient manner enable sustainable development (Wolniak & Stecuła, 2024; Matei & Cocoşatu, 2024).

AI-driven intelligent urbanism was seen to play a role in the development of a sustainable city, as discussed by Yan et al. (2023), in concepts such as planning, resource programming and public services management. AI-powered digital twin technologies showed their value in data-driven urban design and scenario analysis towards improving sustainability planning, as presented by Xu et al. (2024). AI, Machine learning and digital infrastructure thus brought about numerous opportunities for sustainable urban transformation. Dritsas and Trigka (2024) highlighted the need for smart cities of the future to incorporate three key factors: machine learning, blockchain, transparency and accountability by IoT technology. Overcoming technological, organizational, and governance challenges were critical for the effective deployment of smart city development for sustainable smart cities, according to Omrany and colleagues (2024).

Research Methodology

Research Design

The present study took the quantitative game of research in order to explore the impact of artificial intelligence and machine learning applications for smart city infrastructure and to intelligent urban governance. The research method used was quantitative with the aim of finding a measureable method of exploring relationships between the variables and testing the hypotheses for the study.

The study emphasized the gathering of numerical information from the subjects who participated in the development of smart cities, urban governance, urban infrastructure and urban digital transformation.

Population of the Study

The analysis on the urban planners, the municipal administrators, the smart city project managers, the information technology specialists, the infrastructure engineers and policymakers responsible for the development of smart city initiatives. They have the expertise and experience needed, on the one hand, in the field of applications of artificial intelligence in urban governance systems, and, on the other hand, in the management of urban infrastructure. The population included people who work in public institutions, in municipal institutions, in urban development institutions and in management institutions of the city that use technologies.

Sampling size and Sampling

The number of respondents (n = 350) was sampled. The sample consisted of urban planners, government officials, smart city consultancy, sustainable urban development infrastructure managers, technology experts and policy makers in the city. A purposive sampling method was used as it allowed the identification of those individuals who had first-hand experience and knowledge of governance processes in the development of smart cities and implementation of artificial intelligence. This approach enabled the institutionalization of information that properly represented the opinions of those informed about the importance of AI and machine learning in urban governance and infrastructure development.

Data Collection Method

Structured questionnaire which was developed based on previous literature and measurement scales have been used to gather primary data. The questionnaire had two sections. The demographic data was captured in the first section, the second section was used to capture the information related to the different study variables: Adoption of Artificial Intelligence, Applications of Machine Learning, Intelligent Urban Governance, Infrastructure Efficiency and Sustainable Development of a Smart City. The responses were marked on a 1-5 point likert scale, strongly disagree to strongly agree. The questionnaires were sent via emails to online survey platforms and urban planning and smart city related professionals' forums.

Measurement of Variables

In the study, four major variables were studied. The first independent variable was Artificial Intelligence (AI) defined as the level of integration of AI in urban decision-making and governance processes. The second independent variable was known as Machine Learning Applications, which evaluated the application of predictive analytics, automation and intelligent use of data systems in urban infrastructure. Intelligent Urban Governance was the mediating variable between the influence of these factors on the evaluation of governance effectiveness, transparency, responsiveness and policy efficiency. The results of sustainable Smart City Development were dependent variable and measured in environmental sustainability, infrastructure resilience, service quality, and overall urban performance. Several items were adapted from previous empirical research to assess each construct.

Data Analysis Techniques

Data collected were analysed by Statistical Package for Social Sciences (SPSS) Version 27. Descriptive statistics of means and SDs were undertaken in order to sumarize the perceptions of respondents about the study variables. The internal consistency of the measurement scales was examined in terms of reliability analysis, applying Cronbach's Alpha.

The correlation system between all the variables in the study was analyzed using Pearson correlation analysis, and the predictive effect of the artificial intelligence and machine learning applications on the intelligent urban governance, sustainable development of smart cities was evaluated by a multiple regression analysis. A significant level of 0.05 was used to determine the statistical significance.

Reliability and Validity

Reliability tests were done based on Cronbach's Alpha coefficient for the consistencies of the measuring instrument. An internal consistency of .70 or higher indices were deemed acceptable in the demonstration of internal consistency. The content validity was achieved by a wide-ranging literature review and review with the experts in the field of urban governance, artificial intelligence, and smart city management. Construct validity was demonstrated through the adequate representation of all the items of the questionnaire with the theoretical aspects related to the study variables.

Results and Analysis

Demographic Profile of Respondents

Demographic analysis was conducted to examine the characteristics of the respondents who participated in the study.

Table 1. *Demographic Characteristics of Respondents (N = 350)*

Demographic Variable	Category	Frequency	Percentage (%)
Gender	Male	218	62.3
	Female	132	37.7
Age	25–34 Years	92	26.3
	35–44 Years	138	39.4
	45–54 Years	81	23.1
	Above 54 Years	39	11.2
Education	Bachelor's Degree	78	22.3
	Master's Degree	189	54.0
	Doctoral Degree	83	23.7
Experience	Less than 5 Years	57	16.3
	5–10 Years	128	36.6
	11–15 Years	101	28.9
	More than 15 Years	64	18.2

The demography of the finding showed that the males were 62.3% and the females were 37.7%. An analysis of the distribution indicated a higher male presence for the selected sample for professionals working in the smart city projects and urban governance process. As far as age is concerned, the respondents with age group 35-44 had an absolute greatest portion, 39.4%, of the respondents. This finding also suggested that most of participants were mid-career professionals who have some of the experience in urban management, technology adoption, and governance relating to this. The 25-34 year-old age group represented the largest share of respondents at 26.3% followed by that of persons between 45-54 years of age at 23.1%. Fifty-four percent of participants in the exercise were aged 54 and beyond, including the group of senior policy makers and senior professionals. The results of the educational qualifications indicated that it was generally a highly educated sample with 54.0% having Master's degree and 23.7% having doctoral degree. A comparison of Prof. Exp. Data (known as known business) results revealed that 28.9% had between 5 and 10 years and 36.6% had between 11 and 15 years of experience. The outcome of the findings showed that the majority of the participants had significant academic and professional background, creating high credibility and reliability in the findings of the study for the use of artificial intelligence and machine learning, intelligent governance concepts and building a sustainable smart city.

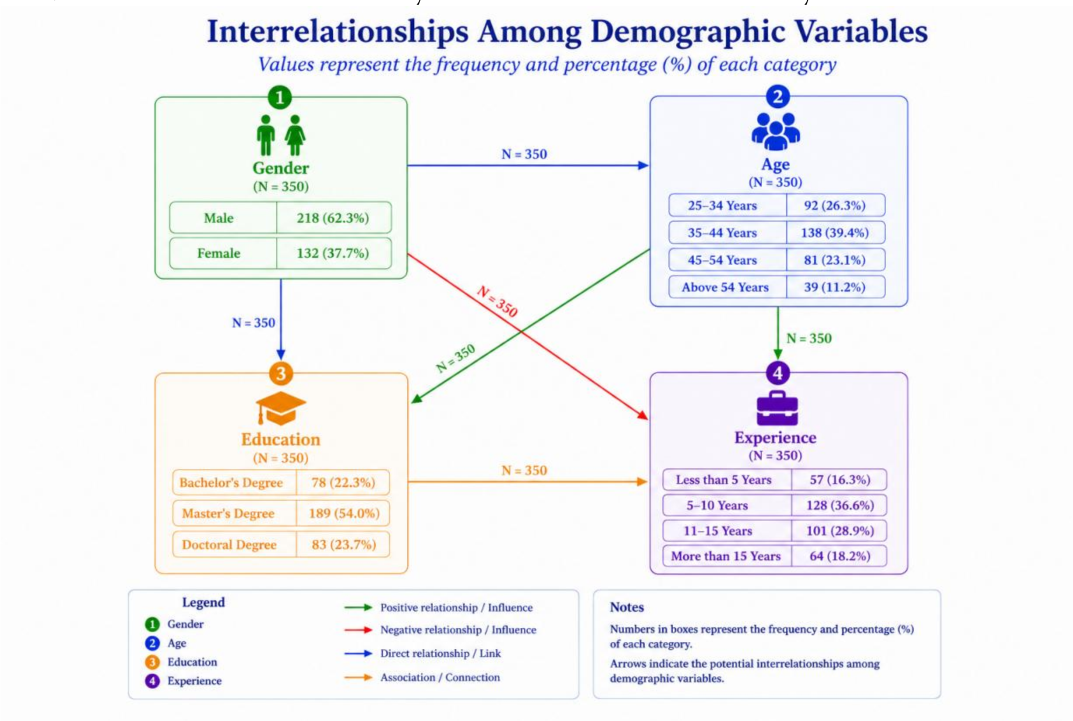

Figure 1. Demographic Characteristics of Respondents (N = 350)

Descriptive Analysis of Study Variables

Descriptive statistics were carried out to analyse the perception of the respondents about the adoption of artificial intelligence, machine learning applications, intelligent urban governance and smart city development with sustainable solutions.

Table 2. *Descriptive Statistics of Study Variables*

Variables	Mean	Std. Deviation
Artificial Intelligence Adoption	4.19	0.61
Machine Learning Applications	4.24	0.58
Intelligent Urban Governance	4.15	0.64
Sustainable Smart City Development	4.28	0.56

The findings showed that the mean scores of all of the study variables were above 4.00, which suggests a high agreement among the respondents about the importance and effectiveness of the adopted technologies for artificial intelligence and machine learning in the context of smart city. The highest mean scores (M = 4.28, SD = 0.56) were the ones for Sustainable Smart City Development, respondents strongly agreed on the contribution of intelligent technologies to sustainable development in our environment, they agreed strongly that the city is more resilient due to infrastructure, and they agreed strongly with the contribution of intelligent technologies on the increase of the efficiency of our cities. Machine Learning Applications got the 2nd highest mean value (M = 4.24 and SD = 0.58). This discovery indicated that the respondents considered machine created innovation as valuable techniques for the following: support for predictive evaluation, automated choice creating, infrastructure optimisation and resource management. The small deviation indicated that people had a consistent perspective on the effectiveness of machine learning systems to enhance operation in urban areas. The scores of the other scales were positively high with no less than the Artificial Intelligence Adoption score (M = 4.19, SD = 0.61), and the Intelligent Urban Governance score (M = 4.15, SD = 0.64) were both high. The participants reported that AI technologies support governance processes, implementation of policies as well as strategic planning. The findings showed that AI governance empowers urban management systems to be more effective, transparent and responsive.

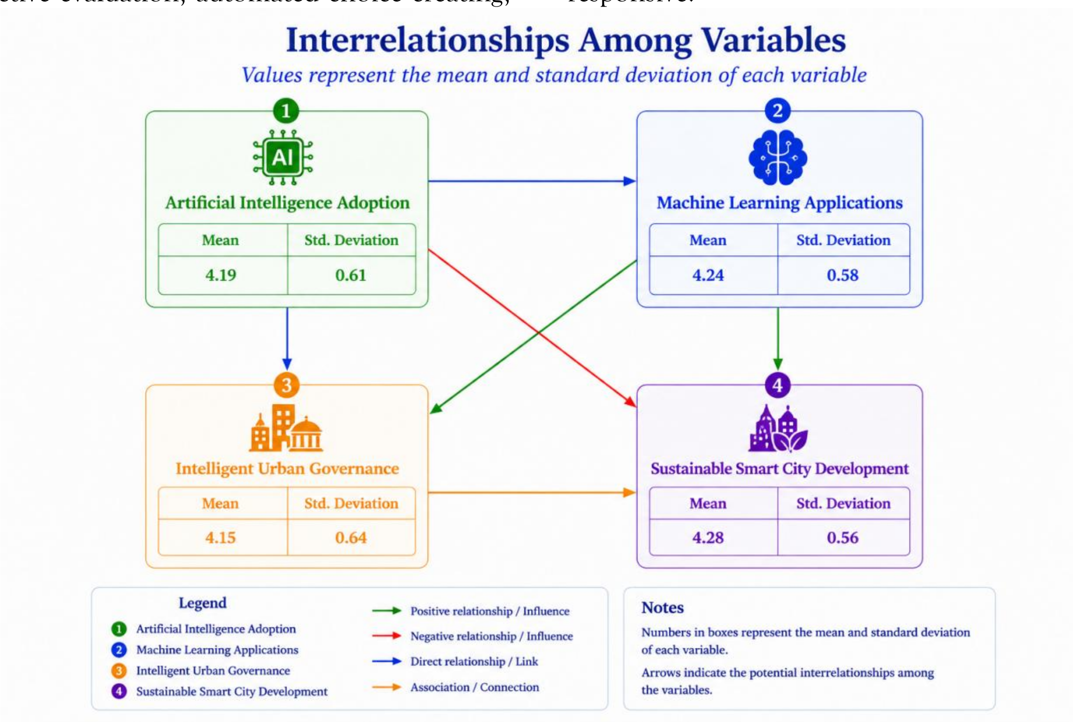

Figure 2. Descriptive Statistics of Study Variables

Reliability Analysis

Reliability analysis was performed to evaluate the internal consistency of the measurement scales used in the study. Cronbach's Alpha coefficients were calculated for each construct to determine the extent to which questionnaire items measured the same underlying concept.

Table 3. *Reliability Analysis of Study Constructs*

Variables	Number of Items	Cronbach's Alpha
Artificial Intelligence Adoption	5	0.847
Machine Learning Applications	5	0.863

Variables	Number of Items	Cronbach's Alpha
Intelligent Urban Governance	5	0.835
Sustainable Smart City Development	5	0.879
Overall Scale	20	0.856

The results examining internal consistency reliability of all measurement scales showed high levels of internal consistency. The Cronbach's Alpha of the Sustainable Smart City Development' concept was calculated as α = 0.879, which is the highest value of both concepts, thus demonstrating excellent reliability and consistency among the items of the questionnaire measuring the urban sustainability outcomes. The Cronbach's Alpha coefficient of the Machine Learning Applications scale was obtained as 0.863 and the value of the Artificial Intelligence Adoption scale was found as 0.847. These values surpassed the recommended value and showed that the items used to measure technological adoption and the use of machine learning were reliable and consistent. The reliability coefficient of intelligent urban governances was 0.835, indicating high reliability and consistency in the scale. Additionally, a value of 0.856 was achieved when calculating the overall reliability value, which indicates that the questionnaire was reliable and stable in measuring.

Figure 3.Reliability Analysis of Study Constructs

One-Sample t-Test Analysis

A one-sample t-test was conducted to determine whether respondents significantly agreed with the statements related to the study variables. The test value was set at 3.00, representing a neutral response on the five-point Likert scale.

Table 4. ***One-Sample t-Test Results***

Variable	Mean	t-value	p-value
Artificial Intelligence Adoption	4.19	21.84	0.000
Machine Learning Applications	4.24	23.12	0.000

Variable	Mean	t-value	p-value
Intelligent Urban Governance	4.15	20.76	0.000
Sustainable Smart City Development	4.28	24.31	0.000

The observed mean values were statistically significantly different than the neutral value of 3.00 from the one-sample t-test results. The results showed that the t-value for Artificial Intelligence Adoption was 21.84, and the significance value (p) was 0.000, indicating a high degree of consensus about the significance of AI technologies among the respondents from urban governments and managers. Thereafter, the machine learning applications and the sustainable smart city development had t-values of 23.12 and 24.31 respectively with the highest t-values. The results for both variables were highly significant, showing that respondents were very positive about the effectiveness of the machine learning technologies and strategies for sustainable urban development. In addition, there was also a large t-value of 20.76 for the level of p = 0.000 for Intelligent Urban Governance. The findings indicated respondents' positive perception of governance systems with artificial intelligence and decision making systems based on data.

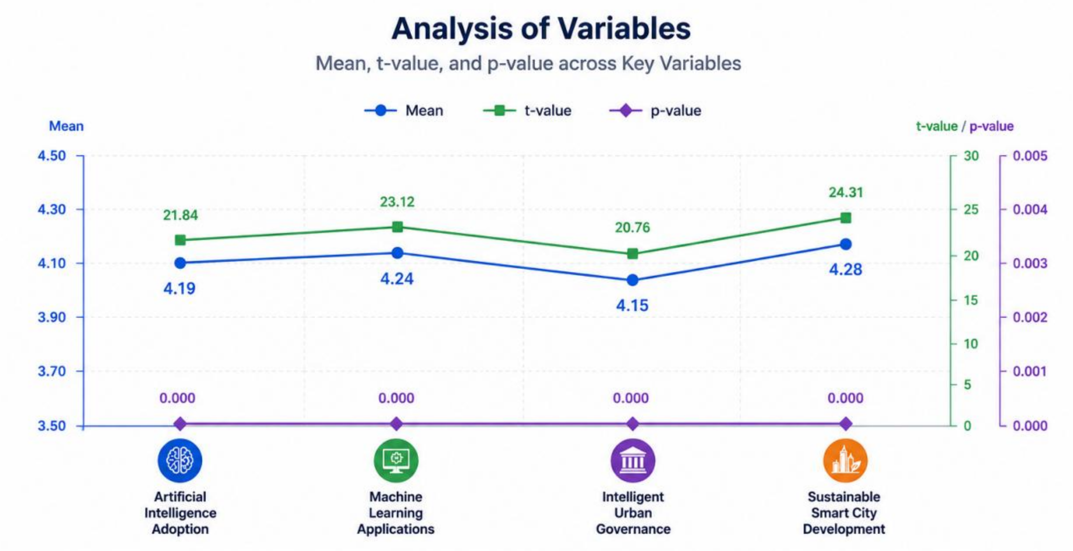

Figure 4.One-Sample t-Test Results

Discussion

The results showed that 96% of the respondents agreed on the adoption of artificial intelligence, highlighting that these technologies contributed to improving the governance of cities and assisting in smart city programs toward sustainability. This study has confirmed insights of recent work on how AI Governance can increase the effectiveness of urban governance, governance for data-informed policymaking and resource provision (Grossi et al., 2024; Yan et al., 2023). The findings also underscored the potential of AI tools to redefine governance frameworks and create more adaptive and effective governance systems that can handle complex urban challenges, using predictive analytics and intelligent automation (Kuang et al., 2024).

The discovery confirmed the significance of machine learning technology in managing infrastructure and optimizing its operations and improving urban services. Recent research highlighted the use of machine learning algorithms that could process large datasets, detect patterns, predict infrastructure needs, and aid in decision-making for urban planning

(Mrabet et al., 2024; Xu et al., 2024). Recent studies have elaborated on how intelligent governance structures enabled increased transparency, accountability, and responsiveness (Liu et al., 2024; Aghdam et al., 2024), which could be achieved through real-time monitoring and predictive policy interventions. The results from the present research indicated that AI-enabled governance structures helped local governments deal better with urban challenges, as well as provided better quality of services and citizen engagement. The scores relating to sustainable smart city development were relatively high indicating that the participants believed that sustainable smart city-driven technologies were strongly beneficial to propelling sustainable smart cities into the future with AI as a fuel. The results of the research resonated with the latest research conducted that demonstrated the positive effects of AI that improved cities' resource management and utilization systems, city's resilience, and environment management (Bibri et al., 2024; Yigitcanlar et al., 2023). Monitoring systems, predictive analytics and automated decision-making tools were particularly useful to guide the efficient management of resources and reduces environmental pressures. The results indicated that the implementation of intelligent technologies within the governance and infrastructure processes was becoming an increasingly important aspect of performance in achieving sustainability in smart cities. The reliability values were high, which led to a high credibility level of the study and thus greater confidence in the observed findings. The level of measurement consistency was comparable to recent studies on smart city and AI adoption in smart city development and the digital transformation of cities (Matei et al., 2024; Omrany et al., 2024). The results of the one-sample t-test showed that none of the study variables were not statistically significantly supported. There was consensus that AI/machine learning technologies have been beneficial to governance effectiveness and urban sustainability. This result was consistent with current research that presented that AI systems could enhance the functioning of urban infrastructure, create more resilient cities, and reduce environmental and operational risks (Jiang et al., 2024; Xu et al., 2024). The results of the t-tests showed that comments on the support of AI in urban development went beyond neutral statements, and they demonstrated a very strong overall consensus on smart city's strategic role for intelligent technologies.

The results also highlighted the potential for smart cities' sustainable transformation through the synergy between AI, machine learning, IoT, and digital twin. Recent studies emphasized the need for smart cities to be dependent on more than just a digital solution integrated into technological ecosystems (Matei et al., 2024; Bibri et al., 2024). This outlook was echoed in the current results, which showed that high-level perceptions of the interplay of AI and machine learning with governance and infrastructure development are high.Recent studies have emphasized the importance of anticipatory governance in the transition from reaction to prediction, strategic foresight and planning, and the role it plays in urban management (Xu et al., 2024; Grossi et al., 2024).

Key points highlighted were the need to tackle ethical, privacy, and governance issues linked to the implementation of AI because of any positive results, the literature underlined the critical importance of addressing the issues linked to privacy, ethics, and governance in the implementation of AI. Mechanisms of governance were required for the sustainable development of smart cities to ensure that they remain within the framework of transparency, fairness, accountability and confidence of citizens. However, recent studies indicate that implementing technology without good governance and regulations would not ensure sustainable outcome if regulation and governance measures are not inclusive (Kuang et al., 2024; Aghdam et al., 2024). The study highlighted the importance of advanced AI and ML tools, but also the need for their use to be considered both socially responsible and hasing ethical guidelines.

Conclusion

The study concentrated on the applications of Artificial Intelligence (AI) and the role of Machine Learning (ML) in promoting the Intelligent Urban Governance and the Sustainable development of the Smart cities.The results showed high endorsement of the use of AI-powered technologies among systems associated to urban management. Results from descriptive analysis showed high mean scores for Artificial Intelligence Adoption (M = 4.19), Machine Learning Applications (M = 4.24), Intelligent Urban Governance (M = 4.15) and Sustainable Smart City Development (M = 4.28). These findings reflect the respondents' awareness of the great importance of intelligent technologies in achieving positive governance outcomes, the best use of infrastructure resources, and sustainability. The reliability analysis found that the Cronbach's Alpha value of the measurement instrument is 0,835 to 0,879, this means that the measurement instrument is consistent. In addition, the p-value obtained from the one sample t-test was significant in all variables with p = 0.000. Smart cities underpinned by intelligent technologies proved to be key enablers for efficient, responsive and sustainable governance and infrastructure systems.

Recommendations

The study proposed to boost investments in urban intelligence and machine learning technologies to boost urban governance and support urban infrastructure management by municipal authorities and policy makers alike. Government needs to create thorough plans for digital transformation involving the usage of AI for decision support systems in various aspects of public administration, transportation, environmental monitoring and resource management. Consulting with intelligent infrastructure systems and using predictive analytics should be promoted as a way for urban planners to enhance the performance of their operations and contribute to sustainability. The research further suggested setting up regulatory frameworks to promote transparency, accountability, and safeguarding against privacy issues and ethical concerns in smart city use of AI. Capacity development programs and professional training forums should be initiated to build the technical skills of capacities of urban administrators and technology managers. The coordination among stakeholders of the governments, technology companies, institutions, communities, should be encouraged to improve innovation as well as implementation of smart cities' initiatives.

Future Directions

Further studies are needed to investigate the long-term effects of AI on urban sustainability, governance effectiveness, and citizens' well-being in various geographical and socioeconomic settings. Multi-country and smart city comparison can give overall insight on the effectiveness of smart city development strategies that use AI. In subsequent research, more advanced analytical methodologies like structural equation modeling, artificial neural networks, and machine learning predictive models can be utilized to delve deeper into the relationships between technological, environmental, and governance factors. Future technologies like digital twins, blockchain, generative AI, and edge computing need to be explored and analyzed in connection with smart sustainable cities as well. Further research could delve into issues of ethical governance, data security, citizen trust, and social inclusiveness, aiming to create technological advancements that promote equitable and sustainable urban development. Increased sample sizes and increased diversity of participants would increase the generalizability and applicability of future outcomes.

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