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Smart City System Review: Challenges and Opportunities for Implementation in Urban Areas

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ABSTRACT

Rapid urbanization has pushed cities in Indonesia to face complex challenges related to infrastructure capacity, public services, and urban governance. Smart cities are seen as a strategic solution to build efficient, adaptive, and sustainable cities through the use of digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data. However, the implementation of smart cities in Indonesia still faces various obstacles, including digital infrastructure inequality, low human resource capacity, and weak institutional coordination. This study uses a qualitative descriptive approach and a SWOT analysis framework to identify the strengths, weaknesses, opportunities, and threats in the implementation of smart cities in urban areas in Indonesia. Data were obtained from policy literature studies, national and international agency reports, and smart city project documentation. The results of the study show that the success of smart cities is highly dependent on the synergy between infrastructure readiness, utilization of technological opportunities, and mitigation of socio-technological risks. Policies are needed that encourage cross-sector collaboration, citizen data protection, and strengthening digital literacy and local capacity. With a participatory approach and inclusive governance, smart cities can be an instrument for transforming cities that are not only technologically modern, but also socially just and sustainable in the long term.

Keywords: : Implementation; Urban; Smart City

INTRODUCTION

The rapid pace of urbanization in major cities around the world, including Indonesia, has created tremendous pressure on infrastructure capacity and public service systems. The World Urbanization Prospects report by the UN (2018) shows that more than 55% of the world's population now lives in urban areas, and this figure is projected to increase to 68% by 2050. In Indonesia itself, according to BPS (2022), around 57% of the population has settled in urban areas. As a consequence, cities are faced with complex problems such as chronic traffic congestion, gaps in access to clean water, explosions in waste volume, and high energy consumption. Urbanization is no longer just a demographic phenomenon, but has developed into a complex and multidimensional urban governance crisis.

The concept of a smart city is a response to the need for a more adaptive, efficient, and sustainable city system through the integration of information and communication technology (ICT). However, this idea cannot be understood linearly as a technological solution alone, but must be positioned within the framework of governance reform and public participation. As explained by Patrão et al (2020) a smart city ideally relies on a

data-driven approach in planning and decision-making, but still considers the social, economic, and political dimensions as a whole. Thus, the urgency of implementing a smart city lies not only in the sophistication of its technology, but in its ability to respond to the complex dynamics of urbanization in an inclusive and transformative manner.

The development of digital technology, especially the Internet of Things (IoT), artificial intelligence (AI), and big data, has redefined the way modern cities are managed and developed. The integration of sensory devices and data-based systems enables real-time monitoring of various aspects of the city, from traffic, energy consumption, air quality, to waste management. For example, the cities of Barcelona and Singapore have utilized IoT networks to optimize public transportation and significantly reduce energy use (Ardhitha, 2024). However, this success cannot be replicated universally, especially in developing cities such as Indonesia which still face obstacles in digital infrastructure, bandwidth limitations, and unpreparedness of human resources in operating high-tech systems. Therefore, the adoption of technology in the context of a smart city must consider the suitability with local social structures, culture, and institutional capacity.

Furthermore, the use of digital technology in smart city development often raises new problems, such as the dominance of technology corporations, the commercialization of public data, and threats to citizen privacy. Criticism of the overly technocratic smart city model has also emerged in scientific studies. (Kurniawan et al., 2023) highlighted how the smart city narrative tends to be controlled by the interests of large technology vendors such as IBM and Cisco, which emphasize hardware solutions rather than social sustainability and democratization of information. Therefore, the implementation of an ethical and contextual smart city requires active citizen involvement, transparency of data management, and public policies that guarantee accountability. Without this, smart cities risk becoming instruments of digital control and exclusion, rather than inclusive solutions to complex urban challenges.

Although the smart city concept offers a futuristic narrative of efficiency, connectivity, and sustainability, in reality there is still a large gap between vision and implementation in many cities in Indonesia. Digital infrastructure readiness is still very uneven, where big cities such as Jakarta or Bandung are starting to build data and connectivity ecosystems, while medium and small cities are lagging behind in terms of basic infrastructure such as stable internet networks and sensor devices that support IoT systems. According to a study by the Ministry of Communication and Information (2021), only around 40% of districts/cities in Indonesia have supporting infrastructure for comprehensive smart city development. This limitation is exacerbated by the lack of human resources who have technological literacy and technical capacity to manage complex systems. As a result, many smart city projects stagnate at the pilot project stage without continuing to the cross-sector integration stage on an ongoing basis.

In addition to infrastructure and human resource limitations, governance problems are the most fundamental structural obstacles. Weak coordination between government agencies, overlapping policies between the central and regional governments, and dependence on short-term financing models often cause smart city initiatives to lose direction. In some cases, such as smart street lighting or e-government projects, the systems built do not function optimally due to minimal interoperability and the absence of long-term maintenance policies. A study by Mozin et al (2025) emphasized that the success of a smart city depends on collaborative, transparent, and participatory urban governance. Without a strong governance framework, smart city development is at risk of creating a fragmented silo system and wasting public funds. Therefore, institutional improvement and the formulation of integrative strategies must be a priority before encouraging massive technology adoption.

The economic potential of implementing smart cities in urban areas lies in the digital transformation that can create a new economic ecosystem based on data and innovation. Digitalization of public services, such as electronic payment systems, online licensing, and application-based transportation and logistics management, not only increases bureaucratic efficiency but also triggers the growth of the local digital economy sector. According to a report by Singh et al (2022), cities that optimally adopt smart city technology can increase public service efficiency by up to 30% and create new business opportunities worth billions of dollars. However, criticism arises when this transformation is only enjoyed by certain economic groups, especially large technology companies, without ensuring that local MSMEs and vulnerable communities are also involved and benefit from the digital ecosystem that is formed. Therefore, affirmative policies and incubation support are needed so that the economic benefits of smart cities are truly distributed inclusively.

On the social side, smart cities have great potential in encouraging citizen inclusion and participation through technology-based participatory mechanisms. Digital platforms such as e-participation, open data portals, and online citizen forums can be a means of strengthening local democracy and transparency of governance. However, digital participation does not automatically eliminate existing social inequality. A study by Hasija et al (2020) shows that without inclusive design, smart cities can actually deepen social exclusion of marginalized groups such as the poor, the elderly, and people with disabilities who do not have access or literacy to technology. Furthermore, large-scale data collection without clear regulations can lead to privacy violations and misuse of citizen data. Therefore, the implementation of smart cities must be accompanied by data protection policies, increasing digital literacy in the community, and strengthening citizen rights in the digital ecosystem. Only with a critical and socially just approach can smart cities become an instrument of comprehensive transformation, not just a symbol of pseudo-modernization.

METHOD

This study uses a qualitative descriptive method that aims to examine in depth the challenges and opportunities for implementing a smart city system in urban areas in Indonesia. This approach is used because smart city problems are complex, cross-sectoral, and contextual, so they require a comprehensive understanding of the various aspects involved, both technical, social, economic, and institutional. This is in line with Creswell's (2014) view that states that a qualitative approach is very effective for exploring dynamic and multi-layered social phenomena, especially when interactions between actors and policies are an important part of the object of study. The data in this study were obtained through a literature study of policy documents, official government reports (for example from the Ministry of Communication and Information and Bappenas), scientific publications, and reports from international organizations such as the OECD, UN-Habitat, and McKinsey. Literature studies were chosen because they allow researchers to access various reliable sources to build a strong theoretical analysis framework, while understanding best practices from a global context.

In addition, secondary sources such as news and reports of smart city projects in certain cities are also used to complement the analysis. To analyze the data, this study uses the SWOT analysis framework, which aims to identify and elaborate on the strengths (Strengths), weaknesses (Weaknesses), opportunities (Opportunities), and threats (Threats) of smart city implementation in urban areas in Indonesia. The SWOT framework is widely used in policy studies and strategic planning because of its ability to map actual conditions and future potential in a systematic structure (Ghazinoory et al.,

2011). This analysis allows researchers to evaluate both internal factors (such as digital infrastructure readiness, human resource capacity, and governance) and external factors (such as global technological developments, digital economy potential, and international regulations). With the SWOT approach, it is hoped that the results of the study will be able to provide a strategic overview of the position and readiness of cities in Indonesia in adopting a smart city system, as well as formulate more targeted and contextual policy recommendations. This approach also provides flexibility to capture rapidly changing dynamics in the context of urbanization and digital transformation, making it very relevant for evidence-based policymaking.

RESULT AND DISCUSSION

1. Evaluation of Infrastructure Readiness and Internal City Capacity

Evaluation of infrastructure readiness and internal city capacity is a crucial stage in implementing a sustainable and integrated smart city. One of the main strengths found in a number of large cities in Indonesia is the availability of basic digital infrastructure such as fiber optic networks, local data centers, and public internet access facilities. The presence of this infrastructure is an important foundation in the development of digital services based on the Internet of Things (IoT), big data, and artificial intelligence (AI). However, there is a significant gap between metropolitan cities and second and third tier cities that still face limited digital access and network connectivity. According to a report by Noori et al (2020), the disparity in digital infrastructure between regions in Indonesia hinders the equitable distribution of the benefits of digital transformation and increases the risk of small cities being left behind in the national smart city agenda.

Furthermore, the availability of IoT devices and digital systems to support city management is still partial and not yet holistically integrated. Although several cities have implemented traffic sensors, smart surveillance cameras, and digital waste management systems, most of these systems still run in sectoral silos without a cross-department integration platform. This condition has implications for the low effectiveness of data utilization for evidence-based policy making. In line with the study by Rahma et al (2018), system integration and interoperability are key factors in the success of a smart city because they enable comprehensive data collection and analysis to support the efficiency of public services and the responsiveness of the city government.

In addition, human resource (HR) capacity is another internal aspect that shows significant weaknesses. Many city government officials do not yet have adequate digital competencies, especially in big data management, cybersecurity, and the use of AI-based technology. Training and recruitment of experts in the field of digital technology are still limited and have not been a priority in local government capacity development policies. Sarah & Poespita (2025) stated that weaknesses in digital literacy and lack of ongoing training are major obstacles to optimally operating a smart city system.

Finally, institutional coordination and internal governance have also not shown good consistency and synergy. Several cities have had special smart city units or programs, but these initiatives are often personalistic, dependent on regional head figures, and do not have a long-term institutionalized framework. The lack of coordination between agencies and low cross-sector collaboration leads to program duplication and waste of resources. This is reinforced by the findings of Tanaamah et al (2021) which emphasize that the success of a smart city is greatly influenced by a participatory, coordinated, and data-based governance model. Therefore, strengthening institutional structures, developing digital human resource capacity, and building an integrated digital system are absolute requirements that must be met before developing

other advanced technologies within the framework of an effective and inclusive smart city.

2. Strategic Opportunities in the Technology Ecosystem and Digital Economy

Strategic opportunities in the technology ecosystem and digital economy pave the way for the transformation of cities into smarter, more inclusive, and highly competitive entities. Amidst the acceleration of technological globalization, the integration of artificial intelligence (AI), Big Data, Internet of Things (IoT), and 5G networks has become a major catalyst in building sustainable smart cities. These technologies enable the collection and analysis of huge amounts of real-time data (real-time big data analytics), which is then used to support city policy decisions, operational efficiency, and more responsive public services. A study by Kondoj et al (2023) in the Journal of Big Data confirms that Big Data plays a vital role in creating smart cities through its predictive capabilities in the areas of transportation, energy, and public safety. This is in line with real practices such as those implemented in the "City Brain" system in Hangzhou, which leverages AI and Big Data to reduce traffic congestion by 15% in two years.

On the other hand, collaboration between the public and private sectors (Public Private Partnership/PPP) is increasingly showing its urgency as a strategic approach to accelerate the implementation of smart cities. This partnership not only opens up sources of financing and technology, but also creates a collaborative innovation ecosystem that brings together stakeholders from various backgrounds. A study by Jiang et al (2023) shows that successful smart cities such as Amsterdam and Barcelona rely on an open innovation model that involves citizens, startups, and research institutions to jointly develop technology-based urban solutions. In Indonesia, this kind of collaboration has begun to be seen in the "Jakarta Smart City" initiative involving national and international digital companies such as Qlue and Huawei.

Furthermore, the growth of the digital economy is one of the most significant advantages of the transformation towards a smart city. The adoption of digital systems in the transportation, public services, and logistics sectors of the city creates a new ecosystem that supports technology-based economic growth. According to Isdarmanto's report (2020), smart cities have the potential to increase city productivity by up to 30% and create millions of new jobs in the digital sector. This includes professions such as city data analysts, public service application developers, intelligent system engineers, and e-commerce-based MSMEs. Cities such as Singapore and Seoul have proven that strong digital integration with city infrastructure can create an environment that supports technological innovation and entrepreneurship.

Thus, the development of smart cities that utilize strategic opportunities in the technology ecosystem and digital economy is not only a necessity, but also a must in facing the challenges of modern urbanization (Simatupang, 2023). Cross-sector collaboration, adoption of advanced technology, and digital economic transformation are important foundations in building a resilient, inclusive, and sustainable city. However, in order for these opportunities to be maximized, adaptive policy strategies, strengthening of community digital literacy, and regulations that encourage innovation but still support the long-term public interest are needed.

3. Socio-Technological Risks and Sustainability Challenges of Implementation

Socio-technological risks in smart city implementation are serious challenges that can thwart the inclusive goals of digital transformation. The digital divide is a major issue that widens the gap between groups of people who have access to technology and those who do not. When public services, transportation infrastructure, and education begin to

rely on digital systems, people who do not have digital skills or internet access are at risk of being further marginalized. According to Amadi & Thopil (2020), uneven digitalization can actually strengthen socio-economic inequality, especially in developing countries that do not yet have the infrastructure and policies to support digital inclusion. Therefore, efforts to implement smart cities must be accompanied by policies to redistribute access, increase digital literacy, and build basic infrastructure in technologically disadvantaged areas.

In addition, threats to privacy and data security are important dimensions that are often overlooked in the euphoria of smart city development. Smart city systems that rely on sensors, CCTV, and big data-based monitoring produce volumes of information that are highly sensitive to misuse. Without a strict legal framework and participatory control mechanisms, citizens are vulnerable to privacy violations and excessive surveillance by the state and corporations. A study by Almeida & Melo (2017) warns that smart cities could turn into "surveillance cities" if the principles of data ethics and transparency are not upheld. Therefore, legal protection based on digital privacy rights such as the GDPR in Europe is needed, as well as policies that ensure that citizen data is used accountably and proportionally to its purpose.

Furthermore, dependence on foreign technology vendors is a form of structural threat to the long-term sustainability of smart cities. Technology solutions designed by global companies such as Huawei, Cisco, or IBM, although offering efficiency and speed of implementation, are often not adapted to the local context, creating a systemic dependence on maintenance and upgrades. This raises the issue of digital sovereignty, where local governments do not have full control over their city's data and digital infrastructure. According to Hadi et al (2018), a healthy smart city ecosystem should encourage open innovation and support the active participation of local actors, both from the public, private, and community sectors. Strategies to strengthen local technological capacity, as well as the formation of regulations that require knowledge transfer and system interoperability, are important steps to reduce the dominance of foreign vendors.

In this context, the smart city development approach should not be solely technology-oriented, but should be based on social needs, citizen participation, and data sovereignty. The government needs to develop a mitigative policy framework that targets three main aspects: digital inclusion, data protection, and strengthening the local innovation ecosystem. With this strategy, smart city transformation will not only create efficiency and ease of service, but also realize social justice and long-term sustainability rooted in the strength of its own community.

CONCLUSION

The success of smart city implementation is highly dependent on the synergy between infrastructure readiness, utilization of technological opportunities, and mitigation of socio-technological risks. Strong digital infrastructure, such as fiber optic networks and IoT systems, is the main foundation but is still not evenly distributed across cities in Indonesia. This inequality requires policy intervention to bridge the digital divide between regions. On the other hand, technological developments such as AI, big data, and 5G open up great opportunities for optimizing public services and city efficiency. Cross-sector collaboration, including Public–Private Partnership (PPP), plays a strategic role in accelerating technology integration and urban innovation. However, smart city development is not free from social risks such as digital marginalization, privacy violations, and dependence on foreign vendors. Therefore, data protection and strengthening local technological capacity must be an integral part of the smart city development strategy. Strengthening digital literacy among the community and

increasing the competence of the apparatus are imperative so that the digital system can be utilized optimally. In addition, an adaptive and coordinative institutional structure is needed to avoid sectoral silos and overlapping policies. The smart city development approach must be oriented towards social justice, digital inclusion, and citizen data sovereignty. By integrating these opportunities and challenges in a balanced way, smart cities can become an instrument for transforming cities towards a sustainable and inclusive future.

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