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THE ROLE OF SMART TECHNOLOGIES IN ENHANCING POLICY COMPLIANCE FOR URBAN SUSTAINABILITY

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Abstract: *Malaysia's rapid urbanisation poses challenges for environmental protection and sustainable resource management, particularly in ensuring compliance with existing urban policies. Despite various initiatives, weak enforcement and limited use of technology hinder effective implementation. This paper examines how smart technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Big Data analytics can strengthen policy compliance mechanisms for urban sustainability. Using a conceptual framework supported by Malaysian case illustrations (e.g., smart grids, smart transport, IoT waste management, and smart water systems), the study identifies barriers such as infrastructure gaps, financial constraints, and low public awareness. It further proposes actionable solutions, including enhanced data-driven enforcement, citizen engagement platforms, and public–private partnerships. The findings provide theoretical contributions to policy enforcement and practical implications for urban governance in developing economies.*

Keywords: *smart technology, urban sustainability, policy compliance, urban development, Malaysia*

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Introduction

The rate of urbanisation in Malaysia is experiencing a significant surge, leading to heightened environmental strain, ineffective resource utilisation, and difficulties upholding sustainability within urban areas. Malaysia has implemented multiple strategies to promote urban sustainability, with a specific emphasis on enhancing energy efficiency, managing waste effectively, and controlling pollution. Nevertheless, these policies frequently encounter difficulties in implementation. Intelligent technologies like IoT, AI, and big data analytics offer a hopeful solution for improving policy compliance and enhancing the outcomes of urban sustainability. Despite the implementation of environmental policies, Malaysia struggles with compliance, particularly in urban centres. Challenges such as ineffective waste management, excessive energy usage, and lack of public involvement persist, with minimal incorporation of intelligent technologies in the development and implementation of policies and regulations. In particular, segregation of waste does not reach its target in less than 40 percent of municipalities (KPKT, 2023), and environmental standards are not equally enforced in all states (DOE, 2022). Lack of unified technological processes restrains the ability to have real time monitoring and enforcement. Though the importance of smart technologies in sustainability is a topic of global literature, there are few empirical studies of the same, which are limited to the context of policy compliance in Malaysia. Thus, this research paper will fill this information gap by looking at the effectiveness of smart technologies to reinforce compliance models of urban sustainability in Malaysia. By reviewing the literature on their implementation and effects on policy compliance, this paper seeks to investigate how smart technologies can improve urban sustainability. Hence, this paper aims to achieve the following research objectives: 1) To explore the current application of smart technologies in policy enforcement for urban sustainability in Malaysia. 2) to identify the key challenges preventing the integration of these technologies in Malaysia's urban sustainability policies. 3) to propose actionable solutions and policy recommendations that leverage smart technologies to improve compliance with sustainability policies.

Literature Review

Smart technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), and Big Data analytics, have emerged as pivotal tools in addressing the complex challenges associated with urban sustainability. These technologies enable cities to enhance resource management, reduce environmental impact, and improve the quality of life for residents. As urban populations continue to grow, reaching an estimated 66% by 2050 (United Nations, 2018), the integration of smart technologies becomes increasingly critical for sustainable urban development. In this sense, 2.4 billion people will reside in the global urban population. Due to this, future cities will face challenges related to growth, performance, competitiveness, and residents' livelihoods (Lorsch & Durante, 2013). Achieving urbanisation sustainability is one of the ultimate ways to address challenges and conflicts between limited resource constraints and continued urban growth (Qiao & Huang, 2024). Sustainability-orientated refers to the use of human capital, societal structures, city infrastructure, and material resources integrated via diverse technologies to enhance environmental aspects of the city, boost the economy, and, concurrently, improve the quality of life. Besides, non-sustainability is focused on the importance of smart technologies for the performance optimisation of the city and the use of resources while enhancing and maintaining the quality of life (Toli & Murtagh, 2020). Smart technologies have emerged as critical tools for addressing the growing challenges of urbanisation, particularly the pursuit of sustainable urban development. Smart technology is defined as a non-living system that uses various technologies to give cognitive awareness to objects. (Alshurideh MT, Al Kurdi B, Hamadneh S, et al. 2023). These technologies include

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the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and automated systems that provide innovative solutions for monitoring, managing, and optimising urban infrastructure and resources. By enabling real-time data collection and predictive insights, smart technologies can significantly enhance urban sustainability efforts. In addition, smart technologies align with the global Sustainable Development Goals (SDGs) by supporting efforts to reduce environmental impacts while improving the quality of urban life. Technologies like smart transportation systems reduce traffic congestion and emissions, contributing to SDG 11 (Sustainable Cities and Communities). Meanwhile, smart water and energy management systems help cities conserve vital resources, contributing to SDG 6 (Clean Water and Sanitation) and SDG 7 (Affordable and Clean Energy). As cities continue to expand, the role of smart technologies in achieving these global sustainability targets becomes increasingly important. Internet of Things (IoT) technologies are among the principal solutions driving smart cities (Akhavan, 2023). The Internet of Things (IoT), a subset of smart technologies, has the potential to alter resource management by delivering real-time data and input that may assist in decision-making and optimise resource allocation and usage. IoT applications in urban settings include smart traffic systems, environmental monitoring, and resource management. In this sense, the integration of IoT technologies with predictive analytics and preventative maintenance supports and enhances the resource management systems (Althoey et al., 2024). Artificial Intelligence (AI) has increasingly become a vital technology in addressing urban challenges in smart city environments. AI applications have been used widely across multiple industries, such as transportation, healthcare, energy, and environmental management, by contributing a new set of efficient and sustainable tools to operate the city. Artificial intelligence-based technologies can revolutionise all aspects of traditional urban infrastructure through driverless vehicles, smart grids, and intelligent transportation systems that enable cities to respond to and address the demands of unprecedented growth (Szpilko et al., 2023). In smart cities, AI is used extensively for urban data analytics and planning decision support, improving the effectiveness of urban policies, traffic management, and service delivery. AI's ability to analyse big data and provide real-time insights makes it an essential tool for city planners and policymakers to create sustainable urban environments (Chen et al., 2023). For instance, AI-enabled tools are being used to predict pollution, optimise transportation systems, and improve energy consumption, all of which contribute to the overall goal of making cities more sustainable and livable (Szpilko et al., 2023). A notable example is the use of AI algorithms to forecast traffic patterns in Kuala Lumpur, which has led to a 15% improvement in public transport efficiency (Chen et al., 2023). However, the adoption of AI also faces challenges, such as data privacy concerns and the need for high-quality data inputs. Addressing these issues is essential to harness AI’s full potential in creating sustainable urban environments. However, despite the potential benefits, AI adoption in urban planning faces challenges such as data privacy, security concerns, and the need for high-quality data. There is a growing need to address these concerns by developing ethical guidelines and standardising data handling protocols to ensure AI can be implemented effectively without compromising citizens' rights (Szpilko et al., 2023). Furthermore, the integration of AI with technologies like the Internet of Things (IoT) and blockchain is revolutionising urban governance. These technologies provide robust frameworks for managing complex city systems, from waste management to healthcare delivery (Chen et al., 2023). Nonetheless, issues like cybersecurity risks and the digital divide between different social groups are significant barriers that must be overcome for AI to achieve its full potential in smart city contexts (Szpilko et al., 2023; Chen et al., 2023). In conclusion, while AI offers transformative possibilities for the development and management of smart cities, addressing the associated ethical, social, and technical challenges is crucial for sustainable progress. Future research should focus on bridging the gap between AI's theoretical

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potential and its practical applications, ensuring that urban planners and policymakers are equipped to harness these technologies responsibly (Szpilko et al., 2023; Chen et al., 2023). Public engagement in smart technologies within smart cities plays a vital role in fostering transparency, trust, and active citizen participation in urban governance. In smart cities, technologies such as blockchain, artificial intelligence (AI), and the Internet of Things (IoT) are being used to create platforms that allow citizens to engage in decision-making processes, provide feedback on services, and collaborate with city authorities (Testi et al., 2023; Garcia-Font, 2021). These technologies enable a shift from traditional top-down governance models to more participatory, citizen-driven approaches where the public can contribute to urban planning, policy formulation, and service delivery. Engaging the public not only fosters transparency and trust but also enhances the effectiveness of urban governance and policy compliance. Smart technologies have the potential to transform traditional governance models by enabling participatory approaches that allow citizens to actively engage in urban planning and policy formulation. Technologies such as mobile applications and online platforms empower residents to provide feedback on urban services, report issues, and participate in community decision-making processes. Blockchain is highlighted for its ability to ensure secure, transparent, and immutable transactions, making it a crucial tool for public participation in decision-making and voting processes in smart cities (Sifah et al., 2020). Cities such as Barcelona, for example, utilize a blockchain-based platform to enable citizen-led co-production that allows much wider resident input into urban governance (Testi et al., 2023). However, there are several challenges associated with public engagement in smart cities, such as the scalability of technologies, inclusivity, and the need for adaptable governance systems. As the volume of data grows, the capacity of blockchain systems to handle large datasets becomes a concern, particularly in cities with large populations (Khan et al., 2020). Additionally, ensuring that all citizens have access to the necessary technology remains a key challenge, potentially leading to inequalities in participation (Sifah et al., 2020)

Methodology

The study employed a PRISMA-based screening process, selecting 50 articles from an initial pool of 100 based on relevance, recency (2010–2024), and empirical contribution. Data synthesis was conducted using thematic analysis to identify patterns linking smart technology use and policy compliance. Articles were sourced from Google Scholar, Scopus, and Web of Science between 2010–2024 using keywords such as “smart technologies,” “urban sustainability,” “policy compliance,” and “Malaysia.” An initial pool of 100 articles was screened based on relevance, recency, and contribution, with 50 retained for analysis. Case illustrations of Malaysia’s smart city initiatives (e.g., Cyberjaya smart grid, Kuala Lumpur traffic systems, Putrajaya IoT waste management, Selangor smart water management) were included to provide contextual evidence. This approach allows synthesis of theoretical perspectives and practical examples, forming the basis of the proposed conceptual framework.

Results and Discussion

Current Use of Smart Technologies in Malaysia

Smart technologies are increasingly playing a pivotal role in advancing urban sustainability in Malaysia. The integration of these technologies enhances the efficiency of urban services, promotes environmental conservation, and improves the quality of life for residents. These are some Malaysian examples of applications for smart technology.

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Case 1: Cyberjaya Smart Grid (Energy Efficiency)

Smart grids use digital communication technology to detect and respond to local changes in energy usage. In Malaysia, smart grids are being implemented to optimise energy consumption and reduce greenhouse gas emissions by integrating renewable energy sources, like solar and wind power. This system is critical for minimising energy waste, promoting efficiency, and maintaining a reliable energy supply (Abdullah et al., 2021). Tenaga Nasional Berhad (TNB) has been actively implementing smart grid technologies across the country. TNB introduced the Smart Grid Initiative to digitalise the power distribution network and enhance reliability, efficiency, and sustainability. TNB Smart Grid is occupied with key features called smart meters that allow real-time monitoring of electricity consumption by both consumers and TNB (Husin, H., 2021). Such monitoring leads to more accurate billing that is able to help customers manage their energy use. The TNB smart grid project in Cyberjaya demonstrated a significant 10-15% reduction in energy consumption demonstrating how digital infrastructure supports compliance with energy efficiency policies and national low-carbon targets.

Case 2: Kuala Lumpur Intelligent Transport Information System (ITIS)

The use of intelligent transport information systems (ITIS) has been a key focus in Malaysian urban areas. Kuala Lumpur introduced ITIS to optimise traffic flow through real-time monitoring and adaptive traffic signals. The system led to a 20% reduction in traffic congestion, improving compliance with transport-related sustainability policies by reducing vehicle emissions and fuel wastage. Additionally, electronic toll collection and GPS-based fleet management systems are helping reduce traffic delays and fuel consumption (Rahman et al., 2020). To be specific, RapidKL's Automated Fare Collection (AFC) System has been implemented to allow seamless travel across different modes of transportation with a unified ticketing system, such as the use of Touch'n Go cards (Akmal Hakim, 2020). Passengers can easily pay for their trips using smart cards or mobile apps, and the system collects real-time data to help with route optimisation and scheduling. AFC has improved the efficiency of public transport services and encouraged people to use public transportation.

Case 3: Putrajaya IoT Waste Management

The Internet of Things (IoT) is being used in Malaysia to revolutionise waste management. Smart bins equipped with sensors detect waste levels and notify collection services when full. This system optimises waste collection schedules, reduces fuel consumption for garbage trucks, and minimises environmental pollution. The examples of products that use IoT technology are Erecycle by ERTH (E-waste Recycling Technology Hub funded by Khazanah Malaysia and iClean Selangor. ERTH smart bins are equipped with sensors that notify the collection centre when they are full. While iClean integrated smart waste bins with sensor technology to monitor waste levels, these smart bins send data to collection vehicles. As a result, there are fewer overflowing bins in public areas, and operational costs are decreased. The city of Putrajaya has been leading in adopting these smart waste management solutions (Yusoff & Yaacob, 2022). It has been reported that the implementation of IoT-based waste management systems in Putrajaya has led to a 20% reduction in waste collection costs and a 30% improvement in recycling efficiency. This study shows the potential for IoT technologies to optimise waste collection routes and reduce operational costs.

Case 4: Selangor Smart Water Management

Water conservation and management have become crucial in Malaysia, particularly in urban areas experiencing rapid population growth. IoT-based water management systems have been implemented by Selangor's Smart Water Management, which serves as the region's main

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provider of water services. Smart water meters and leak detection technologies help monitor water usage, detect leaks early, and ensure efficient distribution of water resources. These technologies are part of the national effort to improve water management and reduce wastage in major cities (Khalid et al., 2021). The deployment of smart water meters by Pengurusan Air Selangor decreased water leakage by 25%, improving water management efficiency and making a major contribution to urban water conservation efforts. This case illustrates how smart technologies enhance compliance with water conservation and resource management policies.

It can be concluded that the case studies from Selangor, Kuala Lumpur, Putrajaya, and Cyberjaya show how smart technologies can improve urban sustainability in real, measurable ways. These examples highlight the crucial role Smart technologies contribute to addressing urban challenges in Malaysia by achieving a 10-15% reduction in energy consumption in Cyberjaya and a 20% reduction in traffic congestion in Kuala Lumpur.

Table 1: Case-Based Evidence of Smart Technologies in Malaysia

Technology	Application Area	Example Location	Reported Impact	Link to Policy Compliance
Smart Grids	Energy Efficiency	Cyberjaya	10–15% energy reduction	Supports compliance with energy efficiency and low-carbon policy goal
Smart Transportation	Traffic Management	Kuala Lumpur	20% reduction in congestion	Aligns with transport emission reduction and urban mobility policies
IoT Waste Management	Waste Collection	Putrajaya	20% cost reduction, 30% recycling efficiency	Strengthens compliance with waste reduction and recycling policies
IoT Waste Management	Waste Collection	Putrajaya	20% cost reduction, 30% recycling efficiency	Ensures compliance with water conservation policies and SDG 6 targets

To visually summarise the impact of smart technologies on policy compliance across different urban sectors, Figure 1 presents the percentage improvements observed in energy, transport, waste, and water management initiatives in Malaysia. The bar graph highlights that smart technologies contribute to measurable gains in compliance, supporting the framework proposed in this study.

Figure 1 illustrates the measurable impact of smart technologies on policy compliance across four urban sectors in Malaysia. The observed improvements in energy efficiency, traffic management, waste collection, and water conservation demonstrate how the adoption of IoT, AI, and Big Data facilitates evidence-based enforcement and monitoring mechanisms. These quantitative outcomes provide empirical support for the proposed conceptual framework, showing that smart technologies act as enablers for policy compliance, which in turn drives urban sustainability. The graph visually reinforces the flow from technology adoption → enhanced compliance → improved sustainability outcomes, highlighting the practical relevance of integrating smart solutions into urban governance strategies.

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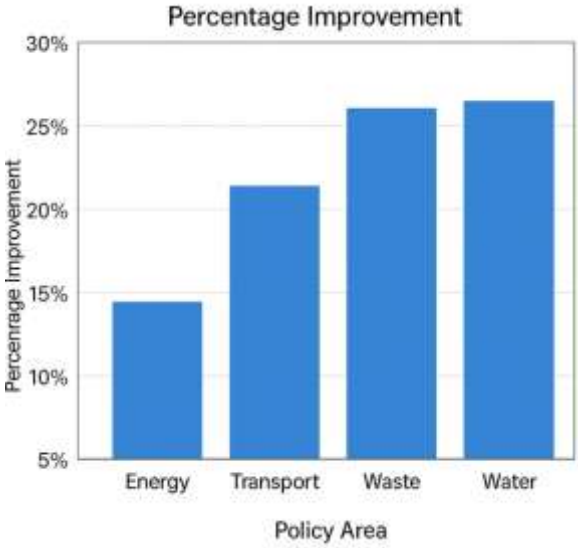

Figure 1: Percentage Improvements Observe

Key challenges preventing the integration of these technologies in Malaysia's urban sustainability policies

Malaysia's rapid urbanisation presents both opportunities and challenges for sustainable development. With more than 75% of the population expected to live in urban areas by 2030, the need to address issues such as traffic congestion, waste management, energy inefficiency, and pollution is becoming more critical. The government has introduced various policies and initiatives aimed at promoting urban sustainability, such as the Low Carbon Cities Framework (LCCF) and the National Smart Cities Framework. However, these policies often struggle to achieve their intended outcomes due to gaps in implementation and compliance. In response to these challenges, smart technologies including the Internet of Things (IoT), Artificial Intelligence (AI), and Big Data analytics have been identified as key enablers for improving policy enforcement and fostering sustainable urban growth. These technologies can provide real-time data, enable predictive maintenance, and optimise resource management, giving cities the ability to become more efficient, resilient, and sustainable. Despite the potential of smart technologies, their integration into Malaysia's urban policies has been met with several obstacles. The following section outlines the key challenges preventing the widespread adoption of smart technologies in Malaysia's urban sustainability framework.

Infrastructure gap

Smart technologies (IoT and AI), whether in transportation, waste management or water systems, rely heavily on real-time data and internet connectivity, and these are implemented inconsistently in some areas because of a lack of adequate digital infrastructure. Telecommunications networks such as high-speed internet and 5G are more developed in urban areas compared to rural ones. Cities like Kuala Lumpur, Klang Valley, Penang, and Johor Bahru have excellent connectivity, but rural areas like Raub, Kodiang, and Kunak in Sabah still struggle with slow or unreliable internet connections. Although Malaysia is continuously making efforts to improve its digital infrastructure through several policies, such as National Broadband Initiative (2010), followed by Fiber Plan 2017-2019 and the National Fiberisation and Connectivity Plan (NFCP) 2019-2023, there are still gaps in coverage, particularly in semi-urban and rural areas. This uneven access limits the effectiveness of these technologies in underdeveloped areas. Thus, the Malaysian government, through their urban policies, needs to

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address the digital divide issues. The intent is to ensure that telecommunication upgrades are not limited to high-income or densely populated areas. If it prolongs without any solutions, 'Smart City Island' syndrome will happen, where only specific zones benefit from smart innovation while the majority of people are left behind, and it's further exacerbating inequality.

Financial obstacles

The incorporation of smart technologies into urban infrastructure and daily life faces significant financial barriers in Malaysia and other developing countries. The implementation of smart technologies requires a high cost related to enhancing current systems to integrate smart technologies such as a fiber optic network, 5G Tower, and IoT-enabled devices. Maintenance and technology upgrades also require a significant financial investment. These costs are beyond the capabilities of many local governments, particularly in developing regions. According to Abdullah and Osman (2020), the cost of setting up digital infrastructure, including sensors, smart grids, and data centres, is one of the primary barriers to the adoption of smart technology in Malaysia. Financial constraints often delay or limit the scope of smart city initiatives. Projects such as the deployment of smart grids and smart traffic systems in Malaysia have been hampered by budget constraints. As a result, the implementation of smart city initiatives is limited to affluent urban areas, leaving smaller municipalities behind. Developing countries like Malaysia often experience limited access to funding and financial support for large-scale smart technology projects. The financial return on investment (ROI) for smart infrastructure may take years to materialise, which discourages private sector participation (Tan & Premkumar, 2017). Due to the enormous financing required to boost connectivity in rural regions, Malaysia's National Fibersation and Connectivity Plan (NFCP) has been difficult to roll out, rendering smart technology unavailable to huge segments of the population. To increase the accessibility and long-term sustainability of smart technology, the government needs to develop creative funding methods, initiate more public-private partnerships, and target financial incentives.

Public awareness and digital literacy

Public awareness and participation in adopting smart technologies in Malaysia are gradually increasing but remain relatively low, especially compared to more advanced nations. Several studies reported that many Malaysians are aware of basic smart technologies like mobile apps, ride-sharing, or cashless payments, but there is still a lack of in-depth understanding and engagement with more complex technologies, such as smart infrastructure or Internet of Things (IoT) systems. This phenomenon happens due to digital literacy levels in Malaysia, where urban populations are generally more familiar with technology than those in rural areas. Digital literacy is a critical factor influencing the adoption of these technologies. According to a report by the Malaysian Communications and Multimedia Commission (MCMC), while 80% of urban residents report feeling comfortable with digital tools, only about 50% of rural residents feel similarly equipped. This disparity illustrates the importance of targeted educational initiatives. Abdullah and Osman (2020) found that rural and older populations are less likely to adopt smart technologies due to lower digital literacy. Lack of digital literacy among citizens causes difficulty in using e-governance tools such as MySejahtera, online tax filing, and digital identification systems that require users to navigate through mobile apps or websites. Many users find it challenging to manage the technical components of e-governance platforms (Chua et al., 2019). They were uneasy about it and were deterred from taking part in digital governance systems. Many people find it challenging to embrace and use smart technology in a comfortable way due to the skills gap. Good digital literacy enables people to understand how technology works and how personal information is managed. However, when levels of digital literacy are low, they may mistrust smart technologies used in e-governance systems, particularly those

Volume: 10 Issues: 78 Special Issue [November, 2025] pp. 215 – 227
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involving sensitive data such as health records or financial transactions. Moghavvemi et al. (2018) stated that a lack of trust in technology stemming from inadequate knowledge contributes significantly to low participation. Citizens may be hesitant to use online portals for essential services like tax payment, voter registration or healthcare management because they do not understand the security features in place. In Malaysia, e-filing is a taxation mechanism that falls under e-governance but receives lower participation from the public. People continue to be ignorant and distrustful of cybersecurity ideas and data protocols in electronic filings. According to Tan and Premkumar (2017), those with less proficiency in digital literacy frequently find it difficult to finish the steps required for e-governance, which results in non-compliance. This means that the government is committed to developing e-governance through the use of smart technologies; still, the people themselves refuse to use the facilities provided, and this lack of response makes it difficult for the country to move forward. The government's role in e-governance extends beyond merely providing services; it is also essential to disseminate accurate information regarding these services and promote their use among the populace. Many citizens lack comprehensive knowledge about the benefits of e-governance and the proper use of smart technology tools. Research by Yigitcanlar et al. (2018) emphasises that clear and accessible communication is essential for encouraging adoption. Public interest and confidence decline when governments are unable to articulate how smart technology streamlines procedures or enhances the provision of services. Insufficient communication about the management, preservation, and safeguarding of data diminishes adherence to digital policies (Moghavvemi et al., 2018). For instance, the people in Malaysia opposed the installation of smart meters because they were unaware of the implications for data privacy and billing accuracy. The government did not adequately address the issues and, due to a lack of transparency, contributed to poor adoption rates of smart meters even though the technology promised increased efficiency. The absence of effective communication strategies that highlight the benefits of smart technologies is leading to low adoption of technologies and policy compliance.

Practical solutions for enhancing policy compliance through technology

Urbanisation continues to be a defining trend in the 21st century, with more than half the world's population now living in urban areas. Rapid urban expansion brings numerous challenges, particularly in emerging economies like Malaysia, where the growing population exerts pressure on infrastructure, resources, and the environment. The need for sustainable urban development has become paramount to mitigating the effects of urbanisation, such as pollution, traffic congestion, and inefficient waste management. To address these issues, the integration of smart technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), and Big Data analytics, offers transformative solutions. These technologies enable real-time monitoring, predictive maintenance, and more efficient resource management, which can significantly enhance policy compliance and urban sustainability. However, the effective implementation of these technologies requires overcoming several barriers, such as infrastructure gaps, financial constraints, and public engagement. This discussion will explore practical solutions that leverage smart technologies to address urban sustainability challenges. By focusing on improved data collection, urban planning, resource management, and citizen engagement, we can understand how smart systems reshaping cities are to become more efficient, resilient, and sustainable.

Improved Data Collection and Analysis

Smart technologies like the Internet of Things (IoT) and big data analytics can collect real-time data on urban systems such as traffic, air quality, and energy consumption. These data sources

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help policymakers make evidence-based decisions by understanding current trends and conditions. Szpilko et al. (2023) state that continuous monitoring of air pollution levels is necessary for policies aimed at improving air quality and reducing emissions. Such tracking can be accomplished by installing smart sensors throughout cities. By analysing real-time data, governments can focus on high-impact interventions and modify their urban sustainability strategies. In Malaysia, the implementation of IoT systems in urban areas has shown great promise for optimising resources and addressing sustainability challenges (Abdullah et al., 2021).

Improved Urban Planning

Geographic information systems (GIS) and smart mapping tools offer invaluable support for urban planning by visualising spatial data and creating simulations of policy impacts. GIS enables urban. It enables urban planners to visualise the geographic layout of cities, which helps them assess the effects of urban policies on environmental sustainability. For instance, GIS can simulate the impact of a new urban development on existing infrastructure and resources, such as water and energy systems (Garcia-Font, 2021). These technologies allow urban planners to better allocate resources, lessen urban sprawl, and create cities that are more climate change resilient.

Efficient Resource Management

Smart grids, smart water management systems, and waste management technologies are at the forefront of efficient resource management. For example, smart meters can monitor energy and water usage, providing both citizens and authorities with data that optimise consumption (Rahman et al., 2020). Similar to this, IoT-enabled waste bins use sensors to monitor their fill levels, guaranteeing that waste is collected only when required and cutting down on fuel consumption for garbage trucks and operating costs (Yusoff & Yaacob, 2022). In Malaysia, smart water systems like Selangor's IoT-based water management have significantly contributed to reducing water wastage by monitoring leaks and usage patterns.

Citizen Engagement and Participation

Public participation is essential for successful policy implementation. By using platforms powered by blockchain and IoT, citizens can engage more actively in decision-making processes related to urban governance. For example, smart city platforms in Barcelona enable residents to provide feedback on urban services, contributing to more transparent and responsive governance systems (Testi et al., 2023). Such systems can be adapted to Malaysian cities to improve the public's involvement in urban sustainability efforts.

Recommendations for Enhancing Policy Compliance Through Smart Technologies

The integration of smart technologies into urban sustainability frameworks presents a substantial opportunity to enhance policy compliance in Malaysia. To effectively leverage these technologies, the following recommendations are proposed:

Public-Private Partnerships (PPPs)

Strong public-private partnerships must be established to promote innovation and resource sharing in the application of smart technologies. Collaborative frameworks must be established to enable joint ventures that unite government agencies and private sector technology experts in the design and implementation of smart infrastructure projects. Furthermore, it can establish collaborative investment models in which private entities supply financial resources for technology implementation while the government offers regulatory assistance and policy

Volume: 10 Issues: 78 Special Issue [November, 2025] pp. 215 – 227
Journal of Islamic, Social, Economics and Development (JISED)
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Journal website: www.academicinspired.com/jised
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frameworks that foster innovation. This strategy can alleviate financial pressures on local governments and guarantee sustainable project execution. In order to overcome financial barriers associated with the adoption of smart technologies, it is imperative to identify and secure diverse funding sources, such as engaging with international climate initiatives, such as the Green Climate Fund (GCF), and leveraging resources from development banks, including the Asian Development Bank (ADB) and the World Bank. These entities offer low-interest loans and grants aimed at supporting sustainable urban development projects. The government can also implement fiscal incentives, such as tax breaks and subsidies, for businesses and municipalities that adopt smart technologies. By providing economic incentives, the government can encourage wider participation in smart initiatives.

Education and capacity building

Enhancing public awareness and digital literacy is vital for fostering a culture of engagement with smart technologies. The government of Malaysia should launch comprehensive digital literacy programmes aimed at educating citizens about the benefits and functionalities of smart technologies. Such initiatives can be implemented through partnerships with educational institutions and non-governmental organisations (NGOs). This initiative cannot be implemented without community involvement. Hence, promoting community engagement in the planning and implementation of smart technology projects, allowing residents to contribute their insights and needs. This participatory approach will foster public ownership and trust, ultimately improving the likelihood of successful technology adoption.

Conclusion

Smart technologies offer transformative potential to address the complex challenges of urban sustainability, particularly in rapidly urbanised countries like Malaysia. By integrating solutions such as IoT, AI, and big data analytics into urban policy, cities can enhance resource efficiency, improve public services, and foster greater compliance with environmental regulations. These technologies facilitate real-time monitoring and data-driven decision-making, allowing for more effective urban planning, traffic management, and resource optimisation. Moreover, they offer new avenues for public engagement, helping to create more inclusive and transparent governance systems. However, despite their promise, the successful implementation of smart technologies faces several challenges. Low public awareness, financial constraints, and infrastructure gaps are some of the main obstacles preventing widespread adoption. Addressing these issues requires a concerted effort by both the government and the private sector to develop smart infrastructure, create innovative funding mechanisms, and raise public digital literacy. Furthermore, the digital divide between urban and rural areas must be minimised to ensure that all regions benefit from these innovations. This study presents a conceptual framework and provides practical insights into how smart technologies can enhance policy compliance, but it is important to recognise certain limitations. The availability of data specific to Malaysia's urban sustainability context is limited, restricting the generalisability of findings to other regions or countries. Moreover, the focus on IoT, AI, and big data analytics excludes other emerging technologies like blockchain and 5G, which may play an increasingly significant role in the future. Furthermore, as these technologies continue to evolve, future studies must explore their long-term impacts on environmental quality, resource efficiency, and the overall quality of urban life. Looking ahead, future research should focus on several critical areas to ensure the continued success of smart technology integration. Developing models and frameworks for the ethical and effective implementation of these technologies will be crucial for aligning smart city initiatives with sustainability goals. Comparative studies across different cities or regions in Malaysia can offer insights into best practices and lessons learnt, facilitating more tailored

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and context-specific strategies for smart technology adoption. Lastly, long-term studies that assess the environmental, social, and economic impacts of smart technologies will provide a clearer understanding of their role in enhancing urban sustainability and improving the overall quality of life in cities. In conclusion, while smart technologies hold significant promise for urban sustainability, their success will depend on addressing the existing barriers and continuing to refine and adapt these systems to meet the unique needs of Malaysia's urban landscape. With the right frameworks, public engagement, and policy support, smart technologies can help cities not only overcome their current challenges but also build more resilient, efficient, and sustainable future.

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