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Analysis of the Operational Performance of TPS 3R and its Development Potential Towards Indonesia's Zero Waste 2050 Target

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ABSTRACT

Waste management remains a major challenge in Indonesia, requiring innovative and sustainable solutions to achieve the national goal of Zero Waste by 2050. One strategic approach is the development of Reduce, Reuse, Recycle Waste Processing Sites (TPS 3R), which aim to reduce the volume of waste disposed of in final landfills (TPA). This study analyzes the operational performance of TPS 3R and explores their potential to enhance waste management efficiency. A mixed-methods approach was employed, combining quantitative analysis of TPS 3R operational data with qualitative insights gathered through interviews with TPS 3R managers, government officials, and community members. The findings reveal that TPS 3R operations face key challenges, including limited funding, underdeveloped regulatory frameworks, and low community participation in waste sorting activities. To address these issues, this study proposes strategic recommendations to strengthen TPS 3R effectiveness through policy enhancement, increased financial support, and optimized waste processing technologies. With proper implementation, TPS 3R holds significant potential to serve as a cornerstone in achieving Indonesia's Zero Waste 2050 vision.

Keywords: TPS 3R, Recycling, Circular Economy, Zero Waste Indonesia 2050

INTRODUCTION

Indonesia is navigating a significant challenge in waste management, driven by rapid urbanization and a growing population (Wikurendra et al., 2024). According to the Ministry of Environment and Forestry (2023), the country generates approximately 33.67 million tons of waste annually. This waste is primarily composed of 60–70% organic material and 30–40% inorganic material. As global waste production continues to rise, its associated negative impacts—such as climate change—have become increasingly urgent. The World Bank warns that, without immediate intervention, global waste generation could increase by 70% by 2050 (Tong et al., 2021).

To address this pressing issue, Indonesia has implemented several innovative strategies, one of which is the development of Reduce, Reuse, Recycle Waste Processing Facilities (TPS 3R). Initiated by the Ministry of Public Works and Housing, TPS 3R aims to manage waste independently at the village or sub-district level, reducing the volume sent to final disposal sites (TPA) through the application of 3R principles (Yulda, Nurcihikita, & Efriyandi, 2024). In addition to delivering clear environmental benefits, TPS 3R also holds substantial socio-economic potential. A case study at TPS 3R Bungo Lintas showed an operational efficiency increase from 58.3 % in 2021 to 61.1 % in 2023, with a positive cost–benefit ratio indicating real economic value (Yulda et al., 2024). Community-based TPS 3R facilities have generated new employment opportunities in the waste management sector and

lowered operational costs for local governments by enabling local processing and recycling (Trihadiningrum, Sunaryo, & Dhokhikah, 2017). Moreover, environmental communication strategies—such as socialization and collaboration—enhanced public awareness and participation in sustainable waste practices (Mamangan Journal, 2024). In Sleman Regency, TPS 3R units also demonstrated improved waste segregation and easier processing, contributing further to circular economy goals (ScienceDirect case study, 2024). However, research shows that many facilities still face challenges in public understanding, managerial capacity, and stakeholder policy support, underscoring the need for holistic integration of technology, education, and institutional backing to fully realize TPS 3R's socio-economic promise (Yulda et al., 2024; Firmansyah et al., 2024).

Achieving a waste-free Indonesia by 2050 is a key national target, established as part of the country's commitment to reducing greenhouse gas emissions from the waste sector (Ministry of Environment and Forestry, 2024). TPS 3R is envisioned as a cornerstone in realizing this vision. However, its practical implementation still encounters several challenges, including regulatory, technical, institutional, financial, and community engagement issues.

Through structured interviews and questionnaires with TPS 3R staff, the research assesses the facilities' effectiveness and identifies key success factors. Moreover, the study proposes strategies to improve operational efficiency, explores opportunities and challenges for integrating circular economy principles, and examines the potential for scaling TPS 3R as a long-term national waste reduction strategy. The novelty of this research lies in its integrated, multi-dimensional approach that combines technical performance metrics with institutional analysis, an aspect often overlooked in previous studies. By providing data-driven, actionable insights, the findings offer valuable guidance for policymakers and stakeholders and contribute directly to shaping more effective and scalable waste management policies in Indonesia.

Previous research has explored various dimensions of community-based waste management, particularly TPS 3R, in Indonesia. For example, Dewi et al. (2020) examined the operational role of TPS 3R in reducing the volume of waste directed to landfills, highlighting the system's effectiveness in minimizing household waste and enhancing community involvement. However, the study focused narrowly on quantitative waste reduction without assessing the institutional or financial sustainability of TPS 3R. In another study, Hadiyanto and Widiastuti (2022) emphasized the social benefits of TPS 3R, such as job creation and community empowerment, but lacked a technical evaluation framework and did not analyze the scalability of such initiatives. These studies, while valuable, demonstrate fragmented perspectives—either technical or socio-economic—without integrating both into a cohesive model. This research fills the gap by combining a multidimensional analysis of TPS 3R, assessing operational effectiveness through interviews and structured questionnaires while also evaluating institutional and community engagement aspects. The objective of this research is to identify the factors that influence the success of TPS 3R implementation and propose integrated strategies to improve their performance and scalability in supporting Indonesia's 2050 waste reduction target. The study is expected to contribute both theoretically and practically by guiding policy improvements and offering a replicable model for sustainable waste management across the country.

METHOD

This study employed a structured data analysis process to evaluate TPS 3R performance, beginning with the collection of primary data through surveys and interviews with TPS 3R operators, followed by the use of descriptive statistics and correlation analysis to examine relationships between key performance factors. The analysis focused on five main dimensions (technical, institutional, financial, regulatory, and community participation) each assessed using measurable indicators aligned with established TPS 3R performance benchmarks from the Ministry of Public Works and Housing and relevant academic literature. For example, technical performance was evaluated based on waste reduction rates and waste sorting efficiency, while financial performance considered cost recovery and revenue generation from recyclables. The results were then interpreted in relation to these benchmarks, enabling a comparative understanding of each site's operational effectiveness and highlighting areas for improvement. This method ensures that the findings are both contextually grounded and relevant for policy and program development.

Literature Review

The literature review provided a foundational understanding of waste management practices in Indonesia, with a specific focus on TPS 3R facilities, their organizational structures, and recycling activities. It also guided the formulation of the research methodology and workflow.

Data Collection

Data were collected from six selected TPS 3R sites, chosen based on their compliance with the criteria outlined in Ministerial Regulation of Public Works and Housing (PerMen PUPR) No. 3 of 2013, as well as additional considerations such as a minimum of two years of operational activity since their establishment. The selected TPS 3R locations are as follows:

Table 1. Research Location

No.	TPS 3R Facility Name	Location	Year of Establishment
1	TPS 3R Saling Asih II	Bandung City	2019
2	TPS 3R Kebon Jeruk Beriman	Bandung City	2017
3	TPS 3R Hikmah Panjunan	Bandung City	2022
4	TPS 3R Brama Muda	Sleman Regency	2017
5	TPS 3R Kenanga Merdikorejo	Sleman Regency	2018
6	TPS 3R Serogenen Resik	Sleman Regency	2022

At each of the six TPS 3R locations, researchers administered questionnaires and conducted brief interviews with members of the community-based self-help groups (KSM) and operational workers. The total number of respondents was determined using the Slovin formula, resulting in a sample size of 42 workers—seven respondents from each facility. The questionnaires were distributed in person and completed simultaneously by respondents at each site. The questionnaire collected data on respondent demographics, performance evaluations of the TPS 3R across five key dimensions—regulatory, technical-technological, institutional,

financial, and participatory aspects—waste-related data, and additional questions regarding the waste processing activities conducted at the TPS 3R.

Data Analysis

The collected questionnaire data were analyzed using correlation analysis, facilitated by Microsoft Excel (Bagastyo et al., 2023). Correlation tests were employed to identify relationships between the five operational aspects and the overall performance of each TPS 3R facility. Additionally, TPS 3R performance was assessed based on the waste reduction rate, calculated using the Indonesian National Standard (SNI) 19-3964-1994. Waste generation was determined using processed volume data at each facility, while residual waste sent to the landfill (TPA) was calculated to estimate the proportion of waste successfully managed by the TPS 3R.

RESULT

Exixting Conditions of TPS 3R Facilities

The current waste management practices across the six TPS 3R facilities vary in terms of service capacity, site area, technological application, and regulatory support. Older facilities, such as TPS 3R Kebon Jeruk Beriman—which serves approximately 2,200 households—generally have larger capacities. This is often the result of operational expansion and the implementation of additional waste processing methods to increase throughput.

Some TPS 3R facilities also extend their services beyond residential areas. For example, TPS 3R Hikmah Panjunan serves 450 households and a local market, while TPS 3R Serogenen Resik accommodates 270 households, a school, and a food processing factory. TPS 3R Saling Asih II serves 520 households, TPS 3R Brama Muda serves 527, and TPS 3R Kenanga Merdikorejo serves 300 households.

While regulatory frameworks and government support are present in several facilities, improvements are still needed in source-level waste segregation, public education, transportation systems, and technological investment to ensure more efficient and sustainable operations. Survey responses reveal varied patterns of organic and inorganic waste management. Most TPS 3R facilities have implemented composting, commonly using the open windrow method. Some facilities have adopted additional technologies such as Black Soldier Fly (BSF) cultivation and composting drums. Others have also introduced *Lodong Sesa Dapur* (LOSEDA) units for organic waste, which serve as practical models for household-level waste treatment.

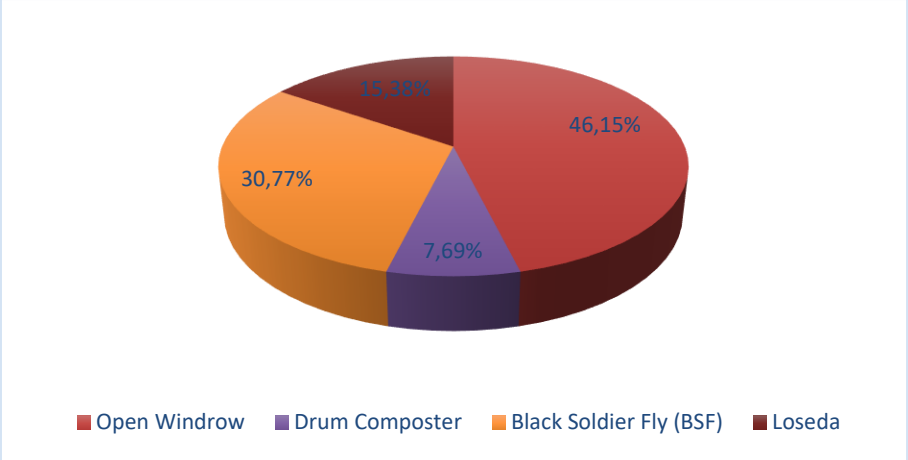

Figure 1. Organic Waste Processing Methods

Managing inorganic waste such as plastics, paper, and metals presents distinct challenges. Questionnaire results indicate that sorting inorganic waste is still suboptimal at several TPS 3R locations, despite some facilities having established recycling systems or partnerships with waste collectors. Respondents' age and level of understanding also influence their awareness of the importance of waste separation.

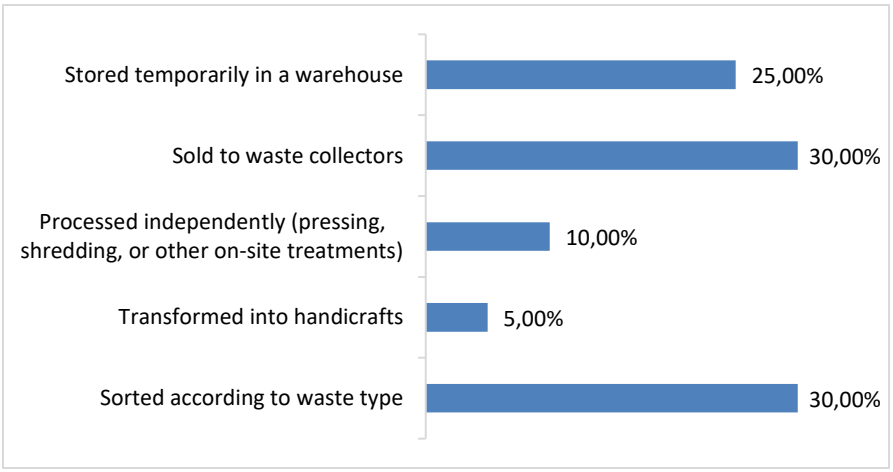

Figure 2. Organic Waste Processing Methods

Overall, the current waste management conditions at TPS 3R facilities reveal significant potential for improvement—particularly in source separation, community education, and optimization of processing facilities. By implementing more structured systems, the effectiveness of waste management can be substantially enhanced, supporting long-term environmental sustainability.

Waste Analysis

Data analysis reveals that organic waste dominates across all TPS 3R sites, accounting for an average of approximately 65% of the total incoming waste. This highlights ongoing challenges in the sorting and processing of organic waste. Optimizing organic waste treatment through composting, Black Soldier Fly (BSF) technology, or biodigesters is essential to reduce the overall waste burden. Strengthening source separation is also crucial to increase plastic recycling rates. Additionally, technologies such as Refuse-Derived Fuel (RDF) and recycling

programs should be implemented to minimize residual waste. Variations in waste volume among TPS 3R sites provide a valuable basis for planning appropriate processing capacities. By enhancing sorting, processing, and public education, the operational effectiveness of TPS 3R can be improved significantly, leading to a reduction in residual waste sent to landfills.

Table 1. Waste Data from Research Location

	kg/daysam						
TPS 3R Facility Name	**Waste Input**	**Organic**	**Plastic**	**Paper**	**Cardboard**	**Metal**	**Residue**
TPS 3R Saling Asih II	985,20	640,38	104,54	53,72	32,91	5,87	147,78
TPS 3R Kebon Jeruk Beriman	1390,17	756,27	204,80	41,43	62,63	16,37	308,67
TPS 3R Hikmah Panjunan	1036,34	777,26	65,93	20,94	12,78	3,98	155,45
TPS 3R Brama Muda	2067,25	1447,08	235,62	94,64	63,96	19,23	206,73
TPS 3R Kenanga Merdikorejo	1532,88	689,80	256,97	103,94	72,76	26,19	383,22
TPS 3R Serogenen Resik	1495,67	972,19	223,67	82,71	42,82	24,72	149,57

Source: Based on observations

After calculations, the average TPS 3R successfully manages between 75% to 90% of the waste it receives. Each TPS 3R adapts its capacity and equipment to suit the specific waste conditions of its service area. The highest waste reduction rates were achieved by TPS 3R Brama Muda and TPS 3R Serogenen Resik, both located in Sleman Regency. These two facilities utilize several advanced waste processing technologies that significantly reduce the volume of waste sent to landfills.

Table 2. Waste Reduction Percentage

TPS 3R Facility Name	**Reduction of Waste***
TPS 3R Saling Asih II	85,00%
TPS 3R Kebon Jeruk Beriman	77,80%
TPS 3R Hikmah Panjunan	85,00%
TPS 3R Brama Muda	90,00%
TPS 3R Kenanga Merdikorejo	75,00%
TPS 3R Serogenen Resik	90,00%

Source: Based on observations

Evaluation of TPS 3R Performance

Correlation analysis reveals a low relationship between regulation and TPS 3R performance (r = 0.18499), indicating that although regulations exist, their implementation remains suboptimal due to weak supervision and limited facility support. The technical aspect shows a moderate correlation with performance (r = 0.389396), demonstrating that the availability of equipment and processing systems significantly influences outcomes but still requires enhancement. Institutional factors exhibit a low correlation (r = 0.167815), suggesting that the effectiveness of TPS 3R largely depends on local initiatives rather than formal policies.

Financial aspects display a moderately significant correlation (r = 0.356466), highlighting that adequate funding plays a key role in improving TPS operations, despite ongoing challenges in budget management. Meanwhile, community participation shows a relatively low correlation (r = 0.175803), underscoring the need for further education and incentives to boost engagement in waste sorting activities. To strengthen TPS 3R performance,

improvements should focus on enhancing regulatory oversight, increasing technical efficiency, reinforcing institutional coordination, optimizing funding sources, and actively encouraging community involvement in waste management. Effective waste processing facilities must be supported by high community participation, and local activities should be directed to foster greater responsibility for waste management within the community (Trihadiningrum et al., 2017).

Table 3. Correlation Analysis Result

Aspect	Correlation Coefficient (r)*	Correlation with Performance**
Regulation	0,184989873	Low Correlation
Technical	0,389395779	Moderate Correlation
Institutional	0,167815294	Low Correlation
Financial	0,356465523	Moderate Correlation
Participation	0,175803168	Low Correlation

Source: *Excel correlation test
**(Sari et al., 2023)

Challenges and Opportunities

TPS 3R management faces challenges related to weak regulatory enforcement and low effectiveness in waste sorting. Although regulatory frameworks exist, many TPS 3R units operate without consistent oversight, clear operational guidelines, or adequate alignment with local government policies. This regulatory gap often leads to fragmented implementation and reduced institutional accountability. Additionally, community participation in waste sorting remains limited due to low public awareness, insufficient educational outreach, and a lack of incentive-based programs to encourage behavioral change. The high volume of untreated residue further highlights the urgent need to improve both processing systems and community engagement. Institutional coordination has yet to reach its full potential, and constraints in funding and infrastructure continue to hinder efforts to increase TPS 3R capacity. If these issues are not addressed promptly, they could impede the long-term sustainability of waste management systems.

However, significant opportunities exist to optimize TPS 3R through the adoption of technologies such as composting, Black Soldier Fly (BSF) bioconversion, and Refuse-Derived Fuel (RDF). Public education and incentives can boost awareness and engagement in waste separation. Financial support from government and private sectors can strengthen TPS 3R operations and infrastructure development. Collaboration among government agencies, communities, and businesses can accelerate innovation in waste management. With the right strategies, TPS 3R can serve as an effective solution to reduce waste and promote a circular economy.

Strategic Recommendations

To enhance TPS 3R effectiveness, it is essential to strengthen regulations and oversight through well-designed systems and regular evaluations. Organic waste processing can be optimized by employing composting, BSF bioconversion, and biodigesters, while waste sorting must be reinforced through education and operational support from government and other

stakeholders. Implementing RDF technology can further reduce non-recyclable residues. Moreover, increasing human resource capacity and fostering public-private partnerships will support the sustainable operation of TPS 3R. These strategies will enable TPS 3R to manage waste more efficiently, decrease landfill residues, and advance a sustainable circular economy.

CONCLUSION

This study highlights the vital role of TPS 3R in sustainable waste management and its contribution toward achieving Indonesia's Zero Waste target by 2050. From six case study locations, TPS 3R demonstrated an average waste reduction rate of 75–90%, reflecting substantial potential to reduce landfill volumes. Nevertheless, management effectiveness is influenced by several factors, including infrastructure availability, human resource capacity, and support from both government and local communities.

Findings indicate that regulatory, technical, institutional, financial, and community participation aspects affect TPS 3R performance to varying degrees. Financial and technical factors showed the strongest direct impact on operational activities, given their critical role in providing necessary infrastructure for waste processing. Meanwhile, regulatory, institutional, and community participation aspects showed less influence, as questionnaires and interviews revealed limited impact of these factors on TPS 3R operations.Further efforts are needed to raise awareness and encourage community involvement in waste sorting and management. Additionally, strong cooperation among government, private sectors, and other institutions is crucial to enhance waste processing through frequent training and capacity-building initiatives. Providing infrastructure support, such as pressing and shredding machines tailored to each TPS 3R's needs, will significantly improve waste management effectiveness.

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