

**SMART ENVIRONMENT ROADMAP CONCEPT FOR THE CITY OF PANGKAL PINANG  
BASED ON LESSONS LEARNED FROM JAKARTA AND MAKASSAR**

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**ABSTRACT**

*This study develops a smart environment roadmap for Pangkalpinang by learning from the experiences of Jakarta and Makassar. Smart environment is positioned as a key pillar of smart city development because it supports sustainable management of air, water, waste, energy, and disaster risk. The research uses a qualitative descriptive approach with comparative case study design. Data are obtained from scientific literature, government documents, and official publications related to smart environment initiatives in the three cities, then analysed using content analysis and cross-case comparison. The findings show that Pangkalpinang is still at an early stage of smart environment development, characterised by limited digital infrastructure, fragmented environmental data, and low levels of digital participation. Jakarta represents a technology-driven model with strong data integration, while Makassar prioritises community participation and context-sensitive innovation. Based on these lessons, the study proposes a phased roadmap consisting of twelve programmes (EN15-1 to EN15-12) that gradually strengthen monitoring infrastructure, data integration, public awareness, smart waste management, smart energy, and coastal environmental monitoring. The roadmap is expected to guide local governments in planning realistic and sustainable smart environment development.*

*Keywords: Smart Environment; Smart City; Roadmap; Pangkalpinang; Comparative Study; Innovation*

## **INTRODUCTION**

A smart city is a concept of urban development that integrates information and communication technology to improve public services and the quality of life for citizens (Sofa, 2023). One of the key pillars in smart city development is the smart environment, which focuses on intelligent environmental management through technology, such as waste management, pollution control, flood control, energy efficiency, and environmental quality monitoring. The implementation of smart environment is becoming increasingly important as urbanization challenges such as pollution, waste accumulation, and degradation of green open spaces increase.

In Indonesia, smart environment development has begun to be implemented in various cities as part of the smart city initiative. In Jakarta, the city government has developed several environmental innovations, such as the Refuse Derived Fuel (RDF) waste processing facility in Bantargebang, a sensor-based flood and air quality monitoring system, and an environmental reporting service through the JAKI application. Although they are part of the Jakarta Smart City framework, these innovations are carried out through different programs and platforms according to their respective focuses.

On the other hand, Makassar City, through its Sombere and Smart City concept, has also implemented various smart environment programs, including digital waste management, green open space development, and environmental monitoring integrated with the city government's war room. These two cities demonstrate the application of the smart environment concept in an urban context in Indonesia, albeit with different approaches and priorities.

However, not all cities are equally prepared to adopt technology-based environmental innovations. The city of Pangkal Pinang, as the capital of the Bangka Belitung Islands Province, still faces various obstacles in developing a smart environment system. These challenges include suboptimal integration of environmental data, a lack of innovation in waste management, digital inequality between regions, and limited capacity of local government institutions (Bastian et al., 2022). This situation highlights the need to develop a targeted smart environment roadmap that is tailored to local needs in order to guide sustainable environmental transformation.

Based on these conditions, the problems addressed in this study include: (1) the current conditions and challenges of environmental management in Pangkal Pinang City; (2) lessons that can be learned from the implementation of smart environments in Jakarta and Makassar; and (3) a smart environment roadmap concept that is suitable for Pangkal Pinang City based on the local context and regional potential. These issues are important to examine because improving environmental quality requires not only technology, but also good governance, cross-sector collaboration, and policy sustainability.

With increasing environmental pressures due to population growth and urban activities, the development of a smart environment roadmap concept has become urgent for Pangkal Pinang City. This study aims to formulate a smart environment roadmap concept that is relevant to Pangkal Pinang by adapting best practices from Jakarta and Makassar and adjusting them to the characteristics of the region.

## **LITERATURE REVIEW**

### **The Relationship between the Concepts of Smart City and Smart Environment**

A smart city is a concept of urban development that integrates information and communication technology to improve the quality of public services and community welfare (Sofa, 2023). In this context, smart cities not only focus on the digitization of services, but also on improving efficiency, transparency of governance, and social, economic, and environmental sustainability. In various countries, including medium-sized cities facing the pressures of urbanization but with limited resources, smart city development is based on six main dimensions, namely smart governance, smart people, smart mobility, smart environment, smart economy, and smart living.

Among these six dimensions, smart environment occupies a strategic position because it contributes directly to maintaining the ecological sustainability of cities. Smart environment emphasizes technology-based environmental management, which includes pollution reduction, efficient waste management, natural resource protection, flood mitigation, and real-time air quality monitoring. According to Mohanty (2016), IoT sensors, data analytics, and digital platforms are the main foundations for the implementation of a modern smart environment. This is in line with international standards such as ISO 37122, which states that the success of a smart environment is determined by the integration of environmental data, automatic monitoring capabilities, and the

existence of an early warning system that assists in the decision-making process (International Organization for Standardization, 2019).

Therefore, a smart environment is not only one element of a smart city, but also a pillar that ensures that cities can grow sustainably, adapt to environmental risks, and be more resilient in facing the challenges of climate change and urbanization.

### Implementation of Smart Environment in Jakarta and Makassar

Jakarta is one of the most advanced cities in Indonesia in terms of implementing a smart environment. Through Jakarta Smart City (JSC), the government is building a digital ecosystem that includes a data integration center, a sensor-based flood monitoring system, and the JakISPU air quality information service (Syalianda & Kusumastuti, 2021). In addition, waste management is being directed through the Refuse Derived Fuel (RDF) facility in Bantargebang, which converts waste into alternative energy, thereby reducing dependence on conventional landfills (Resmianty et al., 2022). This is supported by a citizen reporting channel through the JAKI application, which helps accelerate the response of relevant agencies.

Unlike Jakarta, the city of Makassar stands out with its Sombere and Smart City approach, which combines digital innovation with local cultural values. The implementation of a smart environment in Makassar is realized through the Makassar War Room as an environmental monitoring center, the digitization of the waste system, the development of green open spaces, and technology-based emergency services such as NTPD 112 (Alfian & Margono, 2023). This approach places the community as key actors in environmental monitoring, making citizen participation the foundation for the success of the smart environment program and demonstrating that even medium-sized cities can build smart environments through the integration of technology that is in harmony with the local socio-cultural context (Setiawan et al., 2025).

**Table 1. Comparison of Smart Environment Implementation Between Jakarta and Makassar**

Aspect	Jakarta	Makassar
Key Approaches	High-tech approach and data integration through Jakarta Smart City (JSC)	Sombere and Smart City approach that combines digital innovation with local cultural values
Control Center/ Monitoring	Jakarta Smart City data integration center that manages flood sensors and environmental dashboards	Makassar War Room as a center for monitoring the environment and city activities
Environmental Monitoring	Flood monitoring sensors and JakISPU air quality information displaying real-time data	Application-based waste monitoring system and NTPD 112 environmental emergency services
Community Involvement	The JAKI app as a channel for citizens to report issues related to cleanliness, flooding, and environmental quality	Active community involvement in environmental monitoring supported by the Sombere socio-cultural approach
Waste Management	The Bantargebang Refuse Derived Fuel (RDF) facility, which converts waste into energy, and the digitization of sanitation reporting	Digitization of waste management systems and development of green open spaces to improve environmental quality
Innovation Characteristics	Strengthening digital infrastructure, using environmental sensors, and integrating large-scale data	Technology tailored to the needs of medium-sized cities and emphasizing social proximity
Key Strengths	Robust environmental data integration, real-time monitoring, and high-tech solutions	High level of community participation, application of appropriate technology, and flexibility of implementation

The literature shows that there is no single smart city model that fits all cities. Instead, adaptation based on context, capacity, and community characteristics is required (Tan & Taihigh, 2020). Jakarta provides an example of strong smart environment development in terms of technology and data integration, while Makassar presents a human-centered model that emphasizes social collaboration. The combination of these two approaches can serve as a strategic learning foundation for other cities that want to gradually build a smart environment roadmap. For the city of Pangkal Pinang, Jakarta and Makassar are two complementary references for creating a realistic hybrid model that is tailored to the region's capacity.

### Pangkal Pinang as a Smart City Candidate

The challenges faced by the city of Pangkalpinang include waste management, which still uses conventional methods (collection, transportation, and disposal to the Parit Enam landfill, which has exceeded its capacity), as well as limited facilities, infrastructure, and local government institutional capacity to handle the volume and complexity of waste issues (Arkum et al., 2023). These challenges often result in delays in the implementation of environmental monitoring systems, a lack of innovation in waste management, and minimal adoption of technology by the community. Therefore, the smart environment model that is implemented must take into account the readiness of resources and local adaptation capabilities.

Pangkal Pinang City has the potential as a medium-sized city that can develop a smart environment through a phased approach. The implementation of SPBE and the Satu Data Indonesia program shows initial efforts to strengthen data-based governance. However, challenges such as suboptimal data integration, limited digital infrastructure, and low community participation indicate the need for a more focused strategy (Bastian et al., 2022). Lessons learned from Jakarta can help Pangkal Pinang strengthen its technology and digital infrastructure, while lessons learned from Makassar can support the strengthening of social and participatory aspects. Thus, these two cities serve as strategic references in formulating a relevant and sustainable smart environment roadmap for the city of Pangkal Pinang. In summary, Pangkal Pinang needs to build an integrated data system, environmental sensors, and reporting applications, as well as adapt technology to the local context and increase community participation.

### RESEARCH METHODS

Based on the results of the analysis of the Smart Environment conditions in Pangkalpinang City, comparisons with Jakarta and Makassar, and the key lessons learned outlined above, a Smart Environment development roadmap has been compiled and translated into a series of priority programs. This roadmap is designed to bridge the gap between existing capacity and ideal conditions through stages of strengthening sensor infrastructure, integrating environmental data, improving digital literacy, and utilizing smart technology more comprehensively. Table 2 below presents a series of programs EN15-1 to EN15-12, which include objectives, success indicators, implementing parties, cooperation partners, and implementation timelines as the basis for the operationalization of Smart Environment development in Pangkalpinang City.

**Table 2. Smart City Roadmap Concept**

ID	Program	Sub Program	Target	Success Indicators	Implementers	Cooperation	Timeline	Program Code
EN15-1	Environmental Monitoring Technology Development Program (strengthening city sensor infrastructure)	Construction of 8 water and air sensor stations (real-time environmental quality monitoring)	Improving the water and air monitoring system	Air and water quality indices improved	DLH, Dinkes	Campus & Lab	2022-2025	Environmental Pollution Control
EN15-2	Urban Air Quality Monitoring Program (industrial and transportation emissions monitoring)	Monitoring of 4 industrial/transportation points (identification of pollution sources)	Improving air quality	Decrease in pollution index	DLH, Dinkes	Higher Education Institution	2022-2025	Pollution Control
EN15-3	Municipal Water Quality Monitoring Program (river/lake monitoring)	City Water Quality Monitoring Program (river/lake monitoring)	Improving water quality	Water quality index improves	DLH	Lab & Campus	2022-2025	Water Pollution
EN15-4	Environmental Education and Awareness Program (strengthening an environmentally friendly culture)	Public campaign on clean air and water (public education)	Increasing public awareness	Community participation increases	DLH	Community	2022-2025	Environmental Education
EN15-5	Integrated Monitoring System Program (integration of water, air, and waste sensors)	IoT integration for environmental dashboards (single-source data)	Monitoring real-time	Active & integrated dashboard	DLH, Kominfo	IoT Campus	2022-2026	Integrated Monitoring
EN15-6	Early Warning System Program (reducing the risk of flooding/tidal)	Early Warning System - High water & rainfall sensors	Disaster risk reduction	Increased warning speed	BPBD, DLH	BMKG	2022-2026	Disaster Mitigation

waves)								
EN15-7	Smart Green Open Space Program (technology-based green space)	Green space with air quality & heat sensors	Improving the quality of green open spaces	Percentage of green open space	DLH	Green Community	2022-2027	Urban Green Space
EN15-8	Smart Waste Management Program (IoT-based waste management)	Waste volume sensor + truck route optimization	Waste transport efficiency	Decrease in time & cost	DLH, Kominfo	Startup Waste Tech	2022-2027	Waste Management
EN15-9	Smart Energy Government Program (energy efficiency in government buildings)	Electricity smart meters & energy monitoring	Energy efficiency	Decrease in electricity consumption	PUPR	PLN	2022-2028	Energy Efficient
EN15-10	Smart Mobility Environment Program (low-emission transportation)	Digital emissions testing & CO <sub>2</sub> sensors	Reduction in vehicle emissions	CO <sub>2</sub> reduction	Dishub	Motorcycle Repair Shop & Community	2022-2026	Green Transportation
EN15-11	Coastal Smart Water Quality Program (marine and coastal monitoring)	Seawater & coastal sensors for fishermen	Water quality improves	Pollutant reduction	DLH	Fishermen & Campus	2022-2027	Clean Coast
EN15-12	Environmental Data Hub Program (city environmental data portal)	Data integration of air-water-waste-energy	Single-window data	Active web-based dashboard	DLH, Kominfo	Startup Data	2022-2028	Environmental Digital Transformation

## RESULTS AND DISCUSSION

### Analysis Results

#### Smart Environment Conditions in Pangkalpinang City

Based on the results of literature analysis, the Smart Environment conditions in Pangkalpinang City indicate that digital and institutional capacity are still in the early stages of development. Environmental data integration is not yet optimal because the air, water, and waste quality monitoring systems are not yet connected to a single integrated platform. Community reporting is still done manually, so the response to environmental risks is slower than in cities that have implemented digital systems. In addition, waste services have not yet utilized technologies such as waste volume sensors or route optimization. In general, these conditions indicate that the technological foundation and community participation need to be strengthened before Pangkalpinang can comprehensively implement a Smart Environment system.

#### Comparison Results for Jakarta and Makassar

A comparison with two reference cities, Jakarta and Makassar, shows differences in the approach to implementing Smart Environment. Jakarta implements a high-tech strategy, including the use of flood sensors, real-time air quality sensors, waste treatment facilities through RDF, and environmental data integration through Jakarta Smart City. Meanwhile, Makassar adopts an approach that is more oriented towards community involvement, community-based waste digitization, and the use of the Makassar War Room as a center for monitoring city activities. These differences in approach illustrate that Smart Environment can be developed through various models, both those focused on technology and those emphasizing public participation.

#### Key Lessons for Pangkalpinang

The comparison results provide several key lessons for Pangkalpinang. From Jakarta, there are lessons on the importance of environmental data integration, the application of air and water quality sensors, and a centralized dashboard-based rapid response mechanism. Meanwhile, from Makassar, the main lessons relate to community involvement, the use of appropriate technology, and the development of environmental monitoring that adapts to local socio-cultural conditions. A combination of these two approaches can serve as a basis for Pangkalpinang to gradually adapt its Smart Environment roadmap in line with its fiscal capacity, institutional framework, and the level of digital literacy among its citizens.

## **Discussion**

### **Analysis of Smart Environment Gaps in Pangkalpinang**

A comparative analysis between Pangkalpinang and Jakarta and Makassar shows a fundamental gap in infrastructure readiness and environmental governance. Jakarta, for example, has adopted Internet of Things (IoT)-based flood and air quality monitoring technology that is integrated with the city's data platform (Farabi & Sintawati, 2024). Waste management is also being directed through Refuse Derived Fuel (RDF) facilities and the Jakarta Recycle Center (JRC) as part of the smart environment strategy (UPST DLH DKI Jakarta, 2021). Makassar, through the development of the War Room, the Makassar Tidak Rantasa (MTR) application, and the digital waste bank system, emphasizes city monitoring and environmental cleanliness based on community participation (Nasir, 2025). In contrast, Pangkalpinang still relies on a conventional monitoring system without the support of real-time sensors, citizen reporting applications, or an integrated environmental dashboard. Low public participation is also influenced by the lack of easily accessible digital platforms and the absence of environmental data integration that can support local government decision-making (Nasir, 2025).

This gap confirms that Pangkalpinang is still in the early stages of developing a smart environment. This is in line with the findings of Viale Pereira and Schuch de Azambuja (2021), who emphasize that a sustainable smart city roadmap needs to begin with strengthening technical foundations, infrastructure, and institutional capacity so that digital transformation has a long-term impact. Purnomo et al. (2020) also show that the smart environment dimension is only effective when integrated with good environmental management and community involvement.

Other studies provide additional support. Fatimah et al. (2020) emphasize the need for digitizing waste management and utilizing Industry 4.0 technology to create efficiency and sustainability in waste management systems in Indonesian cities. On the other hand, Tulungen and Batmetan (2022) assert that developing cities need to prioritize smart environment strategies that are simple, adaptive, and appropriate to local capacities, especially in terms of digital literacy and community participation.

With reference to this view, Pangkalpinang's roadmap needs to be designed in a gradual and contextual manner. A number of studies emphasize that sustainable urban planning must balance technological capacity, institutional and social readiness, and local needs in order for transformation to take place effectively. Therefore, Pangkalpinang's initial priorities should focus on developing sensor infrastructure and environmental monitoring systems, integrating cross-sector data, and improving digital literacy and citizen participation capacity before entering the advanced stages of smart analytics and data-based environmental monitoring.

### **Relevance of the Roadmap Program (EN15-1 to EN15-12)**

The programs in Table 2 are arranged in stages and reflect realistic developments for implementation in Pangkalpinang. The initial stage (EN15-1 to EN15-4) focuses on installing water and air quality sensors and educating the community, which are basic requirements for increasing awareness and digital readiness. The integration phase (EN15-5 to EN15-7) begins to focus on the development of an integrated dashboard and technology-based green open spaces, drawing lessons from Jakarta's strengths in data integration and Makassar's approach to strengthening local values. The advanced stage (EN15-8 to EN15-12) includes the development of smart waste and smart energy systems, coastal monitoring, and an Environmental Data Hub, which serves as the foundation for a long-term and sustainable Smart Environment. The sequence of these stages shows a structured roadmap that is in line with the region's capacity.

### **Alignment of the Roadmap with the Problem Statement**

All of the analysis results in the journal successfully answered the proposed problem statements. The first problem statement regarding the conditions and challenges in Pangkalpinang was answered through the identification of the Smart Environment gap. The second problem statement about learning from Jakarta and Makassar was also answered through comparative analysis. The third problem statement, namely the preparation of a Smart Environment roadmap, was realized through a series of programs EN15-1 to EN15-12, which were prepared in stages. Thus, the research was able to provide comprehensive, structured solutions that can be used as a basis for local governments in planning the implementation of Smart Environment.

## CONCLUSIONS

Based on the results of the analysis of existing conditions, comparisons with Jakarta and Makassar, and the formulation of programs EN15–1 to EN15–12, it can be concluded that Pangkalpinang has both opportunities and challenges in developing a smart environment. The city is still in its early stages, with limited digital infrastructure, environmental data integration, and community participation, requiring a realistic, step-by-step strategy that is appropriate to local capacity. Lessons learned from Jakarta emphasize the importance of data integration and the use of sensor technology for real-time monitoring of water quality, air quality, waste, and flooding, while Makassar's experience shows that the success of a smart environment is also largely determined by its proximity to the socio-cultural context and the active involvement of citizens. The proposed roadmap addresses the three research questions by providing a structured development direction, starting from strengthening the monitoring system and public education to integrating environmental dashboards and data-based energy and coastal zone management. Consistent implementation of this roadmap is expected to not only improve environmental quality and urban resilience but also strengthen collaborative governance between the government, community, universities, and technology partners in realizing Pangkalpinang as a candidate for a sustainable smart city.

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