








Metaverse, Digital Twins, and Smart Sustainable Urban Development Concepts for Nusantara Capital City, Indonesia

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ABSTRACT

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The metaverse concept for Nusantara Capital City, Indonesia, has become one of the breakthrough innovations in capital city development. Metaverse itself is a virtual world involving interaction among people in a digital environment similar to the real world. This article is part of research entitled "Application of Metaverse Technology, Digital Twins, and Implementation of Sustainable Urban Development to support Urban Future and Urban Governance in the Nusantara Capital City." This article emphasizes the concepts of metaverse, digital twins, and smart sustainable urban development for Nusantara Capital City. The data obtained from in-depth interviews, Focus Group Discussions (FGD), and questionnaires result taken from urban as well as Information and Communication Technology (ICT) experts and policymakers. The research results show that the metaverse concept digital twins must basically consider the needs and benefits in the Nusantara Capital City (Ibu Kota Nusantara / IKN) and ensure inclusiveness for all layers of stakeholders. The metaverse concept and digital twins for IKN is still in early stage of development. However, metaverse and digital twins has the potential to become a transformative technology for IKN. Metaverse and digital twins can help IKN become a smarter, more sustainable and inclusive city.

1. INTRODUCTION

At present, advances in science and technology are able to change the boundaries of knowledge. Therefore, they may give rise to disruptive technologies that have a big impact on urban society, such as metaverse, digital twins, and different other interesting concepts. Metaverse refers to a 3D virtual space formed digitally allowing users to interact with one another and access digital content combining elements of virtual reality [1, 2]. Metaverse is a continuation of digital evolution being able to revolutionize digital adoption and expand the service domain to make it able to go beyond standard systems with online access [3].

Metaverse has the potential to facilitate the delivery of public services in a virtual environment. For example, metaverse can be used to provide services in online administration, remote health, and online education. Metaverse focuses more on user experience, social interactions, entertainment, and activities within a virtual environment. Service digitization has emerged as a key strategy for enhancing efficiency across various sectors,

including entertainment, business, and education, especially through integration with online platforms over recent decades. In contrast to the metaverse, which leverages augmented reality and virtual reality to extend physical spaces, urban digital twins (UDT), as noted by Weil et al. [4], hold significant potential to revolutionize infrastructure planning, management, and the development of sustainable smart city systems. According to Mir et al. [5], digital twins act as real-world representations that align with the metaverse's virtual characteristics. Digital twins are able to form representations of the utilization of technology such as sensors used for real-time monitoring used to monitor, analyze, model physical objects or systems in the real world, and display information in real-time.

On the other side, due to various challenges in urban areas such as population density and urbanization, the need for urban facilities is also a problem that a capital city faces. Population growth in urban areas is in line with the problems of a city [6]. Nevertheless, urban resources, if managed properly, can become an exporter of solutions, one of which is by making innovation [7]. Sustainable urban development is

central in constructing Indonesia’s new capital city, Nusantara. Designed as a futuristic smart city and as a green forest city, Nusantara infuses the precept of sustainability in city planning and its management. The blueprint of sustainable urban development is to design and manage cities that addressing the current needs while safeguarding the ability of young generations to achieve theirs. According to the United for Smart Sustainable Cities (U4SSC), there are three dimensions to assess smart sustainable cities: social, economic, and environmental. This article presents how concepts like the digital twins, metaverse, and smart sustainable city principles be able to contribute to the development of Nusantara.

2. METHODOLOGY

In this study, a case study approach is used to examine contemporary and real-world issues within a naturalistic setting (a real-life context) [8, 9]. The primary objective is to explore the implementation of future urban development concept, especially related to the city’s role as the state capital. Data for this case study were collected through in-depth interviews and surveys conducted with policy stakeholders and experts specializing in urban planning and ICT, aligned with the development plans for the Nusantara Capital City [9]. Questionnaires distribution was conducted through Google form using purposive sampling based on participants’ roles and expertise. The result was 35 respondents’ data collected. The respondents who filled in the form came from the representatives of experts in the urban and ICT fields, representatives of academicians (lecturers and students), representatives of civil servants, and representatives of research institutions, namely the Agency for the National Research and Innovation.

Meanwhile, in-depth interview was carried out with resource persons including central government agencies and institutions from the Nusantara Capital Authority, ministries whose authority is related to urban development and housing, as well as smart city associations and national level planners. Resource persons also included local government agencies from areas around the Nusantara Capital City, namely North Penajam Paser Regency, Balikpapan City and Samarinda City. Apart from that, the resource persons also came from academic circles such as experts from universities, researchers from several study centers, and smart city consultants.

To complement the in-depth interviews and questionnaires, Focus Group Discussions (FGDs) were organized involving key regional and local agencies connected to the development of Nusantara Capital City. Three FGDs were held in Penajam Paser Utara, Balikpapan City, and Samarinda City, each gathering 30 participants from local agencies associated with ICT development for Nusantara Capital City.

The main data obtained through FGDs, interviews, and questionnaires were complemented by secondary data collected from literature reviews as well as analyses of relevant policies and regulations. These data were then examined to uncover and interpret relationships among key pieces of information, enabling a comprehensive understanding of the research objectives. This study employed FGDs, multi-stakeholder interviews, and questionnaires simultaneously, adhering to the triangulation approach (utilizing multiple sources of evidence) [9]. The analysis employed both qualitative and quantitative descriptive methods. The qualitative analysis followed a three-step

process: data reduction, data presentation, and conclusion drawing. During the data reduction phase, several emerging codes or themes relevant to the research objectives were identified, such as “metaverse,” “ICT,” and “Digital Twins” in the Nusantara Capital City, as well as concepts drawn from the “Sustainable Urban Development” and “Smart City” frameworks. Finally, the findings from the qualitative analysis were integrated with descriptive statistical results.

3. RESULTS AND DISCUSSION

The questionnaire results reveal that 35 respondents expressed their support for implementing the concepts of metaverse, digital twins, and smart sustainable urban development as part of the future urban planning and governance framework for Nusantara Capital City. However, some respondents believe that these concepts are not yet essential for application in Nusantara at this stage. They attribute this perspective to the numerous challenges that must be addressed prior to their implementation. The specifics are elaborated as follows.

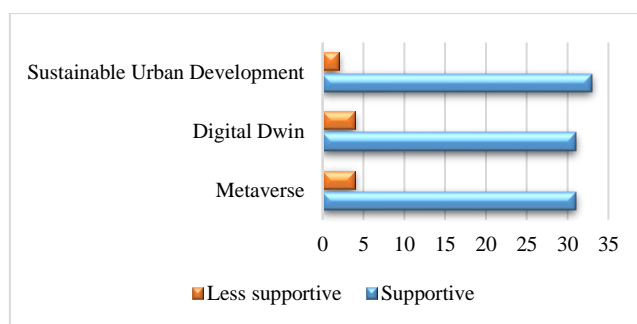


Figure 1. Respondents' perceptions of the implementation of the concept of metaverse, digital twins and the smart sustainable urban development at IKN

Source: Data analysis, 2023

Figure 1 illustrates how incorporating the concepts of metaverse, digital twin, and smart sustainable urban development into the Nusantara Capital City represents a groundbreaking approach that could positively influence various facets of urban growth and community well-being. Through the development of the metaverse, it is possible to create digital replicas of historical places, places of interest, and educational institutions in Nusantara Capital City and enable users to explore the city virtually, visit places of interest digitally and take part in online training with a virtual reality-based approach. In addition, digital twin for efficient city development enables better monitoring and analysis of the infrastructure performance and city resource use, while the concept of smart sustainable urban development can integrate smart technology to manage waste management, transportation, water availability, and energy consumption in an efficient way. Therefore, the application of these concepts at Nusantara Capital City is considered to be an innovative breakthrough that can create a more efficient, sustainable and digitally connected environment, leading to benefits to society, the economy and the environment as well. However, to realize these three concepts, it is necessary to make regional readiness, especially in terms of technological infrastructure, completeness of data, budget, and so on. The findings are explained in more detail in the following sub-chapters.

3.1 Application of metaverse technology in the Nusantara Capital City

The metaverse is often characterized as an advanced iteration of the internet, integrating virtual reality (VR) headsets, blockchain technology, and avatars to merge the physical and virtual worlds seamlessly [1, 10]. Essentially, the metaverse represents a three-dimensional virtual space where augmented and virtual reality services enable diverse activities. For a metaverse to achieve realism, it must accurately incorporate geographical and physical features aligned with specific planning objectives and interpretations [11]. In the context of Nusantara Capital City's future development, the government has identified six key service domains to prioritize: transportation and mobility; governance; living; energy and natural resources; human resources and industry; infrastructure and built environment. Currently, the metaverse is predominantly applied in recreation, education, and tourism. However, its development for Nusantara must be tailored to align with user needs. In addition, metaverse development requires investment, especially in improving the quality of content, which is still a challenge in metaverse development (In-depth interview results, 2023). The availability and quality of content can attract users. For this reason, metaverse must have interesting and high-quality content. However, there is currently a dearth of high-quality information available, making it difficult to use the metaverse (In-depth interview results, 2023).

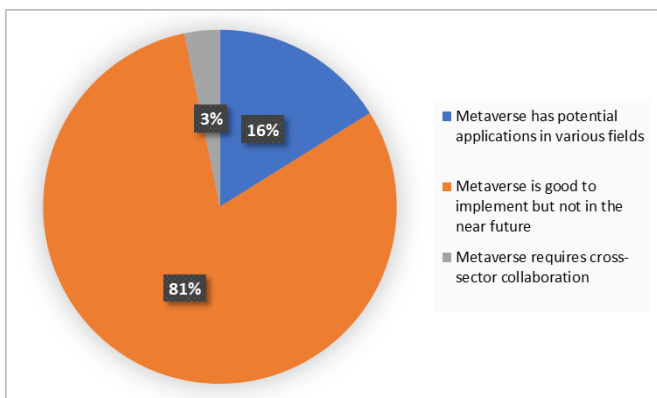


Figure 2. Percentage of respondents regarding metaverse implementation in IKN
Source: Data analysis, 2023

Figure 2 shows that 81% of the respondents stated that the concept of metaverse in IKN was suitable to be implemented but not in the near future. 16% of the respondents stated that it had the potential for application in different fields. Meanwhile, 3% of the respondents stated that it required cross-sector collaboration. Collaboration and communication are important aspects in the implementation of metaverse [12]. This collaboration enables users to transcend space and time. The implementation of metaverse on a city scale certainly requires cross-sector collaboration, large investments in technological infrastructure, and serious attention to data security and the privacy of its user. Therefore, the government, private sectors, academicians and society need to work together to create a sustainable and inclusive vision in implementing metaverse technology in the Nusantara Capital City.

The metaverse serves dual purposes: it acts as a tool to enhance real-world interactions while also being a destination in its own right. The aspect of sustainability plays a pivotal

role in its adoption and implementation [13]. By facilitating the sharing of experiences and knowledge, the metaverse fosters engagement among users, potentially shaping a new digital society with significant structural implications [14]. As a result, it holds broad applications across various sectors, including entertainment, education, tourism, commerce, social interactions, and other commercial industries (Questionnaire results and FGD, 2023).

Big Data, Artificial intelligence (AI), digital twins, XR and IoT (Internet of Things) applications are crucial components driving the development of the metaverse [3]. The technology assists the establishment of intelligent systems capable of interacting with users in a natural and seamless manner. Additionally, the IoT helps to connect and integrate various sensors and devices within the ecosystem of metaverse. On the other hand, Big Data exists as a driver to gather, store, and analyze user-generated data in the metaverse [3]. By leveraging Big Data analytics, it becomes possible to identify user preferences and behavioral trends, offering valuable insights to enhance the overall user experience. Likewise, the utilization of digital twins within the metaverse grant the creation of virtual environments that mirror real-world conditions, supporting accurate modeling and interactive engagement with these digital spaces [3]. The combination of digital twins, Big Data, and AI enables the metaverse to simulate the real world with remarkable realism. Furthermore, ensuring a positive and secure user experience requires addressing concerns related to privacy, security, and ethical considerations during the design and distribution of this technology.

Furthermore, the way how to manage it leads to challenges in governing the behavior of users in metaverse [15]. In order to be successful, the implementation of metaverse requires extraordinary efforts because metaverse is a new breakthrough in the administration process for governance. There are still many rules and services that need to be completed with paper or documents. And more important is the integration, which is currently still a problem that cannot be solved. Furthermore, based on the results of the FGD, in the implementation of metaverse, it is necessary to have an analysis of the identification of feasible parts of the metaverse to be implemented in Nusantara Capital City. One of the important aspects is security, both from the sides of users and vital objects.

3.2 Implementation of digital twins in the Nusantara Capital City

A digital twin is described as a virtual representation of the real world [5]. According to Barricelli et al. [16], digital twin technology, also known as a cyber twin, plays an important role in creating future smart cities and the metaverse. Insights from in-depth interviews and FGDs highlight that digital twins are intrinsically linked to the digital economy's integration within the Nusantara Capital City society. However, one of the key challenges in deploying digital twins in Nusantara is ensuring sufficient data and information availability. Comprehensive data serves as a foundation for developing digital twin models of the Nusantara Capital City (In-depth interview results, 2023). Utilizing sensors, digital twins have the potential to effectively monitor extensive areas of the new capital city.

Digital twin technology, often referred to as the virtual replication of physical systems, processes, and their

surrounding environments [17], is increasingly being adopted in smart cities worldwide [18]. The implementation of digital twins involves addressing eight key categories of challenges. These include: (1) ensuring interoperability and establishing semantic frameworks; (2) developing robust infrastructure for storage, computing, and networking; (3) streamlining data acquisition and actuation; (4) maintaining data quality and achieving harmonization; (5) enhancing modeling, simulation, and decision-making support; (6) improving data visualization and information presentation; (7) optimizing human and capital resource utilization; and (8) addressing governance, organizational, and societal concerns [4]. Digital twin has been implemented in several cities such as Helsinki [18], Zurich [19], and Vienna [20]. The implementation of digital twins is the peak of digitalization of city assets and services, if it meets the following four parts [21]: 1) Digital twin must be based on what a city needs; 2) The need for content support, including mature information; 3) Updating a city's digital twin is of primary importance; and 4) Interaction with the digital twin can only be ensured through a secure system.

Digital twins can be implemented in different ways [22]. For example, digital twin in predictive road maintenance [23], simulation and analysis for traffic [24], energy [25], and the management of water, waste, and telecommunication [26]. Developing a digital twin model can replicate city infrastructure such as roads, buildings, water systems, and electricity. This model can provide a real-time sight of the performance and condition of the infrastructure. In terms of the management of transportation and mobility, digital twin models can be analyzed for city transportation systems, including roads, public transportation, and parking, which can help optimize traffic flow, increase mobility, and reduce traffic congestion. Furthermore, digital twin modeling can be done for Environmental and Air Quality Monitoring. By integrating sensors and environmental data into the digital twin model, air quality control, waste management, and environmental sustainability can be monitored.

The data analysis from digital twin enables the design and development of new commercial activities and services based on data to take place. Additionally, the implementation of digital twin can be used to control, monitor, analyze and simulate the process of achieving Nusantara Capital City's vision, especially in reducing the impact of disasters. The implementation of digital twin requires identifying parts of the real world that can be "twined" by paying attention to aspects of Confidentiality, Integrity, and Availability (CIA) (Questionnaire and FGD results, 2023). Research participants in the FGD, suggested that the implementation of digital twin has several challenges. They are: the availability of supporting data from business transaction processes (human intervention through the process of transcription, verification, etc.), automatic data publishing (IoT sensors and different software supporting facial recognition, number plates, analysis, modeling, etc.), limited strong foreign investors in IT sector, and so forth.

3.3 The implementation of sustainable urban development to support urban future and urban governance in the Nusantara Capital City

A sustainable smart city is characterized as a forward-thinking urban area that leverages Information and Communication Technology (ICT) along with various strategies to enhance the quality of life, streamline urban

functions and services, boost competitiveness, and address the needs of both present and future generations across economic, social, and environmental dimensions [27]. As an evolving concept in urban planning, an eco-friendly smart city adopts and integrates data-driven technologies and innovative solutions to achieve greater sustainability by refining its systems to align with the environmental objectives of sustainable development [28].

Figure 3 shows that 88% of the respondents stated that Nusantara Capital City should be a model for implementing sustainable urban development. And 9% of the respondents stated that implementing sustainable urban development requires multisector cooperation. Meanwhile, 3% of the respondents stated that at Nusantara Capital City the initial concept of sustainable urban development already existed, but needed further development. The implementation of sustainable urban development in the Nusantara Capital City is a relevant and important step. However, it requires collaboration among the government, private sectors, academicians and society to formulate policies that take economic, environmental, and social aspects into account in a balanced way.

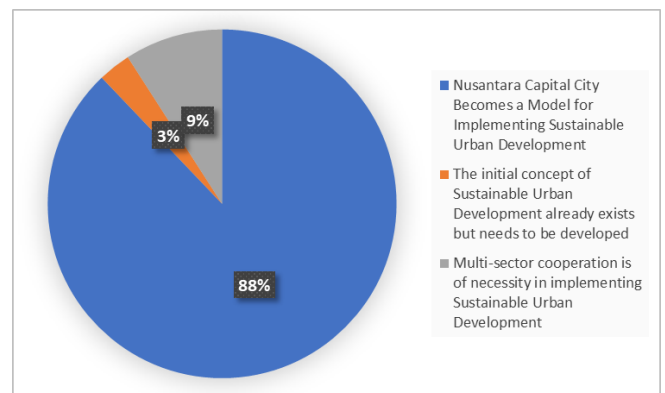


Figure 3. Percentage of respondents regarding the implementation of sustainable urban development

Currently, the intersection of sustainable development, urbanization, and sustainable urban areas has emerged as a growing focus in research, education, and policymaking. The 2030 Agenda for Sustainable Development and its SDGs were established through a broad, participatory process addressing social, economic, and environmental dimensions [29]. Insights from FGDs and in-depth interviews indicate that while the spatial and master plans for Nusantara Capital City incorporate sustainable principles, further evaluation is required to assess the implementation of smart and sustainable urban development in the city. Broadly, smart sustainability involves three key actors: the government (formulating policies), OPD (executing activity programs), and the community (enhancing capacity). Achieving sustainable cities is a key aspiration for future urban development, with Nusantara Capital City as a prime example. Integrating the principles of sustainable and smart cities is envisioned as a vital approach to advancing the development of Nusantara Capital City.

The notion of metaverse, digital twins, and sustainable urban development are gaining traction and being tailored to various urban management applications, such as transportation and traffic systems, energy efficiency, waste management, water resources, infrastructure, and strategies for addressing climate change and disaster resilience. Originally conceived to broaden functionalities within social

media, the metaverse holds promising potential across multiple domains, including industry, commerce, social, education, healthcare, defense, and public administration. In the context of Nusantara Capital City, the adoption of digital twins presents significant advantages, particularly in enhancing urban planning, fostering development, and promoting sustainability.

Based on the results of the perception mapping having been done, all respondents realized the benefits of the metaverse. However, one thing that needs to be considered is the implementation time. Similar results are findings from the Pew Research Center [30] displaying data that 54% of experts say the metaverse will have reached optimal function by 2040. The research also conveys several obstacles in implementing metaverses in the near future. They are, among others, benefits in everyday life, people's readiness to adopt metaverse technology, people's preferences to continue doing activities in 'real' life, and concerns about mass surveillance. Besides the implementation time frame, respondents' concerns are the application function of the metaverse and its cross-sector application. The application of metaverse itself is varied, ranging from marketing, education, and health, to tourism and will fundamentally change the landscape of social interactions of people who are active in it [31]. Furthermore, research conducted by Shi et al. [32] explains that the new social landscape in metaverse depends on Maslow's hierarchical pyramid and consists of 4 pillars, namely connectivity in all spaces (ubiquitous connection), space convergence, space connection, and human-centered communication.





These researches show the basic elements taken into consideration in implementing metaverse in the Nusantara Capital City and that it is expected to become a smart city [33, 34]. The metaverse serves as a pivotal element in fostering smart city initiatives by enhancing the use of information and communication technologies, ultimately aiming to improve urban living through a technological foundation [35-37]. Employing metaverse technology in Nusantara Capital City is particularly relevant, given its role as the nation's




administrative hub. Besides, Indonesia's archipelagic character makes it a challenge to undergo the coordination functions of governance. The utilization of metaverse can be a strategy to create spatial convergence and enable the officials of government to coordinate in a real-time manner. However, attention must also be directed toward addressing public concerns, including data security, privacy, and the optimization of network performance, to ensure successful development [38].

Metaverse is conceptually able to increase the capacity of a region to achieve the aspects of sustainability [39]. Therefore, it can be used as a framework to support smart sustainable urban development and applied to different aspects of urban life as it has been practiced in several cities in India and Ghana [40]. In the case of India and Ghana, using Upland Virtual World that shows a real land pattern, urban planner and community can enhance land planning to further optimize land use-based climate mitigation [40]. Digital twin, has been applied in Singapore in city planning and monitoring through "Virtual Singapore". Digital twin in Singapore is used with the utilization of real-time data for traffic simulation, energy planning, and disaster mitigation. With digital twin and metaverse technology, data transparency and accessibility and collaboration between the public and private sectors are possible to maximize the potential use of technology [41]. The emerging challenges for the implementation of Metaverse and digital twin in Nusantara Capital City based on these lessons learned are digital literacy and infrastructural challenges including network coverage and adequate numbers of sensors.

One of the aspects of sustainability that is the nexus of smart sustainable urban development with metaverse is the consumption aspect in the context of city metabolism [42] arising from different issues and challenges in urban areas today. This is because it is closely related to the resource benefits and impact on environment. Several aspects that are closely related to SDGs elements taken into consideration in smart sustainable urban development can be seen in the matrix in Table 1 below.

Table 1. Relationship between smart sustainable urban development challenges and metaverse

Smart Sustainable Urban Development Challenges	The Role of Metaverse in Nusantara Capital City	Smart Dimension	Related SDGs
Urban sprawl	The convergence of space in metaverse enables the citizen to live in a compact settlement or vertical housing	Smart Living	
Traffic congestion	The presence of metaverse will cut down commuting needs, making the citizen to work from anywhere	Smart Mobility	
Inclusive education	Metaverse melts education barriers by providing education platforms that can be accessed inclusively and enhancing learning experience	Smart Society	
Urban small and medium enterprise	Virtual realm opens possibility to create advance marketing method while decreasing the need to deliver physical goods or items	Smart Economy	

Land cover change	Metaverse decreases the need of physical building hence could help to maintain green land cover	Smart Environment	
Loss of urban biodiversity	Sensitive habitat in real world can be constructed in metaverse, enabling citizen to visit and appreciate biodiversity in virtual world	Smart Environment	
Accessibility to healthcare	Metaverse facilitates patient-doctor interface, saving time and cost for the patient	Smart Living	

Source: [40, 43-49]

The different dimensions in the matrix above provide an illustration of the application of the metaverse to support Sustainable Urban Development in the Nusantara Capital City and that they can become a strong foundation to support a sustainable and efficient urban future. By implementing the Sustainable Urban Development concept, spatial planning is expected to focus on the sustainability aspects by establishing zones for green open spaces, conservation areas and controlled development zones. This is expected to ensure the integration between urban and rural spaces to create ecological sustainability, encourage the use of environmentally-friendly public transportation, develop an integrated transportation system minimizing carbon emissions and reducing traffic congestion, use innovative technology such as the use of environmentally-friendly and energy-saving construction materials, and implement a waste management system that is effective in practice, including recycling, composting and managing waste electronically. Therefore, this is aimed at encouraging community behavior to reduce waste and adopt the lifestyle of zero waste, integrating renewable energy, developing sustainable economic sectors such as green technology, creative industries, and knowledge-based service sectors, encouraging local entrepreneurship and community-based economies, involving communities in planning and decision making processes to ensure that their needs and aspirations are represented, and building partnerships among the government, the private sector and non-profit institutions to support sustainable initiatives as well.

Digital twin technology marks a pivotal advancement for the development of smart cities, offering significant opportunities for economic growth, efficient urban management, and enhanced public services [50]. By implementing digital twins in Nusantara Capital City, the government and stakeholders can utilize real-time data and analysis to improve decision making, increase city efficiency, and create a more sustainable and innovative environment. However, during the implementation process, it is important to consider the issue of data security and privacy and community involvement in the process of developing and using the technology as well. To ensure robust cybersecurity in Nusantara, it is essential to conduct thorough risk assessments, establish effective security governance frameworks, and enhance public awareness about security measures, enabling the chosen technologies to fulfill their intended objectives [51]. Even though the concept of metaverse, digital twin, and smart sustainable urban development offers great potential, their implementation faces a number of obstacles and challenges. The following are some of the obstacles and challenges that may be faced in

implementing these concepts in the Nusantara Capital City:

1. Technological infrastructure: The availability of adequate technological infrastructure, including fast and widespread internet connectivity, is a requirement for the implementation of metaverse and digital twin. Insufficient infrastructure can hinder access and adoption of this technology.

2. The implementation of Budget: Implementing advanced technology such as metaverse and digital twin requires large investment in infrastructure, hardware, and software.

3. Security and privacy: Data security and user privacy are major challenges. In the context of metaverse and digital twin. The risk of data misuse and privacy violation can be a serious obstacle to the adoption of this technology.

4. Involvement of community: The benefits of the Smart Sustainable Urban Development concepts can be achieved through active participation from the community [52]. Their lack of understanding or disagreement with these concepts can be a significant barrier. Therefore, the community is one aspect that needs to be prepared in developing smart city in the Nusantara Capital City [53].

5. Ability to access digital infrastructure: The metaverse concept relies on internet-enabled devices such as VR headsets and AR glasses for access. However, these technologies remain financially out of reach for underprivileged communities [54].

6. Regional Conditions: Given Indonesia's island-based geography, there is a need for the integration of information technology, particularly the metaverse [54].

7. Changes in regulation: The adoption of cutting-edge technologies like the metaverse and digital twin could necessitate updates or modifications to existing government regulations and policies.

8. Human resources: People with the skills and knowledge required to design, implement, and manage this technology may not yet be widely available. Citizen participation is essential to develop sustainable policies [55]. In the Nusantara Capital City, the availability of skilled human resources presents both a valuable asset and a significant opportunity for the successful implementation of the smart city concept [53].

9. Resistance from certain stakeholders: Some parties may face resistance to change, especially if the application of the technology may change their status quo or interests.

To address the challenges of integrating the concepts of the metaverse, digital twin, and sustainable urban development in Nusantara Capital City, it is important to adopt a comprehensive approach. Integrating metaverse and digital twin as the state-of-the-art digital initiatives to digital transformation and education system will strengthen sustainable development capacities across the actors such as

the enterprises [56] and the youth [57]. Therefore, this approach must foster collaboration between the government, private sector, and local communities to guarantee the success and long-term sustainability of the innovative initiatives in the city.

4. CONCLUSIONS

The improvement of the Smart City concept to enhance urban development and governance in Nusantara Capital City encompasses several key areas: transportation and mobility, governance, natural resources and energy, industry and workforce, quality of life, as well as built environment and infrastructure. In particular, metaverse development requires investment, where content quality is a challenge in it. Meanwhile, sensors are becoming an important aspect in the implementation of digital twins. The availability of data and information is still one of the challenges in implementing digital twin in Nusantara Capital City. In addition, limited digital infrastructure, human resources, and budget are some of the challenges in implementing technology in Nusantara Capital City. Considering these challenges, careful planning, developing adaptive policies, and ensuring the involvement of all stakeholders in this transformation process are needed to ensure successful and sustainable technology implementation in Nusantara Capital City.

Challenges and obstructions in implementing the concept of metaverse and digital twin require smart strategies or innovative ways to transform computing principles into applicable practices. In addition, while the spatial and master plans for the Nusantara Capital City incorporate sustainable principles, additional analysis is required to assess the execution of its smart sustainable urban development. This development involves the government, which is responsible for creating regulations, local government agencies (OPD) that play a key role in carrying out program activities, and the community, which is engaged in strengthening capacity building.

To successfully implement the concepts of the metaverse, digital twin, and sustainable urban development in shaping the future of Nusantara's Capital City and its governance, all involved stakeholders must show strong commitment. By crafting and executing strategies that prioritize sustainability, Nusantara's Capital City can set a positive example for other regional authorities. Additionally, the development and application of these concepts can be relatively straightforward, given that it is a newly established area.

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