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E-B Environment - Behaviour Proceedings Journal

ARCADESA2024Yogyakarta

https://arcadesa.isi.ac.id/index.html

8th Art, Craft and Design in Southeast Asia International Symposium

ISI Yogyakarta Indonesia, 27-28 September 2024

Organised by: Institute Seni Indonesia, Yogjakarta, Indonesia

e-IPH e-International Publishing House Ltd., United Kingdom

Future of Waste Bin Design in the Age of Automation in Indonesia

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Abstract

Due to ongoing waste management issues, the Indonesian government is promoting Industry 4.0 technologies to enhance productivity and efficiency, focusing on waste bin design. This research investigates whether Indonesia is ready for automation technology in waste bin and waste management systems or if it remains a distant goal. The study identifies key elements and challenges through a comprehensive literature review and systematic screening, including infrastructure limitations, technological readiness, and socio-economic factors. The findings provide insights and guidelines for future efforts toward achieving efficient, sustainable waste management solutions through automation in Indonesia.

Keywords: Automation; waste bin; Indonesia

DOI: https://doi.org/10.21834/e-bpj.v9iSI23.6180

1.0 Introduction

The future of waste bin design in Indonesia is advancing towards automation and integrating Internet of Things (IoT) systems, aiming to improve waste management efficiency, cut costs, and enhance sustainability. Smart trash bins are a crucial development in this area. These bins have sensors and IoT connectivity, allowing them to monitor waste levels and weights in real time, facilitating efficient waste collection and management. This technology is essential in reducing the cost of waste separation and enhancing the overall efficiency of waste management in smart cities (Huh et al., 2021; Manik et al., 2024).

Another significant innovation is the development of automatic trash cans, such as those based on Arduino Uno. These cans are designed to detect and segregate various types of waste, contributing to sustainable development goals. They can manage different amounts of waste and use actuators to open containers based on sensor data. Moreover, they often include additional features like integrated hand sanitizer dispensers to promote hygiene (Aqilah et al., 2021).

Automating waste management has implications for employment, potentially displacing specific jobs while creating new opportunities. The rise of the gig economy and online commerce in Indonesia is expected to generate new job opportunities. Implementing automation technologies can result in a net gain in employment, especially in emerging and evolving sectors (Agarwal, 2019).

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The Indonesian government is actively working towards transforming the country into an Industry 4.0 economy, which encompasses the adoption of advanced technologies such as automation and IoT. This initiative aims to boost productivity, foster GDP growth, and create jobs while addressing the challenges posed by job displacement (Agarwal, 2019).

The future of waste bin design in Indonesia is closely tied to integrating automation and IoT technologies, which still need to be built. The key challenges are community engagement, education, government support, and policy (Fei et al., 2024; Saffa, 2024). Only now does Indonesia have a littering policy, but it is never really implied in everyday life because of the low execution rate by the local government. Even though this technology integration promises to improve waste management efficiency, support sustainability efforts, and generate new job opportunities while navigating the complexities of economic and employment transformation, Indonesia will need to work hard to make it a dream come true.

This study aims to assess Indonesia's readiness for adopting automation in waste management, focusing on smart bin designs. It identifies key challenges—technological, infrastructural, and socio-economic—and offers recommendations to fast-track sustainable, automated solutions. The research provides insights into how automation can improve efficiency and sustainability while addressing socio-political and economic barriers.

2.0 Literature Review

2.1 Industry 4.0 Technologies in Waste Management

Integrating Industry 4.0 technologies, particularly automation, and IoT, is transforming waste management globally. Smart waste bins are crucial to this transformation, leveraging advanced technologies to enhance waste management efficiency, reduce environmental pollution, and promote sustainable urban development.

Smart waste bins use various technologies such as sensors, microcontrollers, and IoT connectivity to monitor waste levels, detect the type of waste, and facilitate real-time data transmission. These bins can perform functions like waste sorting, remote control, voice recognition, capacity monitoring, wet and dry separation, and sensor-activated lids, making them highly efficient and practical (Fei et al., 2024).

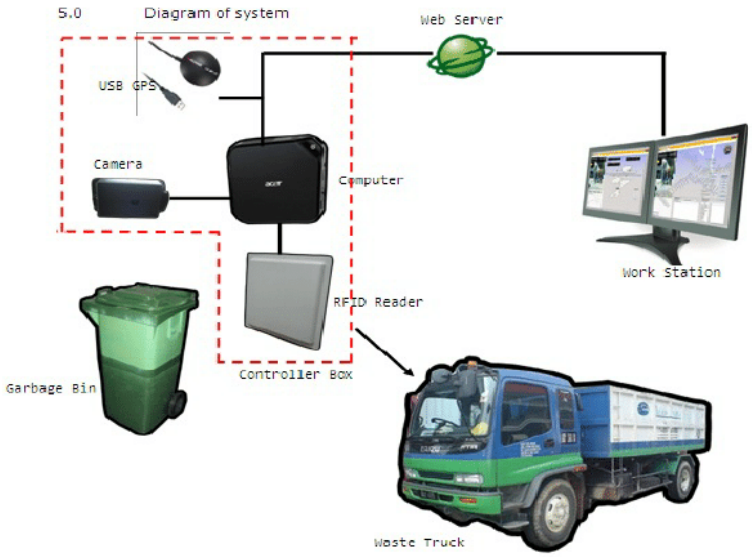

Fig. 1: Illustration of waste bin monitoring using IoT (Internet of Things)
(Source: https://www.researchgate.net/figure/System-Architecture-of-Waste-Bin-Monitoring_fig4_233398879)

2.2 Case Studies from Other Countries

Singapore has successfully integrated smart waste bins with its existing waste management system. This integration ensures that data from the smart bins is seamlessly transmitted to the central management system, enhancing the efficiency and effectiveness of waste collection and management (Fei et al., 2024).

Similarly, South Korea has implemented smart waste bins that utilize IoT technology to monitor waste levels in real-time. This data is then analyzed to optimize waste collection routes and reduce the frequency of emptying bins, thereby improving efficiency and reducing costs. In the United States, smart waste bins equipped with sensors monitor waste levels and detect the type of waste. This system helps reduce the cost of trash separation work and improve overall waste management efficiency (Fei et al., 2024).

Fig. 2: An example of using IoT (Internet of Things) in waste management in South Korea is installing wirelessly connected fill-level sensors in their waste containers. *(Source: https://www.ecubelabs.com/iot-waste-management-detect-a-full-trash-can-remotely/)*

Fig. 3: BigBelly Waste bin in Singapore will send alerts for them to be cleared when they are almost complete.
(Source: https://www.straitstimes.com/singapore/solar-powered-smart-bins-that-act-as-wi-fi-hotspots-launched-at-orchard-road)

2.3 Current State of Waste Management in Indonesia

Indonesia faces significant challenges in waste management due to rapid urbanization and increased waste generation. The current practices often involve manual sorting and collection, which could be more efficient and prone to errors. Organic waste is the most common type of garbage in Yogyakarta, accounting for 50.21% of total waste (Fei et al., 2024).

The Indonesian government has implemented various policies and initiatives to address these challenges and improve waste management. These include mandatory household waste sorting and efforts to promote sustainable urban development. However, the coverage of smart waste management technologies remains limited, and the degree of automation could be higher, with manual sorting still dominating the waste management practices (Okubanjo et al., 2024).

Fig. 4: Bina Bangsa Elementary School (Jakarta, Indonesia) Projects are being done to prototype an smart waste bin using both.
(Source: https://zone.binabangsaschool.com/projectfair/portfolio/automated-trash-bin-with-uv-disinfection-prototype/*)*

2.4 Challenges and Barriers

Indonesia faces significant challenges ensuring reliable network connectivity, particularly in rural areas. Implementing smart waste bins will require robust and widespread network infrastructure to support real-time data transmission and monitoring (Fei et al., 2024). While Indonesia is actively exploring and implementing automation and IoT technologies in waste management, areas still need further exploration. Real-time monitoring, cost-effectiveness, and user interaction experience require further refinement and innovation (Wijaya et al., 2017).

Educating the community about the benefits and proper use of smart waste bins is crucial for their acceptance and successful implementation. Leveraging existing community engagement programs and educational initiatives can promote the adoption of smart

waste bins (Wijaya et al., 2017). Indonesia is making significant strides toward adopting automation technology in waste bins and management systems. However, the country still faces infrastructure, technological readiness, and socio-economic challenges. By addressing these challenges and leveraging successful case studies from other countries, Indonesia can effectively integrate smart waste bins into its waste management systems, improving efficiency, reducing costs, and promoting sustainable waste management practices.

3.0 Methodology

The research design includes a comprehensive literature review to gather and analyze existing studies, articles, and reports on waste bin design, automation, and waste management in Indonesia and other countries. This approach allows for an in-depth understanding of the current state of waste management, the challenges faced, and the potential solutions. The literature review method is justified because it provides a broad and in-depth understanding of the topic, enabling researchers to identify gaps in knowledge and areas needing further investigation. Academic articles, government reports, and case studies were analyzed. Data focused on smart waste bin design, implementation, impact, and efficiency. Exclusion criteria included non-peer-reviewed or theoretical studies.

The data analysis methods include content analysis and spatial analysis. Content analysis involves systematically analyzing the content of the literature to identify themes related to smart waste bin design, automation, and waste management. Spatial analysis is used to analyze the spatial distribution of waste bins and the impact of smart waste bins on waste management efficiency in urban environments (Prastyabudia & Permatab, 2021)

4.0 Findings

4.1 Implementing smart waste bins in Indonesia

Implementing smart waste bins in Indonesia involves several costs, including initial investment, maintenance, and operational expenses. These costs are critical to consider for successful implementation and long-term sustainability. The initial investment encompasses the cost of purchasing and installing smart waste bins, which include sensors, microcontrollers, and network infrastructure. This also covers the expenses for load cells, RFID tags, and other components necessary for real-time monitoring and data collection (Wijaya et al., 2017). Additionally, network connectivity costs are another significant factor, as IoT devices such as LoRa gateways and sensors are essential for transmitting data from the waste bins to the central management system, adding to the initial investment (Azahra et al., 2023; Hanafi et al., 2024).

Training citizens and waste management personnel on smart waste bin usage and maintenance is crucial but costly (Febria et al., 2023). Government support and policy development are essential but require significant investment (Wijaya et al., 2017). Ongoing operational costs, such as energy consumption, add to the overall expenditure.

4.2 Implementing smart waste bins in Indonesia faces several interconnected challenges that must be addressed for successful and sustainable integration.

A major hurdle is ensuring reliable and widespread network connectivity, particularly in rural and remote areas. This connectivity is crucial for effective data transmission and real-time monitoring of waste bins, laying the foundation for the system's functionality and efficiency (Manik et al., 2024). However, the cost and financial sustainability of these systems present significant barriers. The initial investment in smart waste bin infrastructure and ongoing maintenance expenses can be substantial, potentially deterring local governments and communities from adopting the technology (Mousavi et al., 2023).

Adoption and user acceptance are critical to the system's success. Changing citizens' habits to use smart waste bins and ensuring their acceptance of new technologies can be challenging, especially in regions where traditional waste management practices are deeply rooted (Mohammed et al., 2022). This challenge is compounded by the complexity of integrating smart waste bins with existing waste management systems. Significant modifications to the current infrastructure may be required to ensure seamless data exchange and effective operation, adding another layer of complexity to the implementation process (Wijaya et al., 2017).

Data security and privacy also emerge as crucial concerns. Protecting data collected from smart waste bins, susceptible information such as waste composition, and resident data is essential to maintaining public trust and compliance with regulations (Hanafi et al., 2024). Furthermore, the maintenance and repair of smart waste bins, including sensor calibration and replacing faulty components, can be particularly challenging in areas with limited maintenance resources and technical expertise (Mohammed et al., 2022).

Encouraging behavioral change among citizens to segregate waste properly and use smart waste bins correctly requires continuous education and motivation. This slow and demanding process is vital for the long-term success of smart waste management systems. Securing government support and policy backing is equally crucial. Government involvement can provide the necessary funding, regulatory framework, and incentives to promote these systems' adoption and integration (Mohammed et al., 2022).

5.0 Discussion

5.1 Lessons Learned from Successful Cases

Comparing the future of waste bin design in the age of automation in Indonesia with successful cases from other countries can provide valuable lessons and insights for its implementation in Indonesia. Lessons learned from successful cases highlight several vital aspects.

First, the integration with existing systems is crucial. Singapore has successfully integrated smart waste bins with its existing waste management system. This integration ensures that data from the smart bins is seamlessly transmitted to the central management system, enhancing the efficiency and effectiveness of waste collection and management (Okubanjo et al., 2024). Real-time monitoring and data analysis are also essential components. South Korea has implemented smart waste bins that use IoT technology to monitor waste levels in real time. This data is then analyzed to optimize waste collection routes and reduce the frequency of emptying waste bins, thereby improving efficiency and reducing costs (Huh et al., 2021).

Sustainability and cost-effectiveness are vital considerations as well. The United States has implemented smart waste bins that use sensors to monitor waste levels and detect the type of waste. This system helps reduce the cost of trash separation work and improve overall waste management efficiency. Such systems can be adapted to the Indonesian context to achieve similar benefits. Moreover, community engagement and education play a significant role. New York City (NYC) has successfully implemented smart waste bins that include features like sensors and RFID tags. These bins are designed to engage the community and educate residents about proper waste disposal practices. Similar initiatives can be implemented in Indonesia to promote sustainable waste management practices and community involvement (Huh et al., 2021). By learning from these successful cases, Indonesia can effectively navigate the challenges and leverage the opportunities that automated waste bin design presents.

5.2 Applicability to the Indonesian Context

The applicability of smart waste bin implementation in the Indonesian context requires careful consideration of several vital factors. One of the primary challenges is infrastructure and network connectivity. Indonesia needs help in ensuring reliable network connectivity, especially in rural areas. A robust and widespread network infrastructure is necessary to implement smart waste bins effectively to support real-time data transmission and monitoring (Okubanjo et al., 2024).

Cost and financial sustainability also significantly impact the successful deployment of smart waste bins. The initial investment in smart waste bin infrastructure and ongoing maintenance costs can be considerable. Therefore, Indonesia must evaluate the financial sustainability of these systems and explore cost-effective solutions, such as utilizing low-cost sensors and protocols like LoRa (Azahra et al., 2023; Hanafi et al., 2024).

Community acceptance and education are crucial for successfully implementing smart waste bins. Educating the community about these bins' benefits and proper usage is essential for their acceptance. Indonesia can leverage existing community engagement programs and educational initiatives to promote the adoption of smart waste bins (Wijaya et al., 2017).

Government support and policy backing are also vital. Securing government support and establishing regulatory frameworks and incentives are essential for successfully implementing smart waste bins. Indonesia can learn from successful cases in other countries where governments have been pivotal in promoting smart waste management systems (Okubanjo et al., 2024).

By drawing lessons from successful implementations in other countries, Indonesia can effectively integrate smart waste bins into its waste management systems. Key focus areas include ensuring robust network connectivity, considering financial sustainability, promoting community acceptance through education, and securing government support and policy backing. Addressing these challenges will enable Indonesia to improve the efficiency of its waste management systems, reduce costs, and promote sustainable waste management practices.

5.3 The future research directions for the future of waste bin design in the age of automation in Indonesia

Real-time monitoring and data analysis are crucial for optimizing waste collection. Accurate and reliable data from smart waste bins can optimize routes and reduce bin emptying frequency. Improving bin design and functionality is essential for cost-effectiveness and user satisfaction (Wijaya et al., 2017). Seamless integration with existing waste management systems is critical for efficient operations. Effective community engagement is vital for widespread adoption.

Smart waste bins must be adaptable to various environments and waste types. Advancements like deep learning and image recognition can enhance functionality. Integrating sensors, IoT, and AI can optimize waste management processes. Remote monitoring and control can increase efficiency. Developing advanced sorting and classification systems will improve accuracy (Fei et al., 2024). User-friendly interfaces and scalability are essential for broader adoption. By addressing these areas, the future of waste bin design in Indonesia can be significantly improved, leading to more efficient and sustainable waste management.

6.0 Conclusion and Recommendations

Smart waste bins hold immense potential for transforming waste management in Indonesia. While the country has made strides, it still lags in automation technology compared to global leaders like Singapore and South Korea.

Indonesia must develop efficient and sustainable waste management systems to bridge this gap. This involves overcoming infrastructure, technological, and socioeconomic challenges. By investing in robust network infrastructure, exploring cost-effective solutions, and promoting public awareness, Indonesia can accelerate the adoption of smart waste bins. Promoting community engagement and education is vital for acceptance and effective implementation. Strong government support is essential to drive this

transition. By aligning with global advancements and addressing local specificities, Indonesia can create a cleaner and more sustainable future.

However, this study acknowledges limitations, such as the need for localized data on smart bin adoption and potential cost barriers for implementation in less developed areas. Additionally, the research primarily focuses on urban settings, leaving rural waste management issues underexplored.

Paper Contribution to Related Field of Study

This research advances innovative waste management by analyzing Indonesia's smart waste bin implementation potential. It identifies challenges, quantifies costs and benefits, and develops a framework for successful deployment.

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