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Analysis of Circular Economy Potential in Waste Management: Operational Efficiency and Economic Impact at TPS3R Bungo Lintas

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Abstract:

The circular economy-based waste management at TPS3R (Waste Management Center with Reduce, Reuse, Recycle Approach) offers significant potential in reducing waste and creating economic value. This study analyzes the potential of the circular economy in waste management at TPS3R Bungo Lintas, focusing on operational efficiency and economic impact. The study employs a mixed-methods approach with an explanatory sequential design, where quantitative data is analyzed first to measure operational efficiency and economic impact, followed by qualitative interviews to deepen the quantitative findings. The results show that TPS3R's operational efficiency increased from 58.33% in 2021 to 61.11% in 2023, exceeding the minimum waste reduction target of 50%. The economic impact is measured through a cost-benefit ratio (BCR), showing a value greater than 1, with a net value of Rp4,345,000.00, indicating that TPS3R provides positive economic benefits. The challenges faced include a lack of public understanding of the circular economy concept, limited managerial knowledge of TPS3R operations, waste processing technology, and stakeholder policy support. Nevertheless, the potential for economic development through expanding community participation, selling recycled products, and the wider adoption of technologies such as maggot bioconversion offers new opportunities to increase TPS3R's revenue. These findings highlight the importance of policy support, technology, public education, and improved management of TPS3R to strengthen the sustainability of the circular economy model at the local level.

Keywords*: circular economy, TPS3R, waste management, operational efficiency, economic impact.*

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1. Introduction

The issue of waste management has become an urgent global challenge, driven by rapid population growth and urbanization (United Nations Environmental Pragramme, 2024), with impacts that extend beyond the environment to include health, social, and economic aspects (Abubakar et al., 2022). Poorly managed waste can cause ecosystem damage, air, soil, and water pollution, and pose health risks to

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populations worldwide (Alao et al., 2023; Li et al., 2023; S. Ma et al., 2022; Vaverková et al., 2018). Additionally, accumulated or improperly disposed waste can obstruct water flow or block drainage systems, leading to flooding (Asiedu, 2020). In semi-urban areas, community behaviors related to waste management remain a significant problem, including practices such as burning waste, dumping waste into rivers, or discarding it in forests (Karjoko et al., 2022; Wahyudi & Hidayah, 2022). The environmental, health, and social impacts of poor waste management ultimately result in economic losses (Yulda et al., 2024). The United Nations Environment Programme (UNEP) reported in 2024 that the economic losses due to waste amounted to $361 billion in 2023, and if immediate action is not taken to manage waste, the cost is projected to rise to $640.3 billion by 2050 (United Nations Environmental Pragramme, 2024).

In Indonesia, the complexity of this issue is further exacerbated by inadequate waste management infrastructure, particularly in semi-urban and rural areas (Lingga et al., 2024; Tania & Dompak, 2024). Amid this crisis, there is growing interest in the circular economy as a sustainable approach to tackling waste management challenges (Savini, 2021; Schützenhofer et al., 2022). The circular economy offers solutions to reduce waste by reusing resources through recycling and repurposing, ultimately reducing dependence on the linear economic model, which focuses solely on production, consumption, and disposal (Hemidat et al., 2022; Tomić & Schneider, 2020). One emerging approach to addressing this issue is the implementation of a community-based Municipal Solid Waste (MSW) treatment program as an intermediate treatment facility designed to serve at least 200 households, in Indonesia the facility is called TPS3R (*Tempat Pengolahan Sampah dengan Reuse-Reduce-Recycle*, translated into MSW Treatment Facility based on Reduce-Reuse-Recycle) (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2023). TPS3R not only plays a role in reducing the volume of waste sent to landfills but also offers opportunities to create an economic cycle involving various local actors, with proven economic impacts (Fatimah et al., 2024; Yulda et al., 2024). TPS3R Bungo Lintas, located in a semi-urban area of Indonesia, serves as a concrete example of this initiative. By focusing on sustainable waste processing, this TPS3R has the potential to become a circular economy model that empowers local communities while contributing to environmental sustainability (Yulda et al., 2024).

Although 3R-based waste management initiatives have been implemented in various regions, significant challenges remain in achieving a sustainable and efficient system, particularly at the local level (Sadono, 2024). One of the primary challenges is the limited capacity to integrate economic aspects with the waste management process (Hemidat et al., 2022; Sadono, 2024). While circular economy principles have begun to be applied, the operational efficiency and economic impact of waste management have not yet been fully realized (Karjoko et al., 2022). Common issues encountered at TPS3Rs include an imbalance between the amount of incoming waste and the waste successfully recycled, as well as a lack of economic incentives that drive the sustainability of recycling programs (Knickmeyer, 2020; Sadono, 2024). In an ideal system, the waste entering TPS3Rs should be processed efficiently, generating marketable recycled products that provide economic benefits to the operators and the

surrounding community (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2023). However, in reality, many TPS3Rs still operate below optimal capacity, with most of the waste ending up in landfills (Sadono, 2024; Sudrajad et al., 2022). At TPS3R Bungo Lintas, there is significant potential to develop a local economic circulation through waste processing, but there is still a gap in documentation and analysis regarding how these activities can generate sustainable economic value (D'Adamo et al., 2022; Tomić & Schneider, 2020; Yulda et al., 2024). Therefore, in-depth research is needed to understand how the economic potential of this TPS3R can be optimized, as well as to address the challenges hindering circular economy-based waste management at the community level.

This study aims to analyze the circular economy potential that can be applied at TPS3R Bungo Lintas, focusing on two main aspects: operational efficiency and the economic impact of waste management. Operational efficiency will be measured by comparing the amount of waste entering TPS3R with the volume of waste successfully recycled each year. If the amount of processed waste increases significantly year by year, this indicates that TPS3R Bungo Lintas has the potential to become a site for circular economy application. Additionally, this study will analyze the economic impact of waste management by measuring the ratio between operational costs and the economic benefits generated from recycled products. If this ratio shows positive results, it indicates that the application of the circular economy at TPS3R can provide significant economic benefits. Furthermore, this research will explore the challenges and opportunities in implementing the circular economy at TPS3R Bungo Lintas through qualitative interviews. By gathering insights from TPS3R managers, this study is expected to identify the factors that hinder or support the implementation of the circular economy at the community level and provide recommendations to improve the effectiveness of waste management programs at TPS3R.

Although 3R-based waste management and circular economy models have received widespread attention in various academic studies, there is a significant gap in the literature regarding the application of these concepts in semi-urban and rural areas. Most previous research has focused on environmental and technical aspects, such as environmental impacts (Alao et al., 2023), waste volume reduction or recycling efficiency (Fatimah et al., 2024), while little attention has been given to analyzing the economic potential that can be generated from these processes, particularly in the context of TPS3R. In this regard, studies that integrate circular economy with community-scale waste management systems remain rare. TPS3R, as a waste management site designed to reduce waste and maximize recycling, presents a unique opportunity to apply the circular economy concept (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2023), but empirical studies on its economic impact are still limited. This research aims to fill that gap by offering a comprehensive analysis of how TPS3R Bungo Lintas can become a model of sustainable waste management while simultaneously creating local economic circulation. The results of this study are expected to make a significant contribution to the development of more sustainable public policies, while also encouraging innovation in waste management governance at the local and national levels.

2. Theoretical Background

The Concept of Circular Economy in Waste Management

The circular economy is a sustainable economic model that emphasizes the principles of reduction, reuse, and recycling (3R) to minimize waste and maximize resource utilization (Velenturf & Purnell, 2021). In the context of waste management, the circular economy aims to close the material life cycle, turning waste into new resources, reducing the need for new natural resources, and lowering environmental impacts (Hysa et al., 2020). According to research by Hailemariam et al. (2023), the circular economy has the potential to reduce carbon emissions and increase global resource efficiency (Hailemariam & Erdiaw-Kwasie, 2023). This principle is highly relevant in waste management, particularly in developing countries, where adequate waste infrastructure is still limited.

Key Variables: Operational Efficiency and Economic Impact

Two key variables in the application of the circular economy to waste management are operational efficiency and economic impact. Operational efficiency refers to optimizing the processes of waste collection, processing, and recycling while minimizing the costs and resources used. Economic impact is related to cost savings and increased revenue generated through the reuse of waste materials. For example, Abou Taleb & Farooque, (2021) found that implementing the circular economy in the waste sector could reduce operational costs by up to 20% and increase revenue through the sale of recycled materials (Abou Taleb & Al Farooque, 2021). The circular economy also contributes to improving operational efficiency by reducing the amount of waste sent to landfills (Salmenperä et al., 2021). According to Schützenhofer et al. (2022), the 3R principles in the circular economy allow waste managers to focus more on recovering recyclable materials, thus reducing long-term operational costs. This study also shows that circular economy-based waste management can enhance the sustainability of waste management infrastructure (Schützenhofer et al., 2022).

Application of Circular Economy in Waste Management Systems

Various case studies demonstrate the successful application of the circular economy in waste management. Waste management through TPS3R has been proven to have a greater economic impact than conventional waste management (Yulda et al., 2024). Moreover, the implementation of advanced recycling technologies enables energy recovery from non-recyclable waste. However, in developing countries, the application of the circular economy in waste management faces greater challenges. Sudrajad et al.'s (2022) research in Indonesia shows that limited waste management infrastructure, lack of technology, and insufficient policy support hinder the success of the circular economy's implementation (Sudrajad et al., 2022). Nonetheless, some local initiatives, such as Waste Management Sites with 3R Principles (TPS3R), have demonstrated potential in reducing waste generation and increasing revenue through the reuse of organic and inorganic waste (Putri et al., 2020; Sadono, 2024; Salmenperä et al., 2021).

Challenges and Opportunities in the Circular Economy

The main challenges in implementing the circular economy in waste management include a lack of policy support, technological limitations, and low public participation (Askinatin et al., 2023; Karjoko et al., 2022; Kurniawan et al., 2023). To address these challenges, closer collaboration between the government, private sector, and the community is required. External support in the form of funding, training, and technology transfer is crucial to enhancing the capacity of TPS3R in applying circular economy principles more broadly. Some previous studies emphasizes that the success of circular economy implementation is highly dependent on partnerships and innovation, including the development of efficient recycling technologies and the empowerment of communities in the waste management process (Askinatin et al., 2023; Schützenhofer et al., 2022). Overall, the implementation of the circular economy in waste management presents significant opportunities to reduce environmental impacts and create economic added value (Fatimah et al., 2024). However, its success is heavily influenced by the availability of infrastructure, technology, and effective multi-stakeholder partnerships.

3. Methodology

Research Design

This study employs a mixed-methods approach using an explanatory sequential design, where quantitative research is conducted first to measure the operational efficiency and economic impact of TPS3R Bungo Lintas. After the quantitative results are obtained, qualitative research is carried out to deepen the understanding of these results by exploring the experiences and perceptions of key stakeholders. This approach allows the researchers to integrate empirical quantitative data with narrative qualitative data to gain a more comprehensive understanding of waste management based on a circular economy at TPS3R Bungo Lintas.

Population and Sample/Informants

The population in this study includes all actors involved in the management and utilization of TPS3R Bungo Lintas services, both directly and indirectly. Sampling is done using purposive sampling, where informants are selected based on their direct involvement in TPS3R operations or utilization of recycled products. Informants chosen for qualitative interviews include:

- Key stakeholders at TPS3R, such as the chairman, treasurer, and TPS3R workers;
- Related government officials, such as representatives from the Environmental Agency and the Health Agency;
- Local community members, including village heads, heads of RW and RT, and community representatives (farmers, women's groups, waste collectors);
- Representatives from the public who use TPS3R's recycled products.

For quantitative data, samples are taken from the operational data of TPS3R over the last three years, including the volume of incoming waste, recycled waste, and financial reports covering operational costs and revenue from the sale of recycled products.

Data Collection Techniques

Quantitative data are obtained from TPS3R's financial and operational documents, including monthly reports on incoming waste volume, recycled waste, and financial records regarding operational costs and revenue. Waste weighing is done daily by TPS3R officers, who record the volume of incoming waste and categorize it into organic, inorganic, and residual waste.

- Waste volume data is obtained by weighing incoming waste daily, recorded by TPS3R Bungo Lintas staff in the monthly waste report.
- Recycled waste volume data is obtained by weighing sorted waste ready for recycling. Waste sorting is divided into three categories: organic, inorganic, and residual, which are recorded in the TPS3R Bungo Lintas monthly report.
- Financial data is obtained from routine records by TPS3R staff related to retribution fees, operational costs, and revenue from the sale of recycled waste products, noted in the TPS3R Bungo Lintas financial report. Savings in waste transportation costs to the landfill are seen from the financial reports of the Environmental Agency for the TPS3R Bungo Lintas cross-route waste handling.

Qualitative data is collected through semi-structured interviews with selected informants. The interview guide is prepared based on the quantitative analysis results to delve deeper into the informants' perceptions and experiences regarding the circular economy's potential and the challenges faced in waste management. In addition, field observations are conducted to verify the operational practices at TPS3R and directly record the dynamics of the waste management process.

Data Analysis Techniques

Quantitative data is analyzed using simple analysis, i.e., straight-line ratio calculations.

- To measure the operational efficiency of waste management, a ratio of the volume of successfully recycled waste to the total volume of incoming waste is used. This ratio indicates the percentage of waste that is processed and recycled each year, a key indicator in assessing TPS3R Bungo Lintas' performance in reducing waste sent to the landfill, with the formula:

$$\text{Waste Management Operational Efficiency} = \frac{(\text{Recycled Waste Volume})}{(\text{Incoming Waste Volume})}\ x\ 100\%$$

  According to Presidential Regulation Number 97 of 2017 on the National Policy and Strategy for Household Waste and Household-Like Waste Management 2017-2025, the target for waste management is >50% per year (Pemerintah Pusat Indonesia, 2017). Based on the technical guidelines for TPS3R activities in 2023, TPS3R is expected to reduce the amount of waste sent to the landfill by at least 50% and/or produce a maximum of 35% residual waste from the total incoming waste (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2023).
- To measure economic impact, cost-benefit analysis is used by calculating the benefit-to-cost ratio. Net value is calculated as the difference between the revenue from recycled products and the operational costs incurred. The ratio is calculated by comparing total benefits and total costs. If the cost-benefit ratio >

1, it can be interpreted that waste management at TPS3R Bungo Lintas provides a positive economic impact.(Tao et al., 2023)

Qualitative data is analyzed using thematic analysis to identify the main themes emerging from the interviews. These themes are then connected with the quantitative analysis results to provide a deeper understanding of the factors affecting TPS3R's operational efficiency and economic impact.

Triangulation, which involves comparing quantitative data from operational reports with qualitative data from interviews and field observations, ensures that the research results are consistent and valid from various perspectives. Additionally, the interview results will be validated through member checking, where the main findings will be re-confirmed with the informants to ensure accurate interpretation.

4. Empirical Findings/Result

Operational Efficiency of Waste Management

The operational efficiency of waste management at TPS3R Bungo Lintas can be calculated by comparing the volume of recycled waste to the volume of incoming waste.

Table 1. Data on Incoming and Recycled Waste Volumes for the Period 2021-2023

Year	Incoming Waste Volume (Tons)	Recycled Waste (Tons)	Operational Efficiency (%)
2021	120	70	58.33%
2022	150	90	60%
2023	180	110	61.11%

Based on calculations, TPS3R Bungo Lintas has shown an increase in operational efficiency over the past three years. In 2021, the operational efficiency was recorded at 58.33%, rising to 60% in 2022, and reaching 61.11% in 2023. This figure has surpassed the minimum target established by Presidential Regulation No. 97 of 2017, which mandates waste management to achieve a reduction target of 50% per year. This result also demonstrates the success of TPS3R in reducing the volume of waste sent to the landfill and enhancing recycling capacity.

Economic Impact of Circular Economy-Based Waste Management

In addition to improving operational efficiency, implementing a circular economy concept at TPS3R Bungo Lintas has had a significant economic impact on the facility and the community. This impact can be observed through cost savings in waste transportation to the landfill and increased revenue from recycled products.

Table 2. Cost Savings in Waste Transportation to Lanfill and Recycling Revenue

Year	Cost Savings in Waste Transportation to Landfill (IDR)	Recycling Revenue (IDR)
2021	6,000,000	25,000,000
2022	8,500,000	30,000,000

2023	11,000,000	37,000,000

Between 2021 and 2023, TPS3R Bungo Lintas successfully reduced waste transportation costs to the landfill by IDR 11 million in 2023, from IDR 6 million in 2021, along with an increase in the volume of waste processed. Moreover, revenue from recycled products increased significantly, from IDR 25 million in 2021 to IDR 37 million in 2023. This increase not only reflects operational efficiency but also highlights the economic benefits derived from the circular economy principles.

According to financial data from the Environmental Agency (DLH) for TPS3R Bungo Lintas waste management, cost savings were calculated based on expenses for fuel for waste collection vehicles from source to landfill and wages for waste operators. Cost savings in waste transportation mean the funds that would otherwise be spent if waste processing were not conducted at TPS3R. The presence of recycling processes at TPS3R Bungo Lintas shifts these costs into benefits for the surrounding community. The economic impact is also assessed through a Benefit-Cost Ratio (BCR) calculation, which evaluates the economic performance of TPS3R Bungo Lintas.

Table 3. Details of Operational Costs and Benefits for 2023

No.	Component	Total Cost-Benefit TPS3R (IDR)
Cost		
1	Operational Costs	
	Labor Wages	115,200,000
	Electricity and Water	1,200,000
	Fuel	11,760,000
	Packaging	840,000
	Supplies	415,000
	Support Facilities	7,440,000
Subtotal		**136,855,000**
2	Maintenance Costs	
	Waste Collection Service	800,000
Subtotal		**800,000**
Total Cost		**137,655,000**
Benefit		
1	Product Sales	
	Organic	31,380,000
	Economical Waste	5,620,000
2	Convenience Value (retribution)	105,000,000
Total Benefit		**142,000,000**
Net Value		**4,345,000**
BCR		**1.03**

Based on calculations, a Benefit-Cost Ratio (BCR) of 1.03 indicates that the economic benefits generated by TPS3R slightly exceed the costs incurred. This figure is sensitive to price changes; however, it could be further improved through various efforts, such as optimizing resource use, increasing recycling equipment capacity,

expanding methods and waste processing outputs, and providing additional training for the workforce.
The economic impact of waste processing activities at TPS3R Bungo Lintas is also acknowledged by several informants. One waste operator at TPS3R Bungo Lintas explained, "I am very grateful for the existence of TPS3R; not only am I more aware of environmental cleanliness, but I also have a job and income here." Interviews with community representatives indicated, "Since COVID-19, we enjoy gardening in our yards, planting vegetables and flowers. The availability of organic compost products from TPS3R has been very helpful." An interview with a farmer's group member stated, "I have a garden where I grow vegetables, which I harvest daily to sell at the market. Crop quality depends on care, such as fertilizers and regular watering. Since using liquid fertilizers and compost from TPS3R, my vegetables have grown larger, and my customers are satisfied."

The economic impact is evidenced not only by economic calculations but also by tangible benefits for the community, such as job creation and the benefits of recycled products from waste processing.

Circular Economy Potential
Several key aspects identified in interviews reveal the significant circular economy potential at TPS3R Bungo Lintas, including:

- **Sale of Recycled Products**: One primary revenue source for TPS3R comes from the sale of recycled products, such as compost, liquid fertilizer derived from organic waste processing, and economically valuable inorganic waste like plastics, paper, and metals. Marketing managers noted that recycled product prices fluctuate but still significantly contribute to TPS3R's operations.
- **Expansion and Business Diversification Opportunities**: Interviews revealed that TPS3R Bungo Lintas plans to adopt maggot bioconversion technology as a method for organic waste processing. This technology is expected to increase revenue through value-added products, such as organic fertilizers and animal feed. However, its implementation is still pending due to limited knowledge about maggot cultivation.
- **Customer Base Expansion**: TPS3R Bungo Lintas managers emphasize the importance of expanding the customer base to increase operational revenue and optimize waste management. By expanding waste collection coverage from more sources, TPS3R can maximize waste reduction efforts for the landfill while strengthening its role in creating a circular economy in the area.
- **Waste Sorting from the Source**: One of the main challenges in waste management at TPS3R is the lack of waste sorting at the source (households). Although sorting is currently done by TPS3R operators, a waste bank-based approach has been proposed as a solution. This system allows households to save sorted waste, which TPS3R would then buy, potentially increasing community participation and providing economic incentives while enhancing community-based waste management.
- **Support and Partnership with External Parties**: TPS3R's chairman stresses the need for support from the local government and partnerships with non-governmental organizations. External assistance, either in the form of funding or

training, will open up opportunities to expand TPS3R's scale and strengthen the local economy.

Challenges in Waste Management and Circular Economy

- **Lack of Awareness and Knowledge on Circular Economy**: The limited public understanding of the circular economy concept is a major obstacle in increasing their active participation in 3R-based waste management.
- **TPS3R Management's Perspective on Circular Economy**: TPS3R managers have a positive view of the circular economy, acknowledging it as a potential solution for reducing waste volume at landfill and creating new economic opportunities through recycling. Nonetheless, implementing this concept is not without challenges, particularly in management structure, planning, organization, and human resource management at TPS3R. Managers and workers lack clear job descriptions, a written SOP (Standard Operating Procedure), and a complete organizational structure following TPS3R technical guidelines. Additionally, there are limited resources for educating the public c on the importance of participating in TPS3R.
- **Resource and Technology Limitations**: Limited access to modern waste processing technology is a challenge in improving TPS3R's operational efficiency. Informants suggested investing in technology to support recycling process optimization.
- **Limited Policy Support**: No policy support exists from the local government in the form of socialization or regulations on community participation in TPS3R,

5. Discussion

This study reveals that the implementation of a circular economy at TPS3R Bungo Lintas contributes to improved operational efficiency, particularly in more efficient waste management, better resource utilization, and reduced reliance on landfill sites. These findings align with previous studies that state circular economy practices help optimize resource cycles, reduce waste, and extend product life, thus increasing overall operational efficiency in waste management (Savini, 2021; Schützenhofer et al., 2022; N. Sharma et al., 2022). The processing activities at TPS3R fulfill its objective to extend the lifespan of landfill sites. Furthermore, the waste collection practices at TPS3R Bungo Lintas, especially with proper sorting from the start, align with previous findings highlighting that a key element of the circular economy is a structured waste sorting and management process (Salmenperä et al., 2021; Zhang et al., 2022). Better resource management at TPS3R, such as reusing organic waste for compost and liquid fertilizer, also supports previous studies that found small-scale recycling of organic materials positively impacts both the environment and the economy(Hysa et al., 2020).

The increased operational efficiency of TPS3R Bungo Lintas, as seen from quantitative data, indicates a close relationship between effective waste management and economic impact for the surrounding community. These results affirm that operational efficiency-measured by the volume of processed waste and income from recycled products—has direct economic implications for the community, including

job creation and increased household income. The findings also indicate that this improved efficiency benefits not only the economic aspect but also the environmental aspect, where reduced waste sent to landfills directly decreases greenhouse gas emissions and other environmental pollutants. The improved efficiency at TPS3R creates a model that can be replicated in other communities, especially in areas with limited waste management infrastructure. These findings are consistent with previous research emphasizing that implementing a circular economy can serve as a practical solution for waste issues at the community level (Mihai et al., 2021; Salmenperä et al., 2021; Tomić & Schneider, 2020).

The waste processing activities at TPS3R not only increase operational efficiency but also have a significant economic impact in terms of cost savings and income generation, which aligns with the basic concept of circular economy theory (Hysa et al., 2020). Circular economy theory focuses on maximizing the value of products and materials by minimizing waste through sustainable recycling and reuse processes (Velenturf & Purnell, 2021). The increase in the volume of recycled waste and the revenue from selling recycled materials shows that TPS3R has successfully optimized the economic value of the waste it manages. The findings also confirm previous studies that showed increased efficiency in waste management could yield significant economic benefits for communities (Abou Taleb & Al Farooque, 2021; H. B. Sharma et al., 2021). Reduced waste disposal to landfills directly decreases transportation and handling costs, as explained by Yulda (2024), who found that one of the main benefits of waste management activities at TPS3R is reduced transport and disposal costs, proving these activities are economically viable (Yulda et al., 2024). This finding aligns with previous studies, which show that circular economy practices help reduce operational costs, often a major challenge in waste management. Waste handling without processing or recycling is shown to have no economic impact.

Additionally, the revenue generated from recycled materials at TPS3R Bungo Lintas also makes a significant contribution. Organic waste processed into compost and liquid fertilizer, and inorganic waste such as plastic and paper that is recycled, provides stable additional income for TPS3R. This finding is consistent with previous studies showing that waste processing can create new income opportunities through the sale of recycled products and reduce reliance on raw materials (Putri et al., 2020; Utomo et al., 2023). This is also supported by previous studies that demonstrate that recycling and reusing products offer direct economic benefits for companies and communities (Hysa et al., 2020). However, there are some differences in studies on waste management in developing countries, which show that fluctuations in recycled material prices often hinder income stability in this sector (Ebner & Iacovidou, 2021; M. Ma et al., 2022). In the context of TPS3R Bungo Lintas, despite price fluctuations in recycled materials, TPS3R managers have managed to maintain income stability by diversifying the recycled products they produce, such as compost, liquid fertilizer, and recycled plastic.

The economic impact of waste processing activities is also felt by the community, as TPS3R provides new job opportunities for residents in environmental, economic, and business activities. This is further supported by previous research that found large- and small-scale waste processing activities directly create new jobs for the

surrounding community (Mihai et al., 2021; H. B. Sharma et al., 2021). Besides job creation, the products benefit the community, such as gardening materials and other craft supplies. This aligns with previous findings on TPS3R products used in agriculture (Utomo et al., 2023). Holistically, waste processing activities at TPS3R have positive effects not only on the environment but also economically and socially.

Qualitative results indicate the potential of circular economy at TPS3R Bungo Lintas through untapped economic opportunities, such as developing value-added products from recycled materials. Previous studies support this idea, emphasizing the importance of innovation in developing high-value recycled products that can increase income in this sector (Hysa et al., 2020; H. B. Sharma et al., 2021). However, TPS3R faces challenges in accessing advanced recycling technologies or other waste processing methods, and in educating the community on the importance of participation in the 3R (Reduce, Reuse, Recycle) system. These challenges are also supported by previous studies that note limited understanding among managers and the community and limited technology as main barriers to circular economy implementation in developing countries (Ayçin & Kayapinar Kaya, 2021; Salmenperä et al., 2021). TPS3R Bungo Lintas plans to develop waste processing methods using maggot farming but acknowledges the limitations in understanding and skills to implement it. Waste processing with maggot farming has been proven to be more environmentally friendly, with faster waste decomposition time and higher-quality compost, and it has extensive potential for commercializing its by products (Choudhury & Singh, 2020; Lopes et al., 2022; Rehman et al., 2023), which is expected to further promote circular economy activities at TPS3R Bungo Lintas. Additionally, government support in the form of policies facilitating access to technology and resources is crucial to overcoming these challenges (D'Adamo et al., 2022). This study underscores the need for capacity-building through training and support for cost-effective and environmentally friendly methods like waste processing through maggot farming to enhance waste management efficiency, allowing TPS3R to expand its product portfolio and increase its overall economic contribution.

The potential of circular economy is also seen from TPS3R managers who have a positive perception of its economic potential, despite facing challenges such as limited knowledge and technology. This perception is crucial, as the attitudes and understanding of managers are key factors in the success of circular economy implementation. This study reveals that although managers understand the economic benefits of the circular economy, they still face barriers in accessing and understanding TPS3R management patterns. According to the 2023 technical guidelines for TPS3R management, TPS3R should have a complete structure, including a chairperson, treasurer, business and economic section, operations and maintenance section, and counseling section (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2023). However, in practice, TPS3R Bungo Lintas only has a chairperson and treasurer and four waste processing operators. Good and structured management is key to the successful implementation of the circular economy. Previous studies mention that effective management in TPS3R waste management plays a vital role in ensuring economic and environmental sustainability (JAR, 2023; Nizar et al., 2021). With organized management, TPS3R can optimize each stage of the recycling process, from sorting to marketing recycled products, thus maximizing

revenue from the circular economy. This aligns with field findings, where although TPS3R Bungo Lintas managers have a basic understanding of the circular economy, they still need to improve their managerial and operational capacities to fully optimize its economic potential.

This study also identifies several challenges faced by TPS3R in implementing a circular economy, such as the lack of public awareness about the concept, which becomes a major obstacle in increasing active participation in 3R-based waste management. This finding aligns with previous studies that found the biggest challenge in circular economy-based waste management in Indonesia is low public participation and limited policy support (Karjoko et al., 2022; Kurniawan et al., 2023). As explained in interviews, many residents do not fully understand the importance of the circular economy, affecting the level of participation in waste sorting. Increasing community knowledge of the benefits of the circular economy can encourage proactive behavior in reducing, separating, and recycling waste at the household level. Continuous education and effective public campaigns are needed to shift the community's paradigm from traditional waste management to a more sustainable model. The implementation of the circular economy at TPS3R also has the potential to reduce community reliance on conventional waste management systems that are often inefficient and harmful to the environment. By strengthening TPS3R's capacity and promoting recycling practices, the community can directly contribute to reducing the volume of waste sent to landfills while increasing the economic value of the waste they generate. Active community participation can also create positive social impacts, such as improving environmental quality and forming a community more concerned with sustainability issues.(Askinatin et al., 2023; JAR, 2023; Kurniawan et al., 2023; Santini et al., 2024).

The findings of this study also have implications for the development of policies and regulations for waste management in Indonesia. The limited policy support, as identified in this research, indicates that the government needs to be more proactive in facilitating circular economy-based waste management. However, unlike findings from Europe and South Korea, where full support from government and society exists for implementing a circular economy, government involvement in supporting the circular economy at TPS3R Bungo Lintas remains limited. Although there is some support, such as land provision and basic facilities, the sustainability of TPS3R operations largely relies on local initiatives and partnerships with the private sector. This study highlights the need to expand partnerships with external parties. New partners, from the government, private sector, and local communities, can provide essential support in the form of funding, technology, and training to enhance TPS3R's capacity and operational efficiency (Diaz et al., 2021; Sudrajad et al., 2022). Such support will not only strengthen the financial aspects of TPS3R but also expand the reach and broader economic impact of the circular economy for the surrounding community (Diaz et al., 2021).

This study emphasizes that more supportive regulations, such as synergy among agencies, are essential. For instance, the local government could require the community to become TPS3R customers, with the health department responsible for encouraging the community to manage waste by sorting it at home and raising

awareness about TPS3R, while the environmental department could close nearby waste disposal sites, leaving TPS3R as the only option. Additionally, the regional government could ban plastic bags in stores and facilitate funding to improve technology for waste management needs. The study underscores the necessity for a policy approach that not only focuses on law enforcement but also on community empowerment through access to technology and sustainable education. Local policies supporting the circular economy can be a strategic step in addressing waste management challenges faced by many cities and villages in Indonesia (D'Adamo et al., 2022; Diaz et al., 2021). These findings provide an empirical foundation for policymakers to develop more inclusive strategies oriented toward community empowerment in sustainable waste management.

This research makes a significant contribution to the development of circular economy theory, especially in the context of community-based waste management. While most circular economy literature focuses on large industrial sectors and waste management on a macro scale (Kurniawan et al., 2023), this study offers a new perspective by exploring the implementation of the circular economy at a micro level, specifically through TPS3R operations managed by local communities (Mihai et al., 2021). These findings broaden the understanding of how circular economy principles can be applied on a smaller scale, yet have a direct impact on community welfare. The study also adds a new dimension to the theory by highlighting the importance of operational efficiency as a key driver of circular economy success. Most existing theories overlook operational factors in the context of waste management, focusing more on product design and material lifecycle (Diaz et al., 2021; Torkayesh et al., 2022). However, this research shows that operational aspects, such as productivity improvements in waste sorting and processing, have a direct and significant impact on increasing community income. This contribution strengthens the argument that the circular economy is not only relevant at the corporate level but can also be effectively applied in the context of sustainable local waste management.

This study has several limitations, especially in terms of qualitative data collection from interviews, which may be influenced by respondent subjectivity. This aligns with previous research suggesting that qualitative data collection in the context of waste management often faces challenges due to reliance on individual perceptions and limited access to accurate data (Khoa et al., 2023). Additionally, external factors such as fluctuations in recycled material prices and policy changes are constraints that have not been fully measured in this research. As a direction for future research, this study recommends longitudinal studies to observe long-term changes in the circular economy's impact at TPS3R, as well as further studies on implementing new technology innovations to support operational efficiency and enhance the sustainability of waste management. The study also recommends more in-depth research on policy models and public-private collaboration schemes that could support the development of a circular economy in the context of TPS3R.

6. Conclusions

This research reveals that implementing a circular economy at TPS3R (Waste Processing Site with a Reduce, Reuse, Recycle Approach), such as in Bungo Lintas, has significant potential to create sustainable economic, environmental, and social benefits. Qualitative analysis identifies key barriers, such as lack of community awareness, limited management understanding at TPS3R, limited resources and technology, and constrained policy support. On the other hand, quantitative analysis shows that the operational efficiency of TPS3R is directly proportional to economic income growth, positively impacting local community welfare. This research fills a gap in the literature regarding the lack of empirical studies assessing the economic and social impacts of the circular economy in the waste management sector. These findings also strengthen the evidence that integrating circular economy concepts into waste management can not only reduce waste but also create new economic opportunities for communities, particularly in the form of jobs and additional income from recycled products. These conclusions and recommendations confirm that implementing a circular economy in waste management, as done at TPS3R Bungo Lintas, not only provides solutions to environmental problems but also opens new economic opportunities that can improve community welfare. Policy support, technology, and public education are key factors in ensuring the success and sustainability of this model in the future.

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