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Sustainable Water Management Strategies through Smart Technology Integration: Systematic Review

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Abstract

This study aims to review the current literature on sustainable water management strategies in the development of Indonesia's New Capital City (*Ibu Kota Nusantara*/IKN) in East Kalimantan, with a particular emphasis on the integration of Smart Water Management (SWM) with the smart city concept in creating an efficient and sustainable clean water supply system. Based on the literature review conducted, it reveals that the SWM concept is an important component of the IKN vision for a modern city with the importance of implementing a smart water grid, which includes real-time water quality monitoring and leak detection to optimize water resource management. This technology not only improves efficiency but also supports the development of resilient infrastructure that is able to respond to challenges such as flooding, which is a significant problem in Indonesia. In addition, researchers advocate collaborative efforts between the government, private sector, and civil society to ensure sustainable development and effective water management strategies in the IKN. The results of the study are expected to sharpen the sustainable water management strategies that have been prepared by stakeholders in the development of the IKN and highlight the importance of integration with technology to facilitate the transition to a smart city.

Keywords

Water Management, Smart Water Management, Technology, Smart City

1. Introduction

According to what was conveyed by Beppenas in the pocket book on the relocation of the national capital, 2021, the relocation of Indonesia's capital is in line with one of the urgencies faced by Indonesia, which is the water availability crisis on the islands of Java and Bali. The worst conditions are found in the Jabodetabek area and East Java, and this trend is expected to continue for several years to come. Therefore, East Kalimantan was chosen as the new capital city of Nusantara based on geographical criteria, which include being centrally located, having ample land, minimal disaster risk, and sufficient support for land and raw water.

Indonesia's New Capital City (*Ibu Kota Nusantara*/IKN) is designed to be the Smart City of Nusantara with focus on the development of a sustainable, innovative, and inclusive city. The principles of the smart City characteristics are focus on innovation, sustainability, and community involvement. The development of the smart city of Nusantara involves the use of advanced technology to create an efficient and comfortable living environment for its residents. The innovative solutions of the Smart City of Nusantara cover areas such as Smart Governance, Smart Transportation and Mobility, Smart Living, Smart Natural Resource and Energy, Smart Industry and Human Resources, as well as Smart Built Infrastructure and Environment. The smart city in the development of the IKN combines information technology and urban services to improve the quality of life for the people of the Archipelago. The principles of a smart city are based on the master plan of the IKN and the vision of national digital transformation, covering both physical infrastructure and digital networks, resulting in a city that is more effective, responsive, and sustainable (Fatimah et al., 2020; Suprapti & Suparmi, 2022).

The development of technology plays a vital role in achieving sustainable development by enhancing the efficiency and effectiveness of new, more durable ways of water management, building, and living (Permana & Harsanto, 2020). Technological advancements in building sustainable urban water systems, harnessing renewable energy resources, and public infrastructure, and producing eco-friendly materials and products are some of the paths through which technology will significantly contribute to the development of new, sustainable smart cities.

Based on blue print of smart city of Nusantara, 2022: stated that 'Built Environment and Smart Infrastructure' domain for the New Capital City (IKN) emphasizes the importance of Smart Infrastructure, focusing on principles of environmental sustainability. Smart Infrastructure includes the application of advanced technology to enhance the functionality and efficiency of buildings and urban environments. One of the main focuses is the efficient management of water resources. Nusantara promotes the application of water-saving technology, reduces water waste, and encourages the use of rainwater harvesting to support water conservation. Following are smart technology solutions for smart water system and smart wastewater management system.

Table 1. blueprint IKN smart city: National capital authority

Planned smart feature	**Technology solutions**
Smart Water Management System.	Supervisory Control and Data Acquisition (SCADA) in Drinking Water Management. A monitoring service that provides data feedback to operators regarding water treatment and distribution across the entire distribution network, detailing flow rate, water pressure, energy consumption, water quality, and the operational status of network devices and treatment units.
	Water Demand Control with Smart Water Metering A notification service for IKN residents and operators regarding excessive water usage and/or leaks in real-time through the IKN smart city application or command center.
	Smart Water Quality Monitoring A service for monitoring the quality of drinking water supply, management, and usage in the IKN area, including pollution levels and hazardous chemical content. It provides real-time alert notifications to operators if the drinking water quality in IKN exceeds the standards set by the Ministry of Health of the Republic of Indonesia.
Smart Wastewater Management System	SCADA in Wastewater Management. A monitoring service that provides data feedback to operators regarding wastewater treatment and transmission across the entire distribution network, detailing flow rate, water pressure, energy consumption, water quality, and the operational status of network devices and treatment units.
	Smart Rainwater and Runoff Management. A service that provides monitoring results to operators and utilizes real-time data from systems that collect, store, and process rainwater (incorporating techniques such as filtration, drainage, and others).
	Greywater Recycling. A service that provides monitoring results to operators and utilizes real-time data from systems that collect, store, and process greywater (involving filtration techniques and others), redirecting it to various points of use within the infrastructure.
	River Water Pollution Monitoring. A service for monitoring the quality of river water management and utilization in the IKN area, conducted in an integrated manner from upstream to downstream. It provides real-time alert notifications to operators if river water quality in IKN exceeds the standards set by the Ministry of Environment and Forestry of the Republic of Indonesia.

The relocation of Indonesia's capital to East Kalimantan presents unique challenges and opportunities for sustainable water management. According to Preparation of strategic environmental studies for the national capital master plan, 2020: In terms of water resources, the IKN region has limited raw and clean water supplies, both from groundwater and surface water. Based on analysis, most of the IKN area has a moderate capacity for water provisioning ecosystem services. Currently, the water carrying capacity in this region has not been exceeded. However, residents still lack adequate access to clean water, making it essential to develop appropriate strategies in the future to meet the demand for raw water without compromising other aspects.

Furthermore, for the residential area development plan, the provision of clean water infrastructure should be prioritized for planned settlements in both Sepaku and Muara Jawa Districts. Potential sources of raw water for these areas include the Sepaku-Semoi Dam, Batu Lepek Dam, Samboja Reservoir, or intake from the Mahakam River. In addition, raw water supply can also be optimized through a rainwater harvesting concept. The concept of Smart Water Management (SWM) is pivotal in developing an integrated and efficient water supply system for IKN. Hernaningsih et al. (2023) emphasize the necessity of a smart water grid, which enhances resource control and infrastructure efficiency while incorporating real-time water quality monitoring and flood early warning systems. This integrated approach aims to ensure safe and sustainable drinking water services in the new capital. Rifaid et al. (2023) highlight the Indonesian government's strategic planning for smart city development, which includes prioritizing urban systems, safety, and sustainability. Their findings indicate that technology adaptation and renewable energy are crucial for overcoming challenges related to human resources and infrastructure in IKN. This aligns with the need for a robust governance framework to facilitate the transition to a smart city.

Moreover, Arif & Toersilowati (2024) utilize artificial neural networks to predict water availability in IKN, demonstrating the potential of advanced technologies in water resource management. Their study indicates a high percentage of vegetation water, suggesting that sustainable practices must be integrated into urban planning. Anggraeni (2020) stress the importance of understanding water supply and demand dynamics, which is essential for effective urban water planning. Their analysis provides a framework that can inform sustainable strategies for IKN's water management, ensuring that the new capital can meet its future water needs effectively.

The concept of the smart water system is becoming increasingly popular in urban water management, with various terms associated with it. To better understand this concept, several definitions have been summarized based on scientific references. According to Gunther et al. (2015), a smart water system includes devices such as smart meters, smart valves, data communication, data fusion, and tools for data analysis and management. In another study, Hernaningsih et al. (2023) emphasized that a smart water network comprises elements like smart meters, smart pumps, and smart valves.

Furthermore, Ye et al. (2016) defined the smart water network as being built upon Internet of Things (IoT) technologies and the architecture of smart water systems. Yu and Hazen (2010) described how these networks leverage technology, software, and middleware to maximize the benefits of smart metering data for stakeholders. Allen et al. (2012), through a case study in Singapore, demonstrated how smart water systems utilize technology to manage water more efficiently.

Another definition by Rachmawati et al. (2021) highlights the potential for real-time data integration between a micro-smart water test bed and a hydraulic model. Meanwhile, McKenna & Keane (2016) explained that smart water management differs from traditional methods because it integrates information and communication technologies (ICT) with water management practices. Finally, Rifaid et al. (2023) introduced Waterbox as a test bed for monitoring and controlling smart water networks, showcasing the capabilities of technology to support more adaptive and efficient water management.

Smart water management differs from traditional water management by integrating information and communication technology (ICT) with water management practices to improve efficiency and decision-making. This approach is reflected in various interconnected components. The smart water system includes tools such as smart meters, smart valves, data communication, data fusion, and data management to enhance overall water management. Meanwhile, the smart water

network optimizes water distribution and usage through integrated components like smart meters, smart pumps, and smart valves. Built on the Internet of Things (IoT), the smart water grid provides an architectural framework that facilitates connectivity and seamless data exchange within the system. Additionally, technology integration plays a vital role, leveraging advanced technologies, software, and middleware to maximize the utility of smart metering data for a wide range of stakeholders.

2. Literature Review

The development of smart water management (SWM) systems is increasingly viewed as essential for sustainable urban development (Permana & Harsanto, 2020; Arief et al., 2022). In the context of Indonesia's new capital city, Nusantara, SWM plays a vital role in addressing the challenges of water scarcity, flooding, and efficient resource use. This literature review summarizes key studies in SWM and sustainable urban planning, focusing on Nusantara's objectives and relevant global innovations that can inform its development. Smart water management systems are integral to modern urban development, offering solutions for real-time water monitoring, conservation, and efficient distribution (Anggraeni, 2020; Rachmawati et al., 2021; Basthiani & Pangestuti, 2024). Studies by Allen et al. (2012) and McKenna & Keane (2016) highlight the transformative role of information and communication technology (ICT) in water management, particularly using smart meters, IoT sensors, and SCADA systems, which provide operators with instant access to critical water quality and usage data. These technologies not only help reduce water waste but also support preventive maintenance by identifying leaks and inefficiencies early on, an approach aligned with Nusantara's sustainability goals. Global examples, such as Singapore's smart water grid, showcase the potential of these technologies to reduce water demand while maintaining high standards of water quality. Singapore's approach has inspired similar SWM initiatives in water-scarce regions, including Indonesia, where cities like Nusantara can benefit from smart grids to manage and optimize limited water resources effectively.

Flooding and water scarcity are significant concerns in Indonesia, where frequent extreme weather events necessitate resilient infrastructure (Segarwati et al., 2022; Rifaid et al., 2023). Hernaningsih et al. (2023) discuss the importance of integrating flood early warning systems within SWM frameworks, particularly in tropical countries where urban areas face recurring flood risks. In Nusantara, integrating flood early warning systems with SCADA and real-time monitoring can enhance resilience by allowing rapid response to potential flooding events, ensuring the safety of residents and infrastructure. Additionally, Arif & Toersilowati (2024) demonstrate the effectiveness of Artificial Neural Networks (ANNs) and spectral indices in predicting water availability in Nusantara and surrounding areas. Their study highlights that by using advanced technologies to forecast water resources, cities can better manage water supply amid climate variability. Such predictive tools will be essential for Nusantara, enabling planners to balance water use with ecosystem preservation.

Effective smart water management requires not only advanced technology but also robust governance and collaboration among stakeholders (Asif, 2021; Prabowo et al., 2023; Indana & Pangestuti, 2024). Rifaid et al. (2023) argue that a comprehensive governance framework is crucial for implementing smart city elements, such as SWM, to ensure that technological advances align with policy goals and community needs. Their study emphasizes the importance of collaboration between government, private sector, and civil society in addressing challenges related to infrastructure, data privacy, and resource allocation. For Nusantara, developing a governance model that encourages public-private partnerships and community involvement could accelerate the adoption of SWM technologies. Such

a model would also promote transparency and accountability, essential factors in building public trust and fostering sustainable urban growth.

Internationally, cities are increasingly adopting SWM as part of broader smart city initiatives (Lassiter & Leonard, 2022; Sutriadi, 2023). For example, Günther et al. (2015) discuss how European cities have implemented smart water grids that incorporate real-time monitoring, water quality assessments, and data fusion for efficient water distribution. Similarly, Ye et al. (2016) describe China's application of smart metering and IoT in urban water management, which has improved both water conservation and pollution control. These cases demonstrate that a well-designed SWM system can significantly enhance water efficiency and sustainability. The practices from these cities provide valuable insights for Nusantara, where similar technologies can be adapted to address Indonesia's unique environmental and infrastructural challenges.

The concept of smart city development for Nusantara envisions SWM as central to sustainable urban infrastructure (de Vries, 2021; Husnah & Ichwan, 2023; Ramadhan et al., 2024). Studies by Rachmawati et al. (2022) emphasize that SWM systems, when integrated with digital platforms and ICT, can facilitate seamless water distribution and encourage conservation at the household and community levels. Moreover, the Indonesian government's blueprint for Nusantara includes features such as rainwater harvesting, greywater recycling, and eco-friendly wastewater treatment systems, which are expected to support a holistic approach to water management. These strategies aim not only to optimize water resource use but also to create a sustainable and resilient environment for residents. They align with the broader goals of achieving environmental resilience and reducing reliance on traditional water sources, making Nusantara a pioneering example of sustainable urban development in Indonesia.

Smart water management (SWM) is crucial for building efficient, resilient, and sustainable water systems, especially in fast-growing urban areas. In Nusantara, SWM technologies are being introduced to improve water quality, make better use of resources, and support the overall smart city vision. Here are some key features of SWM, along with detailed explanations and examples from recent studies:

1. Supervisory Control and Data Acquisition (SCADA) Systems
   SCADA systems are a core part of smart water management, allowing for real-time monitoring and control of water distribution and treatment processes. These systems collect data on water flow, pressure, quality, and consumption, enabling operators to make informed decisions quickly. Research by Gunther et al. (2015) shows that SCADA enhances resource efficiency by providing a comprehensive view of the water network, which helps identify issues like leaks or changes in water quality. In Nusantara, SCADA systems are essential for effective water distribution across urban and residential areas. For example, by monitoring water flow in real-time, SCADA can help prevent excessive water use and lower operational costs through optimized distribution.
2. Smart Water Metering
   Smart water meters are invaluable tools that allow both consumers and operators to track water usage in real-time. These meters provide detailed insights into consumption patterns, enabling households to manage their water use more effectively. For instance, Rifaid et al. (2023) explain how smart water meters can detect leaks or unusual usage, sending alerts to both users and system operators to help reduce water waste and avoid costly repairs. In Nusantara, integrating smart water metering into the city's smart infrastructure would empower residents to monitor their water usage and receive alerts about potential leaks. This aligns with Indonesia's goals of minimizing water waste and promoting conservation in urban areas.

3. Real-Time Water Quality Monitoring
   Real-time water quality monitoring systems use Internet of Things (IoT) sensors to measure important parameters like pH, temperature, turbidity, and pollutant levels. This technology allows for continuous assessment of water quality, ensuring that the water supplied to residents meets health standards. Research by Ye et al. (2016) highlights how these systems are vital in densely populated areas, where quick responses to contamination can prevent public health risks. For Nusantara, real-time water quality monitoring would provide immediate feedback to operators, allowing them to address potential issues before they impact residents. This proactive approach supports the city's goal of ensuring safe, high-quality drinking water for everyone.
4. Smart Wastewater Management Systems
   Effective wastewater management is a key aspect of smart water systems, especially in urban environments. Smart wastewater systems, supported by SCADA technology, monitor the flow, quality, and treatment of wastewater. They also incorporate features like greywater recycling and runoff management, which help reduce the pressure on local water sources (Allen et al., 2012). In Nusantara, smart wastewater management systems could enhance recycling and water conservation efforts. For example, greywater recycling could lessen the demand for freshwater by repurposing treated wastewater for landscaping or agricultural irrigation.
5. Flood Early Warning Systems
   Flooding is a major concern in Indonesia, making early warning systems (EWS) essential. These systems utilize IoT sensors, weather data, and predictive analytics to provide timely alerts about potential floods. Hernaningsih et al. (2023) emphasize that EWS can reduce the impact of floods on infrastructure and public health by facilitating timely evacuations and preparedness measures. For Nusantara, integrating a flood EWS with the smart water grid would enable city planners to monitor rainfall, river levels, and drainage capacities, ensuring a quick response to rising water levels. This system would enhance Nusantara's resilience to extreme weather, supporting the city's sustainable urban development goals. This paper explores the vital role of SWM in achieving Nusantara's smart city objectives. It provides a thorough review of the strategies and technologies needed for a sustainable urban water system. By examining how SWM aligns with the smart city concept, this study aims to offer practical insights for stakeholders committed to making Indonesia's new capital a model of sustainable urban development.

3. Methods

The research method uses a literature review, adopting from prior studies to investigate variables characteristics of smart water management such as smart water system, smart water network, smart water grid, and technology integration for developing conceptual design on the sustainable water management for the IKN (Nusantara Capital). The exploration of smart water management strategies will focus on the relationship between the planned water management system in IKN and the integration of smart technologies as a defining characteristic of a smart water management. The literature study will involve a comprehensive review of relevant documents and reports related to the IKN project. Key sources will include publications from Bappenas (National Development Planning Agency), the Nusantara Capital Authority, and the Ministry of Public Works and Housing. This review will provide insights into the planned strategies and goals for water management in IKN. Integration of Smart Technology: The study will specifically

explore how sustainable water management practices can be enhanced through the integration of smart technologies. This includes examining smart water management indicators that align with the broader objectives of the smart city concept. The analysis will focus on identifying innovative solutions that promote efficiency, sustainability, and resilience in water management. Expected Outcomes: By synthesizing the relevant information from the literature, this paper aims to generate a conceptual design for a sustainable water management system in IKN. The proposed design will incorporate indicators of smart water management, ensuring that the system not only meets the immediate needs of the community but also aligns with the long-term goals of sustainability and smart city development.

4. Results

The reviewed studies collectively emphasize the critical role of technology, sustainability, and collaboration in urban planning and resource management, particularly in the context of Indonesia's new capital city (IKN), Nusantara. Hernaningsih et al. (2023) highlight the potential of integrating 5G networks, 3D printing, and photovoltaic solar energy into IoT-based smart water management systems to enhance scalability, sustainability, and environmental benefits. Meanwhile, Arif & Toersilowati (2024) discuss the importance of capacity-building strategies and interorganizational collaboration for sustainable infrastructure development, offering insights into gamification in e-government and climate change resilience.

Anggraeni (2020) provide a conceptual framework for smart sustainable city planning in Nusantara, with a focus on balancing digital and green infrastructure, prioritizing green spaces, and disaster mitigation. Complementing this, Hernaningsih et al. (2023) propose an integrated Smart Water Management (SWM) framework featuring flood early warning systems and real-time water quality monitoring, which align with sustainability goals and address public health and disaster resilience.

Arif & Toersilowati (2024) demonstrate the effectiveness of artificial neural networks (ANN) and remote sensing data in predicting water availability, showcasing its application for sustainable urban planning. Similarly, Rachmawati et al. (2021) and Rifaid et al. (2023) highlight the integration of smart city concepts with urban governance to address environmental and social challenges while promoting sustainability. Their studies underscore the importance of using ICT, renewable energy, and predictive models for effective water and urban resource management. Permana & Harsanto (2020) focus on the relationship between public input and sustainable development, emphasizing the integration of smart and green city concepts in planning. They highlight the significance of public communication, comparative studies, and strategic financing approaches to ensure the success of IKN development. Collectively, these studies provide actionable insights for policymakers, urban planners, and stakeholders to align urban development with technological innovation and sustainability goals.

The development of a smart city in Nusantara is designed to prioritize advanced technology and sustainability principles. This strategy aims to enhance the quality of life for residents through the implementation of digital technologies in governance, infrastructure, and daily life. Its main focus includes developing smart infrastructure, efficient transportation, and technology-based living systems that support a safe, healthy, and comfortable urban environment. Additionally, this strategic framework is designed to attract investments by ensuring technology-driven economic growth and sustainable industrial practices. As part of this development, the use of generative AI becomes a critical pillar in urban risk management. This technology enables proactive data analysis to identify patterns and anomalies, allowing risks to be mitigated early. On the other hand, this approach

also serves as a strategic foundation for investing in and developing a more responsive smart city infrastructure that meets the needs of the community.

In terms of sustainability, the research highlights the importance of environmental protection and biodiversity conservation in the new capital in East Kalimantan. Infrastructure planning is designed with careful consideration of land carrying capacity and wildlife corridors to minimize ecological impacts. The Strategic Environmental Assessment (SEA) serves as a key tool to ensure that every stage of development aligns with sustainable development principles. Furthermore, various zones, such as residential, industrial, and infrastructure areas, are identified to have varying environmental impacts. Some areas, such as agricultural zones and public service centers, show minimal environmental impact, making them highly suitable for sustainable development. However, population density in core and buffer zones requires strategic management to prevent excessive strain on the environment.

5. Discussion

The Indonesian government's decision to relocate the capital from Jakarta to Nusantara stems from the need to address critical challenges such as congestion, environmental degradation, and recurring floods in Jakarta. Nusantara is envisioned as a sustainable and smart city, incorporating advanced infrastructure to support its growing population. A key feature of this vision is the establishment of a state-of-the-art water management system capable of providing clean, drinkable water to approximately 2.6 million residents by 2045. The government has set an ambitious target to ensure a water supply capacity of at least 9,300 liters per second, meeting the demands of both residential and business sectors.

To achieve this goal, the government has adopted a holistic approach to urban planning, integrating water management with land use, transportation, and environmental sustainability. This approach ensures that urban development is aligned with ecological preservation and efficient resource utilization. By prioritizing sustainability, Nusantara aims to set a benchmark for modern urban centers. The smart water management system in Nusantara is designed to revolutionize water distribution. It features a direct consumption water supply system that delivers potable water directly to households, eliminating the need for additional filtration or treatment. Advanced treatment facilities equipped with modern technologies will ensure water quality meets the highest standards, enhancing the health and well-being of residents.

A cornerstone of the city's infrastructure is the Multi Utility Tunnel (MUT), which enables the simultaneous installation of essential utilities such as water, electricity, and telecommunications. This innovative design minimizes surface disruptions, streamlines utility management, and enhances the overall efficiency of infrastructure operations. Incorporating real-time monitoring and management capabilities, the water distribution network will leverage sensors and IoT devices to track water quality, flow rates, and system performance. Data analytics will play a crucial role in optimizing water distribution, predicting demand, and identifying potential issues such as leaks or contamination. This proactive approach ensures a reliable and sustainable water supply for Nusantara's future.

To achieve the ambitious sustainability goals of Nusantara, Indonesia's new capital city, the integration of advanced technologies within water management systems is paramount. Nusantara's smart water management (SWM) solutions will utilize cutting-edge innovations such as IoT sensors, real-time monitoring systems, artificial intelligence (AI), and data analytics. These technologies aim to optimize water usage, enhance resilience against climate risks, and foster sustainable urban development, setting a benchmark for modern urban water management.

IoT sensors will play a pivotal role in monitoring the city's water infrastructure. Strategically placed across water sources, distribution networks, and treatment facilities, these sensors will continuously measure parameters like water quality, pressure, and flow rates. Real-time monitoring will enable the immediate detection of issues such as contamination or leaks, reducing water loss and ensuring a safe, reliable supply for residents. Additionally, Supervisory Control and Data Acquisition (SCADA) systems will provide centralized control, offering operators comprehensive insights into network performance. This data-driven approach will enhance operational efficiency, reduce environmental impacts, and align with the city's broader smart city objectives.

Artificial intelligence and predictive analytics will further elevate the city's water management capabilities. By analyzing historical and environmental data, AI will forecast water demand, anticipate equipment failures, and inform maintenance schedules. These predictive capabilities will enable proactive resource planning, preventing resource strain and supporting sustainable water allocation. Furthermore, the integration of smart meters in residential and commercial buildings will empower users to monitor their water consumption in real-time, promoting responsible usage and reducing overall demand.

Nusantara's SWM framework will also include a flood early warning system (EWS), utilizing IoT sensors, weather data, and predictive algorithms to provide real-time alerts. This system will enhance resilience against flood risks, enabling swift and coordinated responses to potential threats. Complementing these technologies are sustainable practices like greywater recycling and rainwater harvesting. These systems will capture, treat, and reuse water, significantly reducing reliance on primary water resources and ensuring water security during dry seasons. By integrating these advanced technologies, Nusantara's water management system will optimize resource use, reduce waste, and create significant economic efficiencies. Real-time monitoring and predictive analytics will enhance resilience to climate-related challenges, while smart metering will foster a culture of conservation among residents and businesses. As a result, Nusantara will establish itself as a model for sustainable urban water management, offering valuable lessons for other cities facing similar challenges.

6. Conclusion

The Indonesian government is actively advancing smart water management in Nusantara, prioritizing the integration of innovative technologies, collaborative partnerships, and sustainable practices. These efforts demonstrate a strong commitment to creating a resilient and efficient water management system, setting a precedent for sustainable urban development. By addressing current challenges and fostering innovation, Nusantara is poised to become a model for other cities in Indonesia and beyond, offering solutions for managing water resources amid growing urbanization and climate change. Collaboration with international stakeholders is a cornerstone of this initiative, aiming to integrate water management into broader urban planning frameworks while enhancing the city's resilience to climate change. International technical assistance and funding will play a critical role in supporting the development and implementation of advanced water management practices. Equally important is building local capacity through training programs that equip staff with the skills needed to manage and maintain smart water systems effectively.

Community engagement is essential for the long-term success of smart water initiatives in Nusantara. By educating residents about water conservation and sustainable practices, the government hopes to foster a culture of environmental responsibility. Infrastructure development also requires significant investment to upgrade existing systems and construct new facilities equipped with advanced

technologies. These developments must ensure resilience to environmental challenges, such as flooding and climate change, to safeguard the city's future.

A supportive regulatory environment is critical for encouraging innovation and investment in smart water management. Policymakers must also address data privacy and security concerns associated with IoT devices to build public trust and ensure widespread acceptance of new technologies. Continuous ecological monitoring will help protect local water sources and ecosystems, ensuring that water management practices align with environmental sustainability goals. Integrating advanced technologies such as artificial intelligence, machine learning, and blockchain will enhance data management and decision-making processes. A comprehensive data management platform will allow for better coordination among various utilities and stakeholders, streamlining efforts and maximizing efficiency. Additionally, sustainable practices like rainwater harvesting and wastewater recycling will contribute to the long-term sustainability of Nusantara, reinforcing its role as a leader in smart urban water management.

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