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IMPLEMENTATION OF SMART CITY APPLICATION IN SUSTAINABLE TRANSPORT SYSTEMS: PROSPECTS AND DEVELOPMENT OF SMARTCITY IN INDONESIA

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Abstract

The study aims to discuss the prospects and development of the Smart City concept in sustainable transportation systems in Indonesia. The study assesses the various challenges and opportunities emerging from the integration of information and communication technology into existing transport infrastructure. Through an in-depth literature exploration, the research identifies key factors that influence the implementation of Smart Cities and explores strategies that can accelerate the realization of efficient, inclusive, and sustainable smart transport. Research results show that the implementation of Smart Cities in Indonesia is still in its early stages, but has great potential due to the demands of rapid urbanization and development. The Smart City concept is expected to support reducing congestion, improving energy efficiency, and reducing greenhouse gas emissions. However, the research also reveals a number of major obstacles, including the need for massive investment in infrastructure, cyber security, and the digital gap between regions.

Keywords: Implementation, Smart City, Transportation, Prospects, SmartCity Development, Indonesia.

Introduction

The increase in urban population and activity brings significant challenges especially in terms of efficient and sustainable transport management. (Vuchic, V. 2017). Major cities in Indonesia, such as Jakarta, Bandung, Surabaya, and others, face severe traffic jams, increased air pollution, and limited accessibility and mobility. Big cities are struggling with complex transportation problems due to rapid population growth and urbanization. (Ushakov et al., 2022). Chronic traffic jams have become part of the daily

life of urban residents, caused by an increase in private vehicles that are incomparable with the development of road infrastructure. (Welch, T. F., & Widita, A. 2019). In addition to congestion, other issues such as pollution, traffic accidents, and public transport delays add to the list of challenges facing the urban transport system in Indonesia. The impact is not only limited to daily discomfort, but also affects public health, the environment, and economic productivity. (Ye et al., 2021).

City government efforts through the construction of transportation infrastructure such as MRT, LRT, and the expansion of the transjakarta bus fleet, have been carried out as part of a long-term solution. (Gohar et al., 2018). However, the gap between demand and capacity remains a problem. Another factor that complicated the development was the poor integration of transport interfaces, which resulted in inoptimal population movements. On the other hand, uncontrolled urbanization results in the growth of suburban areas that are often not supported by adequate public transport, promoting increasing dependence on private vehicles and worsening traffic conditions. (Cuzzocrea et al., 2019). To meet these challenges, a comprehensive transport policy is needed as well as the implementation of innovative transport solutions that are consistent with technological developments and society's needs.

This problem not only affects the quality of life of urban residents but also causes considerable economic losses every year. There is therefore an urgent need to find innovative solutions that can address these urban transport problems.

The Smart City concept emerged as one of the promising solutions to overcome this challenge. The application of smart technology in urban management can open up new opportunities to make transportation systems more efficient, environmentally friendly, and sustainable. (Angelidou, M. 2014). By integrating information and communication technology (ICT) into city infrastructure, Smart City enables real-time data collection, effective analysis, and then the implementation of proactive solutions for transportation systems. (Anthopoulos, L. G. 2015).

The adaptation of the Smart City concept has become crucial in addressing transportation problems in major Indonesian cities as it offers a systematic and sustainable approach that leverages technological innovation. With the integration of information and communication technology into transportation infrastructure, traffic management can become more efficient through real-time data analysis, traffic pattern prediction capabilities, and responsive control systems. (Lombardi et al., 2012). It will not only reduce congestion but also improve mobility and accessibility for urban residents. In addition, Smart City supports the development of integrated and multimodal public transport, facilitates interconnection of transport modes, and encourages the use of environmentally friendly vehicles. (Anthopoulos et al., 2016). By implementing the Smart City concept, transportation planning and management can be done more adaptively to the needs and challenges of today, towards a greener and more efficient future for cities in Indonesia.

However, this development requires an in-depth understanding of the specific needs of cities in Indonesia, appropriate technology integration, and supporting policies and regulations. The aim of this study is to explore how Smart City implementation can be applied in the context of Indonesia's transportation system, identifying opportunities and challenges.

The implementation of Smart Cities not only promises increased transport efficiency but also supports the existence of greener and more sustainable cities. It is in line with the global agenda for reducing carbon emissions, improving the quality of life, and creating an inclusive and accessible urban environment for all citizens. In the context of Indonesia, this study is expected to provide insight into how the Smart City concept can be used to address the current transport challenges and help formulate strategic steps for the development of sustainable transport systems in the future.

Research Method

The method of literary research is an approach in research that involves the collection, review, and analysis of relevant literature in order to acquire, understand, and interpret existing knowledge on a particular topic. (Reay, 2014; Graue, 2015). This type of research is often used to synthesize existing research results, identify consensus or contradiction in the literature, or determine the direction of further research. This method does not involve collecting primary data through experiments or observations, but focuses on information already available in the form of scientific publications such as journals, books, theses, and conference proceedings. (Sgier, 2012; Noble & Smith, 2014).

In literary research methods, researchers follow a number of interrelated steps. The first step is to determine the scope or scope of the discussion to direct the search for specific and relevant literature. The second step is the search and selection of literature based on the established inclusion and exclusion criteria, which is then followed by a critical stage of review of the collected material to identify important methodologies, results, and conclusions. Finally, the author will integrate the findings into a coherent discussion to support conclusions or recommend future research directions. (Grbich, 2012; Bazeley, 2013).

Result and Discussion

Smart City Concept

The Smart City concept refers to the innovative and strategic use of information and communication technology (ICT) to improve the quality, performance, and interactivity of urban services, while reducing costs and resource consumption. (Kirimtat et al., 2020). In the context of Smart Cities, technologies such as the Internet of Things (IoT), big data, data analytics, and artificial intelligence are integrated into urban systems, ranging from transportation management, electricity, water

management, to public services and security, to create a city that is safer, more efficient, and more responsive to the needs of its inhabitants. (Kumar et al., 2020). Smart cities are not just about digital infrastructure, but also about using innovation to facilitate interaction between citizens, governments, and the private sector, support data-based decision-making, and empower communities through smarter, more sustainable solutions. (Khan et al., 2020).

The key elements of the Smart City concept refer to the critical components that form the basis for the development and operationalization of a smart city. Information and Communications Infrastructure (ICT) is at the heart of building Smart City, ensuring connectivity and data integration between city services (Zheng et al., 2020). The use of technologies such as the Internet of Things (IoT) allows devices and sensors to collect real-time data from the surrounding environment, which can then be analyzed to inform decision-making and city resource management more efficiently. In addition, smart transportation systems, smart energy management, and sustainable natural resource management are key elements in supporting more dynamic and energy-efficient urban life. (Ristvej et al., 2020).

In addition to technological infrastructure, another important element of Smart City is the participation of citizens and innovative city governance. Public participation mechanisms in urban planning and decision-making, supported by digital platforms, ensure that citizens' voices are heard and contribute to urban development. Good governance integrates best management practices with technological innovation to create efficient, transparent and accessible public services for all segments of society. (Allam, Z., & Jones, D. S. 2020). Cooperation between city governments, the private sector, educational institutions, and civil society is also an important foundation in realizing the vision of Smart Cities, fostering an innovative ecosystem that supports sustainable and inclusive development. (Toli, A. M., & Murtagh, N. 2020).

In the context of Smart Cities, the key principles that guide innovation and development in the transport sector include efficiency, sustainability, and inclusive. The application of advanced technologies such as intelligent transport systems (ITS) aims to improve the efficiency of mobility within cities, reduce traffic jams, and ensure that citizens can move from one place to another easily and quickly (Patrão et al., 2020). The integration of real-time data from various sources enables real time traffic flow monitoring and dynamic transport management, enabling city managers to quickly address traffic problems and optimize transport routes. Besides, sustainability is the key, with the aim of reducing the carbon footprint of the transport sector through the use of electric vehicles, building environmentally friendly infrastructure, and promoting environmentally-friendly modes of transport such as cycling and walking. (Laufs et al., 2020).

Inclusiveness emphasizes the importance of accessibility in the urban transport system, ensuring that all citizens, including vulnerable groups such as the elderly, the

disabled, and those living in remote areas, have easy access to public transport. (Jiang, D. 2020). This leads to inclusive and responsive designs, such as public vehicles equipped with facilities for disabled people, user-friendly information systems, and affordable rates. The integration of the transport interface also allows citizens to switch from one mode to another smoothly, increasing the attractiveness of public transport while reducing dependence on private vehicles. (Haque et al., 2022).

Thus, in the realization of Smart Cities, the transport sector plays an important role in providing efficient, sustainable, and inclusive services to its citizens. Through the application of smart technology, innovation in management and operations, as well as a sustainability and inclusive approach, responsive and adaptive transport systems can be realized. It not only improves the quality of life of urban citizens but also leads to more sustainable and sustainable urban development for the future.

Sustainable Transportation System

Sustainable transportation systems are systems designed to meet the needs of today's mobility without compromising the ability of future generations to meet their own needs. (Rajak et al., 2016). In other words, it is an approach aimed at balancing the economic, social, and environmental issues related to the transport system. Its primary objective is to reduce the negative impact on the environment, improve public safety and health, and ensure equitable accessibility among communities. This concept requires that the transportation system must be resource efficient, low emissions, and durable in the long term. (de la Torre et al., 2021). This includes promoting the use of cleaner alternative fuels, low-emission vehicles, and reducing the need for travel through smart city planning. (Awasthi et al., 2011).

Characteristics of sustainable transport systems include reduced reliance on fossil fuels and an incentive to use renewable energy or more environmentally friendly technologies, such as electric vehicles or biofuels. (Maheshwari et al., 2015). Transport infrastructure development projects focus on reducing greenhouse gas and other pollutant emissions, energy efficiency, as well as designs that support a variety of modes of transport, including walking, cycling, or using public transport. Efficiency can be achieved through intelligent traffic management and an effective public transport system. (Zhu et al., 2023). Furthermore, accessibility is a key element, which means that the system must be accessible and also provide facilities that can be used by all members of society, including the disabled, the elderly, and low-income groups. (Mihyeon Jeon, C., & Amekudzi, A. 2005).

The development of sustainable transportation systems also involves the participation of stakeholders, including governments, industry, and society. It is done to ensure the integrity and synchronization of sustainable objectives in the planning and operational transportation. Education and public awareness of transport and environmental issues is considered vital in building demand and support for sustainable

transport systems (Gudmundsson et al., 2016). Integrating urban spatial planning with transportation policies helps reduce the need for long and inefficient travel, thus reducing the carbon footprint and improving the quality of urban life. Finally, supportive government policies, such as incentives for clean transport and restrictions on private motor vehicles, are also important in supporting the development of sustainable transport systems. (Shiftan et al., 2003).

Sustainability in the transport system is becoming increasingly important as population growth and economic developments demand greater mobility. Unsustainable transport can lead to a variety of environmental problems, such as increased greenhouse gas emissions, air pollution and noise, which have a negative impact on climate change and quality of life. (Wang et al., 2018). Moreover, transport systems that do not take into account social aspects and equal access can create social inequality and widen gaps in societies. Sustainability in this sector is also closely linked to the use of energy resources, in which non-renewable and inefficient use of fossil fuels must be minimized and replaced with cleaner and more environmentally friendly alternative energy sources. (Karjalainen, L. E., & Juhola, S. 2021).

Sustainable practices in the transport system not only reduce the negative impact on the environment but also bring economic and social benefits. By increasing operational efficiency as well as reducing expenditure on fuel and health costs due to pollution, significant economic benefits can be achieved. (Tian et al., 2020). From a social perspective, sustainable transport systems can improve accessibility and cross-border connectivity, allowing more people to access employment, education, and health services. Moreover, having a cleaner and safer living environment promotes a healthier lifestyle for people, reduces the incidence of diseases associated with air pollution, and improves traffic safety. (Kumar, A., & Anbanandam, R. 2019).

Therefore, sustainability in the transport system is a crucial issue to be taken into account in order to maintain environmental balance, promote social justice, and guarantee economic growth. Comprehensive efforts from all sides, including governments, industry, and society, are urgently needed to create transportation that is not only efficient and reliable, but also able to meet the needs of the present without sacrificing the ability of future generations to meet their needs. The implementation of sustainable practices in the transportation system enables us all to lead towards a greener, inclusive, and sustainable future for the planet and its inhabitants.

Smart City Implementation with Transportation Systems in Indonesia

Transport in Indonesia is currently facing many challenges, ranging from traffic jams, uneven infrastructure, to issues of efficiency and environmental sustainability. (Ushakov et al., 2022). With the large population and concentration of economic activity in urban areas, especially in major cities such as Jakarta, Surabaya, and Bandung, the need for more efficient and efficient transportation systems has become crucial. (Gohar

et al., 2018). Congestion has become one of the major issues that takes time and productivity, in addition to contributing to air pollution. Public transportation systems lack of integration of interfaces and insufficient capacity are also barriers to the mobility of the population. (Cuzzocrea et al., 2019).

Implementing the Smart City concept in the transport sector in Indonesia could be a solution to a number of these challenges. By implementing intelligent transportation systems, managing and optimizing traffic flows can be done through real-time data analysis (Angelidou, M. 2014). This allows for more dynamic traffic lights setting, monitoring of road conditions, and disseminating information to road users accurately and in a timely manner. Transportation interface integration can be enhanced through integrated information systems, enabling citizens to plan their travel more efficiently, combining various modes of transport such as buses, trains, and non-motorized transportation in one trip. (Anthopoulos, L. G. 2015).

In addition, environmental sustainability has become a critical requirement in transport development in Indonesia. Initiatives such as the promotion of electric vehicles, improved facilities for pedestrians and cyclists, as well as urban planning that supports reducing carbon emissions should be part of the Smart City development strategy. (Lombardi et al., 2018). Thus, investments in smart technology and innovation in transport systems will not only solve issues of efficiency and traffic density, but also drive towards more sustainable and environmentally friendly development. Applying Smart City principles to transport in Indonesia can help create more integrated, reliable, and sustainable transport systems to support inclusive socio-economic development (Anthopoulos et al., 2016).

Prospects and Challenges

Prospects of Smart City implementation in transportation systems

The application of the Smart City concept to transportation systems brings very promising prospects in improving efficiency, sustainability, and transport convenience. Using information and communication technology (ICT), transport systems can be controlled and monitored in real time, enabling more intelligent, efficient and responsive traffic management to the needs of its users. (John et al., 2019). The use of big data and artificial intelligence (AI) in traffic pattern analysis enables proactive congestion prediction and traffic management, thus minimizing waiting times, reducing density, and improving transport flows. (Tran et al., 2023). The integration of this smart system also opens up opportunities for the development of more integrated and accessible public transport, for example through mobile applications that provide real arrival time information, rates, and route choices, all aimed at optimizing user experiences and encouraging the use of public transport as an alternative to private transport. (Yan et al., 2020).

Furthermore, advances in autonomous vehicle technology and electric vehicles in the context of Smart Cities are a turning point towards the future of more sustainable and efficient transport systems. (Smirnov et al., 2024). Autonomous vehicles promise a reduction in human-caused traffic accidents, while electric vehicles contribute to reducing pollutant emissions. The implementation of supporting infrastructure, such as smart electric vehicle charging stations that are interoperable with the city grid, as well as special lines for autonomous vehicles, will accelerate the adoption of this technology (Bıyık, C. 2019). Alignment with the Smart City concept also paves the way for innovation in new modes of transportation, such as drone-based transportation systems or Hyperloop, which align with the needs and future challenges of urbanization. The combination of smart management, environmentally friendly vehicles, and supportive infrastructure, will transform the face of urban transport, leading to a significant decrease in energy consumption and reduction in carbon footprint, whileining mobility and accessibility for the entire population. (Zadorozhko et al., 2018).

Thus, the prospect of implementing Smart City in transportation systems is a step forward towards more efficient, sustainable, and secure transportation solutions. By leveraging state-of-the-art technology, cities will be able to address the challenges of modern urban transport, such as congestion, pollution, and inclusion, while improving the quality of life of their citizens. Intersectoral collaboration and commitment to invest in technological innovation are key to realizing the Smart City vision in the transportation system.

The challenges you might face and how to overcome them

Integrating the Smart City concept into the transportation system presents a number of significant challenges. First, the challenges of infrastructure and financial investment are one of the main obstacles. Construction of infrastructure that supports advanced technologies such as sensors for data collection, wireless communication systems, and electric vehicle charging stations requires large initial investments. (Paiva et al., 2021). Besides, upgrading existing transportation systems to be compatible with this new technology can be a long and expensive process. Later, data security and privacy issues also became special concerns as digitally connected systems increased the risk of personal data leaks and cyber attacks. (Andreev, D. 2023). A holistic approach and cross-sectoral co-operation between governments, the private sector, and academic institutions are essential in raising resources and funding, as well as in implementing strict security standards to protect data and infrastructure from cyber threats. (Kaluarachchi, Y. 2022).

Secondly, social challenges and behavioral change should not be ignored either. Adoption of new technology often requires a change in the way people view and behave themselves. For example, encouraging the use of public transport or electric vehicles as a substitute for petrol-powered private vehicles requires intense

socialization campaigns and attractive incentives. (Tomaszewska, E. J. 2021). Opposition from various groups may emerge, especially from those whose economic activities are threatened by this change, such as the fossil fuel industry or conventional taxi drivers. (John et al., 2019). In this respect, effective communication and public education are key to educating people about the long-term benefits of smart transport systems. A reskilling and upskilling programme can be provided to affected workers, to facilitate their transition to the new sectors of employment that arise as a result of this transformation. (Tran et al., 2023).

Thus, the challenge in implementing the Smart City concept on the transportation system requires a multidimensional and collaborative approach. Significant investments, data security management, as well as comprehensive efforts to change social behavior are some of the key steps to take. Through close cooperation between government, private, public and educational institutions, these challenges can be overcome, paving the way for smarter, more efficient, and more sustainable transport systems.

Conclusion

The implementation of Smart City in Indonesia's transportation system offers great potential in creating more efficient, sustainable, and inclusive transportation systems. This process requires the integration of advanced information and communication technologies, such as AI and big data, for better traffic management and monitoring, as well as the adoption of electric and autonomous vehicles to reduce pollutant emissions. It is an important step towards improving the quality of life of citizens, reducing congestion, pollution, and strengthening user-friendly transport infrastructure. Nevertheless, challenges such as the need for large infrastructure investments, data security, and social behavior change must be tackled strategically through collaboration between governments, the private sector, communities, and academics.

By focusing on innovation and collaboration, Indonesia can overcome these barriers, seize opportunities to improve its transportation system, and move forward towards sustainable and inclusive development. Learning from global best practices and adapting the latest technology to local conditions are key to the successful implementation of the Smart City concept in Indonesia. Success in this transformation will not only improve transport efficiency but also contribute to a significant reduction in the country's energy consumption and carbon footprint, in line with Indonesia's sustainable development goals.

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