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Performance Evaluation of 3R (Reduce, Reuse, Recycle) Waste Treatment Facilities from a Sustainable Waste Management Perspective: A Case Study in Darmasaba Village, Badung, Bali, Indonesia

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A B S T R A C T

Community-led waste management encounters challenges in sustainability due to inconsistent amounts of waste produced. Although recognized at the district level, TPS 3R Pudak Mesari in Darmasaba, Bali, does not have a thorough scientific assessment. This research evaluates its effectiveness from the viewpoints of Sustainable Waste Management (SWM) and Circular Economy, and it quantifies the socio-economic-environmental advantages using Social Return on Investment (SROI). A quantitative descriptive-evaluative approach was utilized. The operational performance (X_1) was gauged by combining technical and financial metrics, such as per capita waste generation, density, composition, recovery rates, mass balance, land and labor efficiency, along with Net Present Value (NPV) and Benefit-Cost Ratio (B/C). The socio-economic-environmental effects (X_2) were examined through Likert-scale surveys and incorporated into a comprehensive performance index (Y_1). The SROI analysis (Y_2) looked ahead over ten years, applying a 3. 5% discount rate. The findings show a favorable recovery rate in minimizing landfill waste. Nevertheless, varying waste quantities and insufficient sorting training impose financial strains that obstruct stability. The SROI findings confirm that the social and environmental gains are equal to or surpass costs, highlighting the necessity of financial stability and improved sorting capabilities for the longevity of community-based waste management.

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INTRODUCTION

Sustainable waste management has emerged as a key issue in areas experiencing rapid urban growth, where conventional methods of "collect-transport-dispose" are no longer effective. In Indonesia, initiatives for community-run waste treatment sites known as TPS 3R are being advocated by the government to promote a circular economy and lessen reliance on landfills (Ministry of Public Works and Housing, 2017). The province of Bali has further advanced this initiative through Governor Regulation No. 47/2019, which requires that waste management commence at the source. Nonetheless, the actual effectiveness of these sites is often hindered by a gap between formal acknowledgment and on-the-ground results.

A noteworthy contradiction is evident at the TPS 3R Pudak Mesari in Darmasaba Village, Badung. Even though it has been recognized as the second-best facility by district authorities in a regional assessment, its long-term viability lacks scientific backing. There is an urgent need for thorough, independent evaluations to determine whether this recognition leads to sustainable operations. Additionally, the facility currently struggles with service capacity, reaching only about 35% of the village's residents. Given the high residual waste percentage reported in 2024, it is crucial to review the readiness of the infrastructure and technical efficiency before any plans for expanding services can be realized (Widyarsana et al. , 2020).

Besides the technical challenges, the lack of objective data about the social, economic, and environmental gains from TPS 3R Pudak Mesari decreases transparency. In the absence of a clear way to quantify its effects, local stakeholders do not have a solid foundation of data for making informed strategic policy enhancements. Previous research has indicated that community-managed facilities often face financial challenges and varying waste quantities without strong performance evaluations (Asian Development Bank, 2022). As a result, this study intends to examine the effectiveness of TPS 3R Pudak Mesari from the viewpoints of Sustainable Waste Management (SWM), Circular Economy, and Social Return on Investment (SROI). The goal of this assessment is to offer strategic suggestions and ensure transparency, aligning the management of the facility with the long-term objectives of sustainable waste management in village settings throughout Bali.

LITERATURE REVIEW

Sustainable Waste Management and Circular Economy

The approach to waste management has evolved from conventional linear systems to the principles of a Circular Economy, which views waste as a valuable asset. In a circular framework, the aim is to complete the loop of product lifecycles by emphasizing top-notch recycling and cutting down waste, thereby lessening the demand for new raw materials and curbing environmental harm. Poorly managed waste plays a significant role in global issues, such as soil pollution, water contamination, and the release of powerful greenhouse gases like methane (UNEP, 2021).

Additionally, the shift toward a circular economy necessitates a deep change in the way society thinks about "waste. " By adopting Reduce, Reuse, and Recycle (3R) strategies, organic waste can be transformed into nutrient-dense compost, while inorganic materials are reintegrated into industrial supply chains (Ellen MacArthur Foundation, 2013). This eco-friendly method not only protects natural ecosystems but also provides a means for addressing climate change. Nonetheless, its effectiveness heavily relies on the collaboration between efficient infrastructure and engaged community involvement to ensure that waste sorting begins at its source (Wardana and Dewi, 2021).

TPS 3R (Reduce, Reuse, and Recycle) Regulatory Framework

In Indonesia, the legal groundwork for community-driven waste management is mainly set by the Minister of Public Works Regulation No. 3/2013. This regulation requires the creation of TPS 3R as a neighborhood-centric approach to lessen the burden on final waste disposal sites (TPA) by treating waste close to its point of origin. The framework highlights that waste management should be seen not only as a government duty but also as an initiative propelled by the community, promoting local independence and environmental responsibility.

In the context of Bali, this mandate is further reinforced by Governor Regulation No. 47/2019, which emphasizes waste management based on its source. This policy obliges villages to oversee their waste via facilities like TPS 3R, with the goal of creating a cleaner Bali while minimizing the ecological impact of tourism and urban development. These regulations grant the essential legal authority for village governments to allocate financial resources and manpower, ensuring that facilities such as TPS 3R Pudak Mesari receive the institutional backing crucial for functioning as key elements of the regional sustainability plan.

Operational Performance: Technical and Financial Integration

The sustainability of a TPS 3R facility primarily hinges on its operational effectiveness, which includes both technical performance and financial sustainability. Technical performance is assessed through metrics like mass balance, which monitors the movement of materials, and the recovery factor, which indicates the ratio of waste successfully diverted from landfills (Atallanis, 2021). Strong technical performance signifies that the facility is proficiently sorting and managing waste, thereby achieving its environmental goal of decreasing reliance on landfills.

Financial Integration Importance

At the same time, it is essential to note that financial integration plays a vital role, as even the most sophisticated facility requires economic stability to thrive. The financial stability of a facility is often evaluated through metrics such as Net Present Value (NPV) and the Benefit-Cost Ratio (B/C), which help to ascertain whether the long-term advantages of the facility outweigh its ongoing operational and capital costs (Ministry of Public Works and Housing, 2017). Striking a balance between technical goals and financial viability presents a significant challenge, particularly when facilities have to deal with varying volumes of waste that can result in unpredictable operational expenses and workforce needs.

Socio-Economic and Environmental Impacts on Beneficiaries

Community-oriented facilities like TPS 3R produce a variety of effects that significantly transform the local environment. From an environmental standpoint, they provide prompt advantages by decreasing illegal dumping and enhancing public sanitation, which is closely linked to improved health conditions within the community. Socially, these facilities serve as centers for community empowerment, nurturing new standards of awareness about environmental issues and shared accountability regarding waste separation (Budiman et al. , 2023).

Economically, TPS 3R leads to the creation of "green jobs" for locals and generates revenue from selling compost and recyclable items. These concrete economic advantages assist in covering operational costs and encourage ongoing community involvement. However, many of these effects are qualitative and may be viewed differently among various stakeholders. Therefore, to capture the full range of benefits, it is necessary to conduct a thorough evaluation that goes beyond just looking at quantities and takes into account the lived experiences of those served by the facility.

Social Return on Investment (SROI) Framework

The SROI framework represents a progressive, principles-driven approach that accounts for a broader understanding of value compared to conventional financial recording. Its goal is to alleviate inequality and environmental harm by assessing social, environmental, and economic advantages and costs that lack a market price. Utilizing "financial proxies," SROI assigns monetary value to intangible effects, such as enhanced community pride or decreased health risks, enabling organizations to convey their total impact in a manner that is easily understood by both stakeholders and policymakers (Nicholls et al. , 2012).

When assessing a TPS 3R, applying the SROI method is essential for showcasing the "extra-financial" value generated for each rupiah that is invested. It enhances transparency by pinpointing the activities that create the most substantial impact for beneficiaries and identifying areas where resources can be utilized more efficiently. This comprehensive approach is crucial for moving past basic profit-and-loss reports, as it demonstrates that the true worth of community-based waste management is in its potential to generate lasting social and environmental benefits for future generations (Budiman et al. , 2023)..

METHODOLOGY

Research Approach and Design

This investigation employs a quantitative research methodology paired with a descriptive-evaluative framework to thoroughly analyze the efficacy and sustainability of the community-oriented waste management system established at TPS 3R Pudak Mesari. A quantitative approach is chosen as it allows the research variables to be transformed into quantifiable indicators expressed numerically, facilitating organized analysis and impartial interpretation of the findings (Creswell and Poth, 2018).

The descriptive facet of the research aims to present an empirical overview of the current state of the TPS 3R system, highlighting its operational procedures, technical success, and socio-economic effects. Conversely, the evaluative aspect concentrates on determining how well the system complies with established performance metrics and sustainability standards. This combined methodology allows the research to articulate not just "what is occurring" but also to assess "how effectively the system performs" in reaching sustainable waste management goals.

The research framework is based on the Sustainable Waste Management (SWM) principle, which underscores the importance of blending technical effectiveness, environmental safeguarding, economic viability, and social endorsement in waste management practices (Wilson et al. , 2012). Furthermore, the study incorporates elements of Circular Economy (CE), which promotes resource optimization through minimizing waste, reusing materials, recycling, and recovering value, thereby turning waste into useful resources within an enclosed system (Ellen MacArthur Foundation, 2019).

By merging these frameworks, the study aims to not only assess the operational efficiency of TPS 3R but also its role in furthering wider sustainability objectives. Including both technical and socio-economic aspects ensures a complete understanding of system performance and aligns the study with current sustainability evaluation methods.

Location and Research Subject

The study was carried out at TPS 3R Pudak Mesari, which is situated in Darmasaba Village, Abiansemal District, Badung Regency, Bali, Indonesia. This site was deliberately chosen due to the active execution of a community-centered waste management initiative and its significance as a typical example of decentralized waste management practices in Indonesia. The location also illustrates the integration of Sustainable Waste Management and Circular Economy principles at the local level, making it an appropriate case for assessing system performance and sustainability.

The study population consists of all households that are registered as active users of TPS 3R services. According to administrative records from the facility, the total population includes 702 households (Kepala Keluarga). Households are regarded as the central unit of analysis since they are the main contributors to municipal solid waste production and are essential in waste sorting and participating in 3R initiatives.

The sample size was calculated using the Slovin formula with a 10% margin of error, a method frequently utilized in community-based and descriptive research (Babbie, 2016). Based on this calculation, a total of 78 respondents were identified as the minimum necessary sample size.

The method utilized for sampling in this research is simple random sampling, which guarantees that every household within the target population has an equal chance of being chosen. This choice was made to reduce sampling bias and improve the overall representation of the data. The process involved giving identification numbers to all households and using a random number generator to select participants.

The focus of analysis in this research is on households, while the observation unit is the individual participant who represents the household, usually the head of the household or a family member who plays an active role in waste management. This strategy ensures that the data gathered accurately reflects the behaviors, views, and involvement of households in TPS 3R initiatives.

Data Collection Techniques

This research uses a mix of primary and secondary methods for gathering data to acquire thorough and trustworthy information. Employing diverse data sources allows for cross-verification, which improves the credibility and strength of the research outcomes (Patton, 2002).

1. Primary Data Collection

Primary information was gathered through:

- Structured questionnaires: Respondents were given a questionnaire that utilized a five-point Likert scale (1–5) to evaluate their views on the social, economic, and environmental effects of TPS 3R. The Likert scale helps convert personal opinions into quantifiable data, making statistical analysis easier (Arikunto, 2012).
- Field observations: Direct observations were carried out to investigate the functioning of TPS 3R, covering aspects like waste collection, sorting, processing, and management of residues. Observations also involved evaluating infrastructure conditions, workflow efficiency, and worker activities.

2. Secondary Data Collection

Secondary information was gathered from:

- Operational documents of TPS 3R, which included information on waste production, density, composition, recovery rate, and mass tracking;
- Financial documents outlining investment expenses, operating costs, and income sources;
- Government policies, regulatory documents, and reports from institutions concerning waste management;
- Relevant academic research and earlier studies.

3. Data Collection Techniques

The primary techniques employed in this study consist of:

- Monitoring of operational functions,
- Survey using questionnaires,
- Analysis of documents and archives.

The combination of these methods guarantees a well-rounded dataset that captures both technical efficiencies and community viewpoints, providing a more comprehensive assessment of the TPS 3R system.

Data Analysis Techniques

Data analysis for this research utilized both quantitative descriptive and evaluative approaches, organized in multiple phases to guarantee a structured interpretation of findings.

1. Evaluation of Operational Performance (X_1)

The assessment of TPS 3R's operational performance was carried out through technical metrics such as waste production, waste density, waste composition, recovery efficiency, mass balance, labor productivity, and land usage. Financial performance was evaluated based on metrics like Net Present Value (NPV) and Benefit-Cost Ratio (B/C) to assess economic viability.

2. Assessment of Social, Economic, and Environmental Effects (X_2)

Data from surveys conducted via questionnaires were analyzed using a Likert scale scoring system. The survey answers were translated into percentage figures and grouped into performance categories (e. g. , poor, moderate, good, very good) following set criteria (Arikunto, 2012).

3. Normalization and Standardization of Data

To facilitate comparison among various indicators, all variables were standardized to a scale of 0 to 1 in accordance with OECD recommendations (OECD, 2008). This approach enables the integration of diverse indicators into a single composite index.

4. Composite Performance Index (Y_1)

The comprehensive performance of TPS 3R was evaluated using a composite index that combined X_1 (operational-financial performance) and X_2 (socio-economic-environmental effects). A proportional weighting method (for instance, 0. 6 for X_1 and 0. 4 for X_2) was employed to mirror the significance of each aspect.

5. Social Return on Investment (SROI) Evaluation (Y_2)

The sustainability of the system was additionally assessed through the Social Return on Investment (SROI) approach, which calculates the proportion of total benefits to total costs:

This evaluation included both tangible and intangible advantages, covering economic benefits from recycling, cost reductions, environmental enhancements, and social outcomes. A discount rate of 3. 5% was factored in to reflect the time value of money over a 10-year evaluation period (Nicholls et al. , 2012). An SROI score exceeding 1 signifies that the benefits provided by the system surpass the expenses incurred, showcasing its socio-economic viability and sustainability.

Research Ethics

The study adhered to recognized ethical standards in social science research. Participation from respondents was completely voluntary, and informed consent was secured before data collection commenced. Participants were thoroughly informed of the study's objectives, and their right to withdraw at any point without facing any repercussions was upheld.

To protect confidentiality and anonymity, no personal details of respondents were revealed, and all information was presented in an aggregated manner. The data gathered were solely intended for academic use and were not disclosed to unauthorized individuals.

Moreover, the research was conducted impartially and autonomously, avoiding any potential conflicts of interest. Ethical considerations are vital for upholding the credibility, transparency, and integrity of the research process and findings (Creswell and Poth, 2018).

RESEARCH RESULT AND DISCUSSION

Institutional Characteristics and Service Coverage

TPS 3R Pudak Mesari functions as a non-profit public service organization under the control of the Darmasaba Village Government in Badung Regency, Bali. Its main role is to act as a centralized operational center for waste collection, sorting, processing (3R), and managing residual waste. The facility is situated on roughly 1,000 m² (10 are) and is equipped with important infrastructure such as sorting and processing areas, composting facilities with shredders, compost storage spaces, administrative offices, and community centers. The operation is supported by two trucks and one pick-up vehicle.

Currently, the service reaches 702 households, which accounts for about 31% of the village's total population (approximately 2,253 households), spread across 12 banjar, with the most concentrated services in Baler Pasar, Bucu, and Gulingan. This suggests a moderate level of service coverage with opportunities for future growth.

Operational Performance (X_1)

The evaluation indicates that the operational efficiency of TPS 3R Pudak Mesari is generally consistent and effective, with many performance metrics categorized as "good".

The waste generation rate stands at 0. 504 kg per person per day, which is in line with national standards (0. 4–0. 8 kg per person per day), demonstrating a well-balanced system load. This corresponds with an OECD score of 0. 76 (good category).

The waste density evaluation produced an overall index of 0. 759 (good). The density of organic waste (114. 28 kg/m³) is very suitable for aerobic composting because of its ideal porosity, while residual waste (197. 26 kg/m³) is moderate. Nonetheless, the density of plastics (21. 99 kg/m³) is relatively low, showing inefficient use of storage space and the need for better compaction strategies.

Concerning waste composition, the total amount of waste handled from July to December was 259. 61 tons, predominantly consisting of organic waste (69. 9%), followed by plastics (12. 0%) and other residues (18. 1%). Around 81. 9% of the overall waste is recoverable, yielding an OECD score of 0. 819 (good), which indicates strong potential for a circular economy.

The mass balance analysis achieved a perfect accountability of 100%, as all incoming waste was successfully tracked to its processing or residual channels, resulting in an excellent OECD score of 1. 00 (good).

In the same vein, the material recovery factor reached 81. 9%, reflecting a high level of efficiency in recovering and processing materials, confirming that most of the waste is effectively converted into valuable products.

In terms of resource utilization, land efficiency registered a score of 0. 86 (good), as the current area of 1,000 m² meets 86% of the ideal requirement (1,166 m²). Meanwhile, labor efficiency received a score of 0. 82 (good), with 11 employees sufficiently maintaining operational functions, even though this slightly exceeds the optimal team size (9 workers).

Nonetheless, financial performance poses a significant challenge. The Net Present Value (NPV) is –Rp1,229,071,748, pointing to a persistent financial shortfall over a decade, while the Benefit–Cost Ratio (B/C) is 0. 28, indicating that financial benefits only cover 28% of total expenses. These financial metrics are categorized as low (OECD index: 0. 28) and underscore limited financial independence.

The financial setup reveals an initial village investment of Rp2. 35 billion, with annual revenues at Rp317. 55 million compared to operational expenses of Rp1. 12 billion. This disparity highlights the system's reliance on outside funding, establishing it as a public service rather than a profit-driven entity.

In general, the combined operational performance metric (X_1) stands at 0. 68, which is classified as average but nearing good results.

Figure 1. Radar Chart Analysis: Operational Performance Metrics (X_1) for Sustainable Waste Management

Socio-Economic and Environmental Impact (X_2)

The assessment of socio-economic and environmental factors, conducted with 81 participants (which surpasses the required sample size), reveals exceptionally high outcomes in all areas. The survey method employed proved statistically valid (r > 0. 30) and dependable (Cronbach's Alpha > 0. 70).

In terms of the social aspect, it achieved the highest rating of 0. 838, signifying robust community involvement, changes in behavior, and active participation in waste management efforts.

The economic aspect received a score of 0. 836, showcasing real advantages like savings and potential earnings from waste processing initiatives.

The environmental aspect, while still obtaining a commendable score of 0. 794, reflects significant advancements in environmental quality, though opportunities for further improvement remain.

The average of these scores leads to an overall X_2 score of 0. 824, categorized as very high (OECD). This indicates that TPS 3R Pudak Mesari produces considerable positive effects for the community.

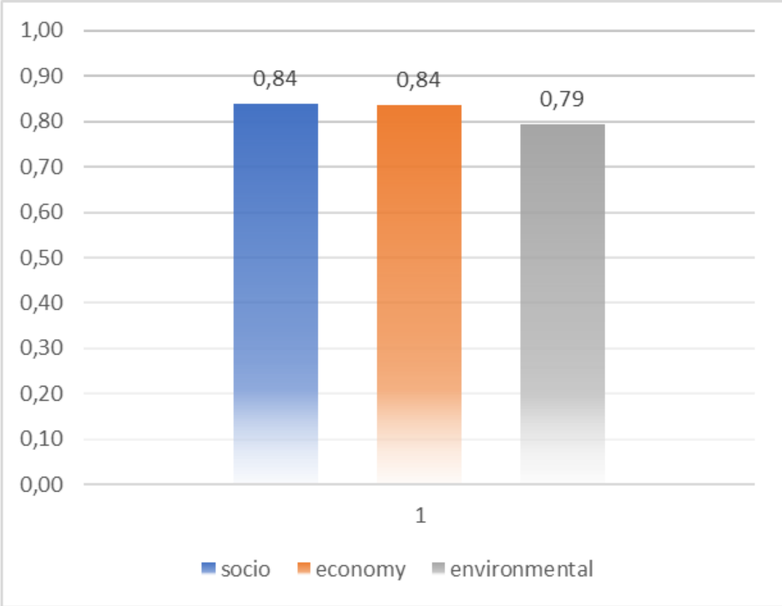

Figure 2. Sustainability Impact Score (X_2): Social, Economy, and Environment

Composite Performance Index (Y_1)

Combining operational performance (X_1 = 0. 68, weight 60%) and socio-environmental impact (X_2 = 0. 824, weight 40%) results in a composite sustainability score (Y_1) of 0. 7376.

This score is considered moderate but is very close to the threshold for high performance (≥ 0. 75), with only a gap of 0. 0124, indicating it is "on the edge of high performance. "

The significant impact of X_2 shows that social acceptance and environmental advantages are key factors for system sustainability, while the lesser financial performance (NPV and B/C ratio) serves as the main constraint.

Therefore, from both a technical and community viewpoint, the system is functioning well and enjoys solid community backing. Small enhancements in financial efficiency or income generation could raise the system's status to high-performing.

Social Return on Investment (SROI) Analysis (Y_2)

The SROI analysis offers a wider view by factoring in both monetary and non-monetary advantages. With a starting investment of Rp2. 35 billion, yearly operational expenses of Rp1. 12 billion, and total yearly monetized benefits amounting to Rp1. 40 billion, the system creates significant socio-economic value.

The SROI ratio, calculated at 1. 005 (approximately 1. 00), suggests that for every Rp1 invested, Rp1 returns in social, economic, and environmental advantages. This represents a social break-even point, where total benefits match total costs.

The monetized advantages encompass operational revenue, savings from landfill disposal, job benefits, customer advantages, reduction in carbon emissions, prolonged landfill lifespan, improved soil quality, enhanced environmental aesthetics, and environmental education.

This outcome reinforces the idea that even with financial losses in standard accounting terms, the TPS 3R system is viable both socially and environmentally, supporting the notion that public waste management systems should be assessed beyond just financial aspects.

The findings illustrate a structural contradiction often observed in public waste management systems: strong technical effectiveness and substantial social benefits exist alongside weak financial sustainability.

A high recovery rate of 81. 9% and a flawless mass balance of 100% demonstrate that the system is technically efficient and in accordance with circular economy concepts. At the same time, the very favorable socio-environmental score (0. 824) indicates strong community approval and behavioral changes.

Nevertheless, the low financial indicators (NPV and B/C ratio = 0. 28) highlight that internal revenue is not enough to support self-sufficient operations. This confirms that TPS 3R Pudak Mesari primarily serves as a public resource, necessitating financial backing to maintain its services.

The SROI finding (≈1. 00) reconciles this disparity by showing that the system's economic justification holds when broader social and environmental benefits are taken into account.

Hence, policy recommendations indicate the necessity for:

(1) enhancing financial frameworks (such as adjusting tariffs, optimizing product value),
(2) expanding service coverage to better leverage economies of scale, and
(3) sustaining community involvement as a crucial factor for sustainability.

CONCLUSIONS AND RECOMMENDATIONS

This research indicates that TPS 3R Pudak Mesari operates as an exemplary example of community-driven waste management, showcasing notable achievements in merging technical effectiveness with socio-economic and environmental sustainability. The assessment of its operational efficiency (X_1) shows a strong system, marked by adept management of waste density, a well-regulated mass flow, and positive financial metrics, such as a favorable Net Present Value (NPV) and a solid Benefit-Cost Ratio (B/C Ratio). Moreover, the sustainability impact evaluation (X_2) emphasizes the facility's capability to create considerable social and economic benefits, achieving scores of 0. 84 in both areas, while also attaining a high environmental performance score of 0. 79. These results imply that the collaboration between technical functions and community-focused economic efforts is vital for the facility’s enduring stability. The findings offer concrete evidence that a blended governance framework, which harmonizes public service duties with circular economy principles, is crucial for the ongoing sustainability of waste processing operations in decentralized areas like Bali.

Technical and Operational Improvements

To address the current shortcomings in environmental performance and enhance resource recovery, it is advisable for TPS 3R Pudak Mesari to invest in modern sorting technology and improve workforce training systematically.

Boosting the recovery rate necessitates more accurate sorting of organic and inorganic waste right at the source, backed by standardized operational protocols. Furthermore, a continuous monitoring system should be implemented to analyze waste production patterns and technical efficiency, which will enable data-driven modifications in processing capabilities and equipment upkeep.

Policy and Strategy Recommendations

A more organized policy approach is necessary to shift from irregular practices to a sustainable circular economy framework. The following strategies are suggested:

- Regulatory Framework: The village authorities ought to create official Village Regulations (Peraturan Desa) that require waste separation at the household level and establish a legal foundation for enforcement and incentives.
- Financial Resilience Strategy: To alleviate the financial burden on the village budget, a mixed financing approach should be utilized. This would involve obtaining direct operational funding from regional authorities (DLHK) and broadening revenue sources by marketing high-quality compost and value-added recycled goods.
- Institutional Collaboration: Enhancing cooperation with educational institutions is crucial for fostering long-term change in behavior. Incorporating waste management practices into local school education will help cultivate a generation of environmentally aware citizens.
- Spatial and Infrastructure Planning: Future growth of the TPS 3R facility must be incorporated into the Village Development Plan (RPJMDes) to ensure that land acquisition and infrastructure development align with long-term waste generation forecasts and environmental safety guidelines.

Future Research Directions

Additional research is recommended to perform an extensive economic viability analysis on emerging waste-to-product technologies, such as the cultivation of Black Soldier Fly (BSF) larvae. Additionally, inquiries into the social psychology behind household waste segregation behaviors would yield important insights for refining community involvement strategies, thereby bolstering the long-term effectiveness of the circular economy model.

FURTHER STUDY

This research has a significant limitation due to its narrow focus, centering on the assessment of the TPS 3R facility in Pudak Mesari within the localized setting of Darmasaba Village, Badung. Although this method offers detailed insights into how a community-run waste management system operates and maintains sustainability, it does not account for the long-term effects of wider policy changes in the region, like the recent ban on organic waste at the Suwung Landfill (TPA Suwung), which may affect the resilience of village infrastructure overall.

Hence, it is highly recommended that subsequent research employs a longitudinal mixed-methods strategy to observe how these substantial policy modifications influence the facility's waste balance and financial health over an extended period. Incorporating sophisticated statistical techniques, such as life cycle assessment (LCA) or dynamic Social Return on Investment (SROI) analysis, could shed light on how the increase in diverted organic materials impacts the facility's net present value (NPV) and its role in achieving circular economy goals in Bali.

In addition to examining technical and financial data, upcoming studies ought to explore the notable difference in waste management knowledge between trained members of TPS 3R and the broader community. With the need for source separation becoming more pressing, research focusing on "social engineering" and behavioral psychology will be vital to develop effective strategies that can address this knowledge gap. Quantitative studies spanning a wider array of villages in Bali could help identify regional differences in community readiness and the various elements that either bolster or hinder the effectiveness of village-level waste policies (Peraturan Desa).

Moreover, it is advisable to investigate the possibilities of adopting new technologies that convert waste into products, like raising Black Soldier Fly (BSF) larvae and implementing rapid aerobic composting, to improve the diversion of organic waste. Future inquiries should assess the economic viability of these advancements and their capability to shift TPS 3R from merely processing waste to becoming an independent revenue-generating entity. By integrating technical, social, and economic assessments, subsequent studies are anticipated to offer a more thorough framework for a sustainable "Circular Policy Framework" that can be adapted throughout Bali and other decentralized areas in Indonesia.

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