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Literature Study: Internet of Things (IoT) as a Transformative Technology in Building a Smart City Concept

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ABSTRACT: The Internet of Things (IoT) has become one of the most transformative technologies in building the smart city concept. With the potential to connect diverse devices through internet networks, IoT enables increased efficiency in sectors such as transportation, energy and health. This research aims to explore the role of IoT in smart city implementation, highlighting its challenges and opportunities. Based on a literature review and empirical analysis, this research finds that although IoT can improve the quality of life in smart cities, there are several major challenges that must be overcome, such as security, scalability and interoperability issues. This article provides deeper insight into how to optimize IoT deployment to achieve urban sustainability. The novelty in this research lies in the integrative approach that combines the analysis of technical and non-technical challenges in IoT implementation in smart cities. This research also proposes practical solutions to overcome these challenges, such as the development of public policies that encourage IoT interoperability and security.

KEYWORDS: Internet of Thing (IoT), Technology, Smart City, Smart Energy System, Smart Transportation, Smart Home.

I. INTRODUCTION

The continuously growing urban population has brought significant challenges to various aspects of life, such as transportation, energy, health, and the environment. Smart cities emerge as a solution by utilizing artificial intelligence (AI)-based technology to create more efficient and comfortable environments. This article explores how AI is adopted in various sectors of smart cities, such as healthcare, education, transportation, energy, security, and environmental management, while also explaining how AI technology can enhance the operational efficiency of cities(Miraz et al., 2015). The development of information and communication technology (ICT) has led to the implementation of the smart city concept. In this concept, technologies like the Internet of Things (IoT) are used to improve operational efficiency, share information in real-time, and provide solutions to urban challenges such as traffic congestion, pollution, and resource management(Srinivasan et al., 2019). IoT, consisting of a network of physical devices connected via the internet to share data, plays a crucial role in the infrastructure of smart cities(Liu, 2020). However, despite its potential, the implementation of IoT in smart cities still faces several challenges that require further research(Gubbi et al., 2013). This research aims to examine the role of IoT in smart city implementation, identify the main challenges in using IoT in smart cities, and provide strategy recommendations to maximize the opportunities of IoT in urban management(Farooq et al., 2015).

Figure 1. IoT in smart homes and smart cities Problem

IoT implementation in smart cities faces several main problems, including:
Security: Risk of data being leaked or hacked due to large and distributed IoT networks.
Scalability: The large number of connected devices requires adequate infrastructure to handle large volumes of data.
Interoperability: The challenge of integrating various IoT systems and platforms from different vendors so that data can be communicated seamlessly.

Previous research has demonstrated the benefits of IoT in smart cities, but there are gaps in the literature regarding how to address challenges related to security, scalability, and interoperability in smart city environments. Additionally, although some studies discuss the implementation of IoT, empirical research examining the real impact of IoT on urban life remains limited, particularly in developing countries.

METHODOLOGY

This research uses a qualitative approach with a literature review as the main basis. Data sources come from academic journals, industry reports, and the latest research related to IoT and smart cities. The data obtained was analyzed using the content analysis method to identify patterns, themes and challenges faced in IoT implementation. Additionally, several case studies of successful smart cities in IoT implementation are also used to provide further insights into best practices.

RESULTS

Previous research has demonstrated the benefits of IoT in smart cities, but there are gaps in the literature regarding how to address challenges related to security, scalability, and interoperability in smart city environments. Additionally, although some studies discuss the implementation of IoT, empirical research examining the real impact of IoT on urban life remains limited, particularly in developing countries.

Table 1

1rd article	*Discription*
title	Adoption of Artificial Intelligence in Smart Cities: A Comprehensive Review
author	H.M.K.K.M.B. Herath dan Mamta Mittal
year	2022
Conclusion	This article concludes that AI has great potential to transform how smart cities operate by automating processes, improving efficiency, and providing data-driven solutions. However, challenges such as privacy, security, and legal frameworks still need to be addressed. The widespread adoption of AI in key sectors, such as healthcare, energy, mobility, and security, demonstrates that this technology is becoming a vital component in the management of smart cities.
Novelty	This article provides a comprehensive review of AI adoption in smart cities, focusing on how AI helps various urban sectors adapt to future needs. The novelty lies in an in-depth analysis of various AI technologies and their role in addressing smart city challenges, including their significant impact during the COVID-19 pandemic.

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Table 3

2rd article	Uraian
title	The Internet of Medical Things: Opportunities, Benefits, Challenges and Concerns
author	Omid Pournik, Leila Ghalichi, Parisis Gallos, dan Theodoros N. Arvanitis
year	2023
Conclusion	The Internet of Medical Things (IoMT) offers significant opportunities for improving healthcare services, but its adoption requires careful attention to issues of security, interoperability, and ethics. To ensure safe and effective implementation, these challenges must be properly addressed before IoMT technology is widely deployed. By overcoming these challenges, IoMT has the potential to revolutionize healthcare delivery, improve patient outcomes, and promote connected and personalized care.
Novelty	The novelty of this article lies in its comprehensive review of the opportunities and challenges faced by IoMT in the healthcare context. The article emphasizes the need for a balance between the benefits of the technology and the management of emerging risks, such as data security and regulatory compliance. It also provides practical guidance on responsibly optimizing the implementation of IoMT in the healthcare sector.

Table 4

3rd article	description
title	Internet of Things (IoT) Security: Current Status, Challenges, and Countermeasures
author	Asneem Yousuf, Rwan Mahmoud, Fadi Aloul, Imran Zualkernan
year	2015

Conclusion	The IoT framework faces many security challenges at each layer, including threats like Denial of Service (DoS) attacks, eavesdropping, and replay attacks. There is a need for new identification, wireless, software, and hardware technologies to resolve the open research challenges in IoT security. The paper emphasizes the importance of adopting new protocols (e.g., IPv6, 5G) and standards to secure the IoT landscape, addressing both the heterogeneity of devices and the increasing scale of IoT networks. Further research is necessary to enhance identity management and session layer protocols for secure IoT operations.
Novelty	The novelty lies in the comprehensive review of IoT security issues across all layers of the IoT architecture (Perception, Network, and Application). The article is among the first to address emerging technologies like 5G and IPv6 for enhancing IoT security and scalability, providing insight into the future direction of IoT security. It introduces lightweight and trust-based security models tailored for the unique constraints of IoT devices, offering practical countermeasures to address security vulnerabilities in IoT networks.

Table 4.

4rd article	description
title	A Survey on 5G Networks for the Internet of Things: Communication Technologies and Challenges
author	Godfrey Anuga Akpakwu, Bruno J. Silva, Gerhard P. Hancke, Adnan M. Abu-Mahfouz
year	2017
Conclusion	The fifth generation (5G) cellular network is expected to be a major enabler for IoT by offering improved connectivity capabilities, lower energy consumption, and greater scalability. Further research is needed to enhance congestion control and device interoperability in IoT environments.
Novelty	This article is one of the first comprehensive reviews to emphasize the role of 5G networks in supporting IoT, with a particular focus on emerging cellular communication technologies such as EC-GSM-IoT, eMTC, and NB-IoT.

The results of this research show that IoT has an important role in facilitating various sectors in smart cities, such as smart transportation, more efficient energy management, and connected health systems. In cities such as Singapore and Barcelona, IoT is being used to monitor traffic in real-time, optimize electricity use, and provide remote health services. However, IoT implementation also faces major challenges, especially in terms of data security, privacy, and the need for adequate infrastructure to support a network of interconnected devices.

Indicators of the Role of IoT in Smart City :

1. **Smart Transportation**

IoT enables smart transportation systems through the use of sensors and connected devices that can monitor traffic in real-time, regulate traffic signals automatically, and provide alternative routes to reduce congestion. Connected vehicles and IoT-based public transportation provide real-time arrival time information to passengers. Smart Transportation in the context of a Smart City is a transportation system that uses advanced technology, data and communications to increase the efficiency, comfort and safety of transportation in urban areas. Smart transportation aims to optimize urban mobility, reduce traffic congestion, improve safety, reduce emissions and provide a better experience for public and private transportation users(Farooq et al., 2015).

Main Components of Smart Transportation:	**Discription**
Smart Traffic Management System:	It uses sensors, cameras and AI to monitor and manage traffic in real-time, reduce congestion and optimize road use.
Integrated Public Transportation	Involves the integration of different modes of transport such as buses, trains and bicycles to make it easier to move between modes, as well as the use of applications for tracking arrival times and electronic payments.
Autonomous Vehicles and Ride Sharing	The use of driverless vehicles connected via a network system, as well as vehicle sharing services (car-sharing, bike-sharing) to reduce the number of vehicles on the road.
Smart Parking System	Using parking sensors connected to a mobile application to help drivers find available parking spaces quickly, reducing search time and congestion in parking areas.
Use of Clean Energy and Electric Vehicles	Encourage the use of electric vehicles and provide widespread charging infrastructure to reduce carbon emissions in cities.

Implementation Example:

1. Singapore: Has a smart traffic management system that monitors traffic in real-time and regulates traffic lights to minimize congestion. The city also uses autonomous vehicles and has a highly integrated public transportation system.
2. Barcelona, Spain: Using a smart parking application that helps residents find the nearest parking space using sensors. The general transportation system is also connected via applications, making it easier to pay and track public transportationMenggunakan aplikasi parkir pintar yang membantu warga menemukan tempat parkir terdekat dengan menggunakan sensor. Sistem transportasi umumnya juga terhubung melalui aplikasi, memudahkan pembayaran dan pelacakan kendaraan umum.
3. Amsterdam, Netherlands: Encourage bicycle use with smart bicycle infrastructure integrated with other modes of transport. Additionally, the city has many charging stations for electric vehicles. Mendorong penggunaan sepeda dengan infrastruktur sepeda yang cerdas dan terintegrasi dengan moda transportasi lain. Selain itu, kota ini memiliki banyak stasiun pengisian daya untuk kendaraan listrik.

Image of Smart Transportation in Smart City:
The following is an illustration that depicts smart transportation in a smart city.

Figure 2. Smart transportation in Singapore implemented in an urban environment

Figure 2 above illustrates how smart transportation in Singapore is implemented in an urban environment. You can see autonomous vehicles such as buses, Electronic Road Pricing (ERP) systems that manage traffic with smart sensors, as well as public transportation such as Mass Rapid Transit (MRT) and buses that are integrated with digital applications. The system enables efficient urban mobility through real-time data collection and intelligent traffic management, making Singapore one of the leaders in smart transportation in the world

2. **Energy and Environmental Management**

Smart grid systems enable efficient monitoring and control of energy consumption, reduce waste, and support the use of renewable energy. IoT sensors are used to monitor air quality, waste management and water use, thereby increasing environmental sustainability. Energy and Environmental Management in the context of a smart city is a strategic approach that uses digital technology and smart infrastructure to manage energy use efficiently and protect the urban environment. It aims to create a more sustainable and environmentally friendly city through the integration of technology that supports energy efficiency, emission reduction and conservation of natural resources.

Main Components of Energy and Environmental Management	**Discription**
Smart Energy System (Smart Grid)	Technology that enables more efficient energy management by monitoring energy use in real-time, enabling energy savings, and the integration of renewable energy such as solar or wind power into the city's electricity system
Integrated Public Transportation	Involves the integration of different modes of transport such as buses, trains and bicycles to make it easier to move between modes, as well as the use of applications for tracking arrival times and electronic payments.
Waste and Water Management	Sensor technology and IoT are used to monitor municipal waste and water distribution, ensuring that these resources are managed properly. Automatic recycling systems and water leak monitoring are examples of technology applications in resource management
Emission Reduction and Renewable Energy	Emission Reduction and Renewable Energy: Smart cities integrate renewable energy sources such as solar panels, wind turbines, or biomass technology to reduce dependence on fossil fuels and minimize the city's carbon footprint..

Implementation Example:

1. Amsterdam, Netherlands: Using smart grids to manage electrical energy distribution efficiently and using renewable energy. Buildings in this city are equipped with energy-saving technology that can significantly reduce electricity consumption.
2. Copenhagen, Denmark: Using smart grids and green transport infrastructure to reduce carbon emissions with a target of becoming a carbon neutral city by 2025.

Illustrations and Images of Energy and Environmental Management in Smart Cities:

The following is an illustration that illustrates how smart technology is used for energy and environmental management in a smart city.

Figure 3 Energy and environmental management Applied in a smart city

The image above illustrates how energy and environmental management is implemented in a smart city, including solar panels, wind turbines, green buildings, and a smart grid system that manages energy distribution efficiently. This technology helps cities reduce carbon emissions, increase energy efficiency and preserve the environment, making cities more sustainable and environmentally friendly.

Figure 4 the image above depicts Masdar City in Abu Dhabi which focuses on environmental sustainability and energy management

The image above depicts Masdar City in Abu Dhabi, which focuses on environmental sustainability and energy management. The city uses solar panels to generate energy, wind towers to cool public spaces, and green architecture designed for energy efficiency. Additionally, there is an advanced water recycling and waste management system that reduces environmental impact. Masdar City is also equipped with charging stations for electric vehicles as well as autonomous transportation, making it an ideal example of a city that integrates sustainability with advanced technology(Dhanaraju et al., 2022).

3. **Public Safety and Emergency Response**

Surveillance cameras connected to IoT and city security monitoring systems can automatically detect suspicious behavior and provide early warning to authorities. IoT systems support faster emergency response by detecting and reporting fires, accidents or natural disasters in real-time. Public Security and Emergency Response in smart cities refers to the use of advanced technology to improve citizen safety and facilitate rapid response to emergency incidents. With the integration of digitally connected systems, smart cities can increase efficiency in dealing with security threats, accidents, natural disasters and other emergencies. This includes the use of sensors, cameras, data analytics, as well as communication devices that enable authorities to manage and respond to emergency situations in real-time.

Main Components of Public Security and Emergency Response in a Smart City	**Description**
Smart CCTV Monitoring System	Smart CCTV Monitoring System: Surveillance cameras equipped with facial recognition and artificial intelligence (AI) technology to automatically detect suspicious activities or law violations
Early Warning Systems	Early Warning Systems: Use sensors and weather data to detect natural disasters such as floods or earthquakes, which then provide early warnings to the public through various channels, including mobile phone applications.
Integrated Emergency Services	Integrated Emergency Services: Integrates police, medics and firefighters in one intelligent communications network that enables rapid response to incidents through real-time tracking and incident mapping systems.
Command and Control Center:	Command and Control Center: A center that manages the entire public safety and emergency

	system with access to real-time data from surveillance cameras, environmental sensors, and public communications devices. This center allows for more effective coordination in dealing with crises.
Connected Public Reporting System	Connected Public Reporting System: A mobile app or online platform that allows citizens to report incidents or threats directly to authorities, who can then respond quickly.

Implementation Example:

1. New York City, USA: Uses thousands of CCTV cameras connected to an AI analytics system to detect security threats. Additionally, the city has a command center that manages emergency responses to fires, medical incidents and terrorist threats
2. Amsterdam, Netherlands: Has an early warning system for floods and severe weather threats, which integrates data from environmental sensors to provide rapid warnings to citizens via a mobile phone app.
3. Seoul, South Korea: Using smart policing technology that combines data from CCTV, citizen reporting applications, and AI analytics to improve public safety and emergency response.

Illustrations and Pictures of Public Security and Emergency Response in Smart Cities:

The following illustration illustrates how smart technology is used to improve public safety and emergency response in a smart city.

Figure 5 Public security and emergency response implemented in a smart city

The image above illustrates how public security and emergency response are implemented in a smart city. There is visible use of smart CCTV cameras with facial recognition that monitor public spaces, command and control centers that handle emergency situations in real-time, as well as emergency vehicles such as police and fire engines that are equipped with GPS tracking. The city also uses drones to help with search and rescue, and residents can use a cellphone app to report incidents. This technology enables rapid and coordinated response in emergency situations, making cities safer(Yousuf et al., 2016).

Figure 6 Public Security and Emergency Response systems in Smart City Seoul, South Korea

The image above shows the Public Security and Emergency Response system in Smart City Seoul, South Korea. This system uses smart CCTV equipped with AI analytical technology and facial recognition to monitor public areas in real-time. Data from these cameras is analyzed in the command center to detect potential threats. Police use mobile applications for smart policing, and citizens can report incidents through the citizen reporting application. This technology helps improve emergency response coordination and maintain security throughout the city

4. Smart Health

IoT-based healthcare enables remote monitoring of patients through connected medical devices, which is especially useful in emergency situations or for the care of elderly patients. Smart cities can provide better preventive health services by using IoT data to monitor environmental conditions that affect citizens' health. Smart Health in the context of a smart city is a health system that utilizes advanced technology such as the Internet of Things (IoT), artificial intelligence (AI), telemedicine, and analytical data to improve the quality of health services, facilitate access to health facilities, and ensure continuous monitoring of citizens' health. real-time. This system is designed to drive efficiency, provide faster diagnosis, and support disease prevention with accurate and up-to-date data (Yuehong et al., 2016)

Key Components of Smart Health	**Discription**
Telemedicine	Telemedicine: This technology allows remote doctor consultations via video call or cellphone application, reducing the need for in-person visits to hospitals or clinics.

Wearable Devices and IoT	Wearable Devices and IoT: Wearable health devices such as smart watches, health sensors, or blood pressure and heart rate monitors connected to a city's health system. This data can be used to monitor residents' health conditions in real-time and provide early warnings regarding health problems.
Big Data and AI for Diagnosis	Big Data and AI for Diagnosis: The use of big data and artificial intelligence to help doctors diagnose diseases, predict health trends, and provide more personalized and accurate treatment recommendations.
Electronic Health Records (EHR)	Electronic Health Records (EHR): Digital medical records that can be accessed by multiple healthcare providers in smart cities, enabling faster and more efficient exchange of health information between hospitals, clinics, and laboratories.
Smart Health Center	Smart Health Center: A facility equipped with advanced technology such as medical robots, AI for diagnosis, and automated patient monitoring. This can improve healthcare services in hospitals by reducing waiting times and minimizing the risk of errors.

Implementation Example:

1. Barcelona, Spain: Has a smart health system that integrates telemedicine services and wearable devices to monitor the health of more vulnerable citizens, such as the elderly or people with chronic diseases.
2. Stockholm, Sweden: Using AI technology to analyze public health data and provide health prevention recommendations, as well as identify disease risks early.
3. Seoul, South Korea: Has smart health services that are integrated with cellphone applications to provide information regarding the availability of health facilities and telemedicine services.

Illustrations and Images of Smart Health in a Smart City:

The following is an illustration that shows how smart health is applied in a smart city with telemedicine technology, health sensors, and AI to improve health services.

Figure 7 illustrates Smart Health in a smart city

The image above illustrates Smart Health in a smart city, featuring telemedicine technology that enables citizens to consult with doctors through mobile devices. It also shows wearable devices that monitor vital signs such as heart rate and blood pressure, along with AI analyzing health data to detect diseases early. Hospitals are equipped with robots and AI systems to assist in patient care, and digital medical records that can be accessed by various clinics to speed up the exchange of information. This system helps create a more efficient and proactive healthcare environment(Dhanaraju et al., 2022)

Figure 8 illustrates smart health in Barcelona, Spain.

The image above illustrates smart health in Barcelona, Spain, which integrates telemedicine services and wearable devices to monitor the health of elderly citizens and those with chronic conditions. In this illustration, citizens use mobile devices for remote consultations with doctors, while wearable health devices continuously monitor their vital signs. Health data is monitored by healthcare professionals at a control center using AI to provide more proactive and personalized care, ensuring the well-being of vulnerable populations.

5. Smart Infrastructure and Building Management

IoT can be used to monitor the condition of city infrastructure (such as bridges and highways) and perform predictive maintenance to prevent major damage. Smart buildings are equipped with IoT systems that automatically manage energy usage, lighting, and security to enhance efficiency and comfort. Smart Infrastructure and Building Management in a smart city refers to the use of digital technology and automation to improve the efficiency, management, and sustainability of buildings and city infrastructure(Singh et al., 2022). This technology enables monitoring and control of various physical aspects of the city, such as buildings, bridges, roads, water networks, and energy, to ensure efficient use and reduce environmental impact(Krotov, 2017).

Main Components of Infrastructure Management and Smart Buildings	**Discription**
Smart Buildings	Smart Buildings: Using automation systems to manage energy, lighting, ventilation and building security. Smart buildings are equipped with sensors and IoT that enable temperature management, energy use, and real-time monitoring of building conditions.
Energy and Water Management	Energy and Water Management: Digitally connected infrastructure to manage energy consumption and water distribution in cities. This includes the use of smart grids, as well as sensors to detect water leaks or anomalies in energy distribution
Predictive Maintenance	Predictive Maintenance: Sensor technology is used to monitor infrastructure such as bridges, roads, or buildings, enabling early identification of damage or wear so maintenance can be performed before major problems arise.
Sustainable Construction and Design	Sustainable Construction and Design: Buildings and infrastructure in smart cities are designed with sustainability principles in mind. This includes the use of environmentally friendly building materials, energy efficiency, as well as the integration of green technology such as solar panels.
Traffic and Transportation Management	Traffic and Transportation Management: Smart traffic management systems integrate IoT technology to control traffic lights, monitor traffic density, and optimize transportation on roads efficiently.

Implementation Example:

1. The Edge, Amsterdam: One of the world's smartest office buildings that uses sensors and automation systems to control lighting, temperature and energy use efficiently.
2. Songdo, South Korea: A smart city designed with a focus on efficiency and sustainability, using sensors to optimally manage energy, water and waste.
3. Masdar City, Abu Dhabi: This city integrates technology to monitor buildings and infrastructure to optimize energy use and ensure long-term sustainability.

Illustrations and Images of Smart Infrastructure and Building Management:

The following is an illustration that illustrates how smart technology is used for smart infrastructure and building management in a smart city.

Figure 9 shows how smart infrastructure and building management is implemented in a smart city

The image above shows how smart infrastructure and building management is implemented in a smart city. There are smart buildings with energy-saving systems, IoT sensors that control lighting, temperature and ventilation, and solar panels installed on roofs to produce clean energy(Hyseni & Bexheti, 2024). In addition, smart grids manage electricity use efficiently, and digital traffic management systems and real-time monitoring of road conditions help optimize city mobility. This technology supports sustainability and efficient use of resources in buildings and public infrastructure(Lee et al., 2013).

Figure 10. depicts The Edge, a smart office building in Amsterdam

The image above depicts The Edge, a smart office building in Amsterdam known as one of the most energy efficient buildings in the world. The building is equipped with smart sensors and automation systems that control lighting, temperature and energy use based on occupancy levels and real-time data. Solar panels are installed on the building's facade and roof to generate clean energy, while its modern architectural design maximizes the use of natural lighting. Office spaces within the building are also equipped with digital controls that enable personal customization of workspaces, highlighting the focus on sustainability and energy efficiency(Weber, 2010).

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Novelty

The novelty in this research lies in the integrative approach that combines the analysis of technical and non-technical challenges in IoT implementation in smart cities. This research also proposes practical solutions to overcome these challenges, such as the development of public policies that encourage IoT interoperability and security. In addition, this research presents empirical case studies that enrich understanding of IoT applications in various geographic and social contexts.

CONCLUSION

This research highlights that while IoT has great potential in improving the efficiency of smart cities, both technical and non-technical challenges need to be addressed. In the context of security, there is an urgent need to develop strong security protocols to protect sensitive data from hacking. Additionally, cities with limited infrastructure, especially in developing countries, require significant investments to build networks capable of handling millions of connected devices. In addition, collaboration between government, industry, and academia is necessary to develop widely accepted interoperability standards. IoT has great potential to revolutionize smart city management by improving the efficiency of public services and people's quality of life. However, there are a number of challenges to overcome, such as security, privacy and infrastructure issues. This research proposes that governments and other stakeholders strengthen cooperation to overcome these problems, while encouraging innovation in the development of more secure and scalable IoT technology.

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