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# Circular Economy-Based Waste Business Transformation through Appropriate Technology and Digital Management

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**Abstract**

**Purpose:** This community service program aims to transform the conventional waste processing unit in Mendalo Indah Village into a self-reliant waste processing enterprise and a productive organic fertilizer producer.

**Methodology:** The program employs a Participatory Technological Development (PTD) approach, integrating field surveys, Focus Group Discussions (FGDs), training, and evaluation based on the CIPP (Context, Input, Process, Product) model. Physical technological innovations implemented include a 7 HP biomass shredder and six 120-liter composting drums, combined with managerial innovation via the AppSheet digital application.

**Results:** The initiative resulted in a 30% reduction in waste residue sent to the landfill and the production of 1,500 kg of solid organic fertilizer and 150 liters of liquid organic fertilizer. The adoption of the digital recording system reached 100%, yielding an operational profit margin of 51.17%, bolstered by an offtaker agreement with a local farmer group.

**Conclusions:** The findings confirm that integrating appropriate technology and digitalization driven by community participation effectively creates a self-reliant circular economy.

**Limitations:** The limitations include the short-term timeframe for evaluating the financial impact (four months) and a raw material supply chain that does not yet encompass the entire village scale.

**Contributions:** This program offers practical contributions, specifically a waste management blueprint for local governments and Village-Owned Enterprises (BUMDes), as well as theoretical contributions to the fields of environmental engineering and social entrepreneurship.

**Keywords:** *Appropriate Technology, Business Transformation, Circular Economy, Managerial Application, Waste Processing*

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## 1. Introduction

Suburban areas are currently undergoing drastic changes driven by high rates of urbanization and population growth. This transformation from agrarian land into densely populated settlements inevitably triggers new challenges, specifically a sharp rise in daily domestic waste generation. In Indonesia and other developing nations, this phenomenon poses a serious challenge, as the pace of waste management infrastructure development often fails to keep up with the rapid expansion of

residential areas in these countries. Addressing this environmental crisis requires more than just the financial capacity of local governments; it demands strong cross-sector collaboration incorporating innovations from higher education institutions and the willingness of local communities to establish a circular waste management system.

At the local level, Mendalo Indah Village in Muaro Jambi Regency serves as a prime example of the distinct characteristics of a suburban or "urban fringe" area. Its geographical location places it at the heart of the province's higher education growth, a fact empirically underscored by the establishment of two large university campuses in the vicinity (Kuswanto et al., 2021). These academic hubs naturally act as magnets, drawing thousands of students and migrants from various regions. This massive influx of people has gradually reshaped village life, transforming the area into a high-density residential and commercial hub of the region. Undoubtedly, the expansion of the property sector, particularly the growth of *Perumnas* (state-owned housing) developments, reflects the rapid trend of construction around Mendalo Indah (Kohar & Kuswanto, 2016). However, these economic activities and residential expansion have posed dangerous environmental threats. A dramatic surge in household waste volume has emerged and continues to escalate year after year; however, this phenomenon has not been matched by any corresponding modernization of waste management practices. Facts on the ground indicate that current waste processing capacities and facilities are completely disproportionate, consistently lagging, and failing to keep pace with the volume of daily waste generated by residents.

Spatial layouts dominated by high-density housing inherently lead to concentrated waste generation within a single area. When analyzed through the lenses of social engineering, economics, and environmental sustainability, these demographic characteristics present a significant strategic opportunity to implement a community-based, collective waste management model. Logistically, road accessibility and fleet transport efficiency in residential areas are far more structured and manageable than traditional rural settlement patterns, which tend to be randomly dispersed and separated by vast distances. However, this immense potential remains an untapped asset that has not been optimally utilized. For years, the environmental management system employed in the area has remained stuck in a linear paradigm, with operations limited to a classic routine of collecting waste from households, transporting it in open vehicles, and simply dumping it. This conventional linear consumption pattern needs to be transformed into a holistic circular approach, which has been proven to maximize the value of waste streams and turn them into cost-saving and revenue-generating opportunities (Romero-Hernández & Romero, 2018). Consequently, virtually the entire volume of household waste is transported directly to the final disposal site (TPA) as mixed waste, completely bypassing circular economy principles and omitting sorting or volume reduction at the source.

At the neighborhood level, the entity spearheading waste management is a local partner unit. This independent enterprise is typically operated by an individual with management capacity akin to that of a small family business. In its daily operations, the partner bears a significant responsibility of collecting waste from approximately 300 residential households within the area. Based on national estimates assuming a per capita waste generation rate of 0.5 kg per day and a standard household size of four, the daily volume of waste requiring removal is substantial (M. A. Pratama et al., 2025). The collection fleet is estimated to handle a mixture of organic and inorganic materials weighing over 600 kg daily, which accumulates to 14 tons of solid waste per month.

Ironically, the workflow implemented by this operator is remarkably brief and generates neither economic nor ecological values. This structural weakness stems from a lack of intermediate treatment facilities. The absence of essential supporting infrastructure, such as ergonomic waste-sorting stations, shredders for reducing plastic and biomass materials, and communal composting facilities, causes management efficiency to plummet to its lowest level (Prasetia et al., 2025). As a direct consequence of these infrastructure limitations, all household waste still commingled within bags, including food scraps, paper, potentially marketable plastic packaging, and hazardous and toxic household waste (B3), is inevitably collected and disposed of en masse at the final disposal site (TPA). This cycle persists, resulting in the absolute disposal of materials without engaging recycling mechanisms at the source.

The systemic issues faced by waste management partners are highly complex. The root causes range from weak management practices and low technology adoption to stagnant innovation in the grassroots supply chain. From an institutional governance perspective, these management entities still operate within the informal sector because of the absence of a legal framework or officially recognized business status. This situation directly precludes them from securing capital injections from banking institutions and hinders the establishment of sustainable partnerships with large-scale recycling companies (Rahman & Wibisono, 2026). Furthermore, day-to-day administrative tasks, such as recording resident fees, summarizing transactions, and tracking material tonnage, still rely on conventional, paper-based bookkeeping methods. These manual practices are not only susceptible to physical damage or data loss, but also frequently lead to record discrepancies, making it difficult for managers to accurately compile monthly profit and loss statements (Aladejebi & Oladimeji, 2019). Transitioning to digital platforms and Industry 4.0 applications, such as the Internet of Things (IoT) and artificial intelligence, is crucial as they enhance collection efficiency and traceability within a circular economy system (Ayeni, 2025) (Cheah et al., 2022). Furthermore, precise digital recording facilitates the tracking of vital solid waste management indicators, such as operating costs and collected volumes, which are necessary for evaluating progress (Reis et al., 2023).

Furthermore, an analysis of financial resilience reveals that the financing structure of this microscale business unit is highly vulnerable. Revenue derived primarily from resident fees, ranging from IDR 20,000 to IDR 30,000 per household, is almost entirely consumed by basic operating expenses. These funds are immediately depleted by the costs of transport fleet fuel, routine vehicle maintenance, and manual labor wages. Meanwhile, upstream challenges are equally complex, stemming from the interaction patterns between service providers and the community, which tend to be rigid and purely transactional. A collaborative mindset has yet to fully emerge; consequently, residents remain passive customers rather than active agents in driving environmental sustainability. This failure to foster public participation directly impacts the quality of the collected recyclable materials (Pambudi et al., 2025). The absence of a culture of waste sorting at the source (i.e., household kitchens) leads to quality degradation in high-value inorganic commodities, such as PET and HDPE plastics, owing to contamination by leachate and organic residues from food waste (Eriksen et al., 2019).

Given the high level of complexity inherent in the previously outlined issues, the philosophical foundation and primary objective of this community service program are directed toward comprehensive transformation. This initiative was designed to redefine the strategic position of waste management partners in Mendalo Indah Village. The specific target is to shift their operational paradigm, hitherto confined to conventional waste hauling services generating only subsistence-level income, enabling them to evolve into micro-entrepreneurs in the organic fertilizer production sector. This fundamental shift in orientation is intended to proceed progressively while remaining steadfastly committed to the principles of circular economy and environmental sustainability.

Reflecting on the program's initial conceptual design, the implementation team had originally recommended establishing a community-level "Waste Bank." The initial scheme proposed a management system requiring active resident participation, supported by a digitally integrated record-keeping system. However, the empirical dynamics observed during fieldwork revealed a far more challenging reality. The team identified several critical obstacles, ranging from the partners' limited human resource capacity to the local community's low level of awareness regarding waste sorting at the household level. Furthermore, the complex bureaucracy and administrative burdens associated with operating a waste bank are likely to create new problems (Budiyarto et al., 2025). Ultimately, these structural barriers were assessed as significant risks that could jeopardize the program's chances of success and its long-term sustainability.

In response to the various technical and sociological challenges encountered in the field, the community service implementation team decided to pivot its strategy. This adjustment was deemed more realistic and immediately applicable to the specific conditions of the target partners. The initial plan, which focused on establishing a community-based waste bank institution, was shifted to specifically initiating an organic fertilizer production unit, covering both solid and liquid forms. The

rationale for this shift in focus is grounded in compelling empirical findings. An analysis of daily waste generation in Mendalo Indah Village revealed that organic waste dominated the material discarded by residents, accounting for 65 percent of the total waste volume.

By focusing on managing this organic material, the team aimed to address the issue of household waste accumulation in a more systematic and measurable manner. This management strategy prioritizes strengthening the operational capacity of waste management partners. The decision to adopt a centralized approach was deliberate; the team recognized that environmental mitigation efforts should not stall while waiting for residents to change their waste sorting habits, given that fostering public awareness and behavioral change requires a long-term process of guidance and support.

To realize these integrated empowerment goals, the community service team provided various forms of physical infrastructure and software support for the project. This technical assistance included the provision of a waste shredder powered by a 7 HP diesel engine and 120-liter composting units, as well as the implementation of a digital administrative system using the AppSheet platform. By integrating the adoption of appropriate technology with improved management systems, the project aims to significantly enhance the socioeconomic well-being of the partner community. Ultimately, this innovative program is designed not only to foster financial independence by generating sustainable income streams for local entrepreneurs but also to play a crucial role in ecological preservation in Mendalo Indah Village by minimizing the volume of waste residues sent to the final disposal site (TPA).

## 2. Research Methodology

This series of community empowerment activities was implemented using the Participatory Technological Development (PTD) framework. The rationale for selecting the PTD method was to ensure that partner groups were not merely passive beneficiaries; instead, they were encouraged to act as key players throughout the transformation process. Fundamentally, the intervention aimed to overhaul a waste management business that was previously operating traditionally and was limited to a "collect-transport-dispose" model, and transform it into an independent waste processing enterprise that also serves as a production center for valuable organic fertilizer. To achieve this goal, an implementation scheme was systematically designed in five integrated strategic stages. Further details regarding the stages, activities, participating parties, outcomes, and indicators for each stage are summarized in Table 1.

Table 1. Stages of Community Empowerment Program Implementation

| Phase | Activities | Participants | Outcomes | Indicator |
|---|---|---|---|---|
| Phase 1: Multi-stakeholder outreach and consolidation | Targeted educational approach and Focus Group Discussions (FGD). | Waste managers, village government officials, and local community representatives were interviewed. | Alignment of perspectives, agreement on the household waste supply chain, and finalization of the legal framework/partner's legal status. | The establishment of communication that shifts the system from conventional fee collection to an integrated communal waste management system. |

| Phase | Activities | Participants | Outcomes | Indicator |
|---|---|---|---|---|
| Stage 2: Capacity building (human resource quality) | Intensive knowledge dissemination across three areas: digitalization (AppSheet), production engineering (sorting, operation of seven HP shredders and composters), and upstream sector development. | The management team, technical operators, residents, and PKK cadre groups. | Enhancement of administrators' skills in digital administration and the operation of physical facilities, alongside the identification of 12 categories of economically valuable waste by residents. | Operators can record transactions in real time via smartphones, while residents understand the 7R principles and waste sorting. |
| Stage 3: Field implementation (technological innovation) | Facility layout optimization at the partner site (organizing waste processing facility zones; positioning sorting tables, 120-liter drum composters, and shredders) and implementation of a fully digital recording system. | Implementation team and partners. | Reconfiguration of upstream-to-downstream operations and implementation of an application to track daily profit and loss. | Partner commitment is demonstrated by 100% participation, the voluntary provision of private land for the waste processing facility (TPST), and mobilization of independent labor. |
| Stage 4: Operational support and evaluation (4 months) | Technical support for application troubleshooting, quality control (QC) of the compost output, and evaluation based on the CIPP framework. | The academic team and partners. | Resolution of digital-related issues and quality assurance for the organic compost produced. | There has been a significant increase in the volume of organic waste that has been successfully composted, alongside improved administrative management efficiency. |
| Stage 5: Formulation of sustainability strategy (exit strategy) | Handover of Standard Operating Procedures (SOPs) for the application and machinery operations, alongside the facilitation of a cooperation agreement (MoU) with a farmer group acting as an off-taker (regular buyer). | Implementation team, waste management team, and local farmer groups were involved. | Handover of the complete Standard Operating Procedures (SOP) to partners and formalization of sales contracts with regular buyers. | Guaranteed market access and stable selling prices for organic fertilizers create a self-sustaining and financially viable business cycle. |

In the first phase, the implementation team initiated a socialization agenda alongside multi-stakeholder consolidation. Targeted educational approaches and comprehensive assistance during this phase are essential, as they can significantly increase community knowledge and awareness of waste sorting and sustainable processing (Harahap et al., 2024); (Safrudin et al., 2026). This initial step was

carried out through Focus Group Discussions (FGDs) involving waste management operators, village government officials, and local community representatives. These discussions were specifically designed to align perspectives and reach an agreement on the supply chain mechanism for waste sourced from households. Furthermore, FGDs served as a foundation for finalizing the partners' institutional legal framework. The meetings also provided an effective communication platform to introduce a new waste service model: shifting from a conventional collection fee system to a far more integrated communal waste management system.

In the second stage, the intervention focuses entirely on capacity building, specifically enhancing the quality of partners' human resources. This knowledge dissemination process is conducted intensively and is divided into three areas of competency. The first area focuses on the management of administrative digitalization; in this session, managers receive technical guidance on mastering the "AppSheet" platform, enabling them to proficiently record daily transactions and maintain financial records in real time using only a smartphone. The second area emphasizes production engineering, equipping operators with practical skills ranging from waste sorting techniques to the operation and maintenance procedures for seven HP shredders and Rotary Kiln composting units. The introduction of shredding machinery, accompanied by structured socialization on the 7R principles, has been shown to effectively enhance community understanding and participation in sustainable waste management (Hadi et al., 2025). Finally, the third area targets the upstream sector to secure the supply of raw materials; this involves providing guidance to residents and PKK cadre groups, enabling them to identify and sort 12 categories of waste that offer high economic values.

Entering the third phase, considered the most critical, the program proceeded with the field implementation of technological innovations. Regarding physical infrastructure, the implementation team reconfigured operations from upstream to downstream by establishing zoning within the Integrated Waste Processing Site (TPST). At the partner's work site, the team organized supporting facilities, including dedicated sorting tables and 120-liter composting units and installed mechanical shredding machines. From a managerial perspective, this phase marked the start of a fully digital record-keeping system, enabling partners to accurately track their business profits and losses. Notably, the partners demonstrated exceptional commitment during this stage, achieving a 100 percent participation rate. This tangible support was evidenced by in-kind contributions, with the operator dedicating private land to serve as the TPST hub and independently mobilizing the necessary workforce to operate the facility.

The fourth stage involved intensive operational support and program evaluation, which was conducted continuously over a full four-month period. During this phase, the academic team assisted the partners in troubleshooting technical issues with the digital application and conducted quality control assessments of the compost yield. To measure success, the team utilized the Context, Input, Process, Product (CIPP) evaluation framework. The key evaluation metrics focused on the significant increase in the volume of organic waste successfully converted into compost and the efficiency gains in administrative management following digitalization. The comprehensive results of the program evaluation are summarized in Table 2.

Table 2. Program Evaluation Matrix Based on the CIPP Framework

| CIPP Components | Evaluation Indicators | Results |
|---|---|---|
| Context | Alignment of the program with environmental issues and partner needs. | Changing the waste management system from a linear model to a circular economy is essential. |
| Input | Availability of physical technology and management software. | Procurement of seven HP chopping machines, six 120-liter composter drums, and AppSheet application. |
| Process | Community participation, technology adoption, and administrative efficiency. | The number of customers increased (from 300 to 360), and the adoption of digital applications by administrators reached 100%. |

| CIPP Components | Evaluation Indicators | Results |
|---|---|---|
| Product | Fertilizer production output, reduction of waste sent to landfills, and financial performance are also considered. | The amount of residue sent to landfill decreased by 30%, solid fertilizer production reached 1,500 kg, liquid fertilizer production reached 150 liters, profit margin reached 51.17%, and a marketing MoU was formed. |

Finally, the fifth stage centered on formulating an exit strategy to ensure the partner's continued self-reliance after the project was concluded. This sustainability plan was implemented by handing over Standard Operating Procedures (SOPs), covering both application management and technical machinery operations, to the management team. To secure the end-to-end commodity supply chain, the implementation team also facilitated a formal agreement, marked by the signing of a Memorandum of Understanding (MoU) with a local farmer group acting as an off-taker (regular buyer). This partnership aims to guarantee a reliable market and stabilize the selling price of organic fertilizer (both solid and liquid forms). Consequently, the partner's business unit can maintain a self-sustaining and continuous financial cycle in the future.

## 3. Results and Discussion

The community service initiative in Mendalo Indah Village went beyond merely testing the feasibility of a management method; it focused on implementing tangible solutions to address the waste management challenges faced by partners on the ground. The previous linear management system, characterized by a "collect-transport-dispose" approach, was successfully transformed into a circular economy ecosystem that generated direct economic value for the partner groups. The intervention prioritized the application of appropriate technology and improvements to management systems, enabling partners to achieve operational and financial independence. The implementation of these practical solutions to empower the partners comprised four key actions: (1) the process of institutional restructuring accompanied by increased resident participation; (2) the optimization of physical waste processing technology, primarily through aerobic decomposition mechanisms; (3) the modernization of management systems centered on administrative digitalization; and (4) the formulation of strategies to ensure economic sustainability through market downstreaming schemes for the resulting derivative products.

### *3.1 Institutional Transformation and Integration of Public Participation Systems*

The initial phase of this intervention program yielded highly positive results, particularly in restructuring the management organization and shifting residents' perspectives on waste management. As visually documented in Figure 1, the implementation team initiated a persuasive approach through Focus Group Discussions (FGDs) and extensive outreach campaigns. These face-to-face activities actively engaged village government officials, local community leaders, and the broader Mendalo Indah Village population. Thanks to this communicative approach, the target partner, which initially operated at a subsistence level providing conventional waste hauling services (focused on a "collect-transport-dispose" model), was successfully transformed into a micro-enterprise within the fertilizer production sector. Meanwhile, the grassroots community, driven primarily by Family Welfare Empowerment (FWE) cadres and individual households, began demonstrating proactive engagement. Empowering communities through cadres acts as a necessary trigger to change public attitudes, fostering independence, and encouraging positive actions in managing household waste into products of economic value (Arti et al., 2024). After receiving in-depth education on the economic value of daily waste, they consciously position themselves as key supply chain agents for organic waste raw materials. The collaborative engagement between the implementation team, local government, and community during the initial dissemination phase is shown in Figure 1.

Figure 1. Dissemination of the community service program to the government, community leaders, and residents of Mendalo Indah Village

Intervention at this initial stage focuses on direct social engineering to address the lack of resident awareness regarding waste sorting by transforming a financial cost into an economic incentive, in line with the community-based waste management principles (Suryani, 2014). Given that Mendalo Indah Village is situated in a suburban area experiencing massive residential expansion (Kohar & Kuswanto, 2016), the practical solution implemented by the team involved providing educational guidance to encourage residents to sort organic waste at source. Through this persuasive approach, the team tangibly repositioned residents from mere "waste disposal service customers" to strategic partners in the raw material supply chain, a form of collective community action that serves as an essential foundation for implementing environmental conservation at the household level (Kurniadi et al., 2024). The direct impact of addressing this social issue is evident in the secured supply of raw materials for partner composting operations, as demonstrated by the increase in the number of participating residents from 300 to 360 (Table 3 ).

Table 3. Increase in the Number of Residents/Organic Waste Customers Before and After the Program

| Period | New Customers Added (Persons) | Total Participating Customers (Persons) | Progress Notes |
|---|---|---|---|
| Pre-Program | - | 300 | Initial baseline before program intervention |
| Week 1 | 6 | 306 | Initial program dissemination phase |
| Week 2 | 15 | 321 | Surge in enthusiasm driven by resident promotion |
| Week 3 | 4 | 325 | Temporary slowdown in growth rate |
| Week 4 | 18 | 343 | Significant increase following process evaluation |
| Week 5 | 5 | 348 | Adjustment of field operational schedules |
| Week 6 | 12 | 360 | Stable growth by the end of the evaluation period |

The success of this social engineering and institutional transformation is not merely qualitative; it is also empirically validated by metrics regarding citizen participation growth, as detailed in Table 1. Prior to the program's implementation, baseline data indicated that only 300 residents were registered as service users. However, as the intervention progressed, a dynamic upward trend in participation emerged over the six-week monitoring period. During the initial week of outreach, the program attracted six new user. Notably, the second week saw a sharp surge in enthusiasm, with 15 additional users joining, driven by the powerful effect of word-of-mouth promotion among residents, bringing the total number of users to 321. Although the growth rate slowed temporarily in the third week (adding only four users), participation figures skyrocketed again in the fourth week, setting a record of

18 new users. This fourth-week surge was a direct result of the evaluation and refinement of the field collection procedures. Following operational schedule adjustments in the fifth week (adding five users), growth stabilized in the sixth week with 12 new participants added. By the end of the evaluation period, the total number of actively participating residents had increased significantly from 300 to 360. The addition of 60 organic waste-contributing users within this short timeframe serves as irrefutable evidence of the high level of public acceptance and adoption of the implemented circular waste management system in the community.

### *3.2 Implementation of Appropriate Technology as a Solution to Reduce Waste Accumulation for Partners*

The subsequent essential phase of this empowerment program focuses on implementing hardware-based innovations to strengthen partners' operational capacity in the field. The implementation team facilitated the procurement of vital infrastructure, specifically a 100 cm material shredder powered by a 7 HP diesel engine, and integrated it with six drum-style composting reactors, each with a 120-liter capacity. The performance of these physical facilities was rigorously evaluated using the "Product" component of the CIPP model framework throughout the four-month assistance period. The results demonstrated a dramatic shift in the partners' waste material management, with the production capacity surging to an optimal level.

Table 4. Waste Generation and Reduction (Recording Period: July 20 – August 22, 2026)

| Production Indicators / Metrics | Capacity / Baseline Monthly Target | Actual Realization (20 Jul – 22 Aug) | Achievement Details |
|---|---|---|---|
| Reduction in Residual Waste Volume | - | Decreased by 30% | A 30% reduction in waste residue sent to landfills was recorded owing to processing optimization. |
| Solid Fertilizer Production | 800 kg | 1,500 kg | An average of 50 kg/day × 30 working days. The production exceeded the baseline monthly capacity. |
| Liquid Fertilizer Production | 100 liters | 150 liters | Average of 5 L/day × 30 working days. Production exceeded the baseline monthly capacity. |
| Operational Days | 24 – 26 days (6 days/week) | 30 Working Days | The total duration was 34 calendar days, minus 4 weekly rest days. |

The quantitative achievements of the technological intervention are clearly documented in Table 4, which breaks down the production metrics during the evaluation period of July 20 to August 22, 2026. Over these 34 days, the partner demonstrated high productivity by logging 30 effective working days, interrupted by only four weekly rest days, thereby surpassing the initial baseline projection of approximately 24–26 operational days. This high level of operational activity directly resulted in an output surge that exceeded the initial expectations. The production of Solid Organic Fertilizer (SOF) reached 1,500 kg, far exceeding the 800 kg monthly target, with a consistent daily output of 50 kg. The successful conversion of this local waste into solid organic fertilizer not only provides an effective solution to environmental pollution but also fosters agricultural independence by reducing farmers' reliance on subsidized inorganic fertilizers (Bolly et al., 2021); (Faizal et al., 2026). In line with this positive trend, Liquid Organic Fertilizer (LOF) production also surpassed targets, rising from a baseline capacity of 100 liters to 150 liters, driven by a consistent daily yield of 5 L. Overall, the operation of this mechanical equipment effectively reduced the volume of household waste sent to the final disposal site (TPA), achieving a 30% reduction. The specific mechanical equipment driving this production capacity (Figure 2, Figure 3), along with the resulting liquid and solid organic fertilizers (Figure 4 and Figure 5), are illustrated in the following sections.


Figure 2. 7 HP Shredder

Figure 3. 120 L Composting Drum

Figure 4. Liquid organic fertilizer

Figure 5. Solid organic fertilizer

A tangible solution to address the slow decomposition of the partner's organic waste piles is the implementation of a 7 HP shredder. This physical intervention directly accelerates daily processing, as the machine efficiently alters the physical characteristics of the biomass into much smaller particles(Ihenyen & Ekemube, 2025). Reducing the size of waste material is a crucial practical step that increases the surface area available for decomposing microorganisms to work optimally, thereby rapidly resolving the issue of waste piles that previously took a long time to break down (Petrášek & Nidetzky, 2025).

Furthermore, the implementation team addressed complaints from the partner and local residents regarding the pungent odor from the waste piles by installing six 120-liter drum composting reactors. The use of these enclosed drums effectively resolves the issue of poor oxygen circulation (anaerobic conditions) associated with open windrow methods, which often trigger the release of foul-smelling gases, such as hydrogen sulfide and methane (Li et al., 2023). Through the application of this appropriate technology package, the cycle of environmental problems at the partner's site was broken, and waste piles were successfully transformed into marketable derivative products (Purba et al., 2023). The success of this solution is evidenced by the physical quality of the organic fertilizer produced by the partner, which now meets premium standards: it has a loose texture, deep black color, and neutral, fresh-soil aroma.

### *3.3 Digitalization of Managerial Governance through Soft Innovation*

A critical area targeted for improvement during this community service program was the fragile conventional administrative system of the partners. Prior to the intervention, all financial transaction recordings and operational cost recapitulations were performed manually using paper-based ledgers. Such practices harbor significant vulnerabilities, ranging from a high risk of data distortion and wasted work time to information asymmetry among management team members (A. P. Pratama & Chumaidiyah, 2025). To overcome these challenges, the program team introduced a software-based solution ("soft innovation") by adopting a cloud-based digital management platform called "AppSheet." This platform was directly integrated into the managers' smartphones. As illustrated by the interface shown in Figure 6, the application was designed for ease of use, facilitating the recording of a business unit's daily financial inflows and outflows. Intensive mentoring demonstrated that migrating to the digital system successfully boosted governance accountability almost immediately. Managers now possess the capability to track various operational metrics in real time, ranging from diesel fuel expenditure and worker honorarium details to calculations of raw material volumes entering the composter and the recording of fertilizer sales transactions to end consumers. The user interface of this AppSheet application, which facilitates the daily recording of income and expense metrics, is presented in Figure 6.

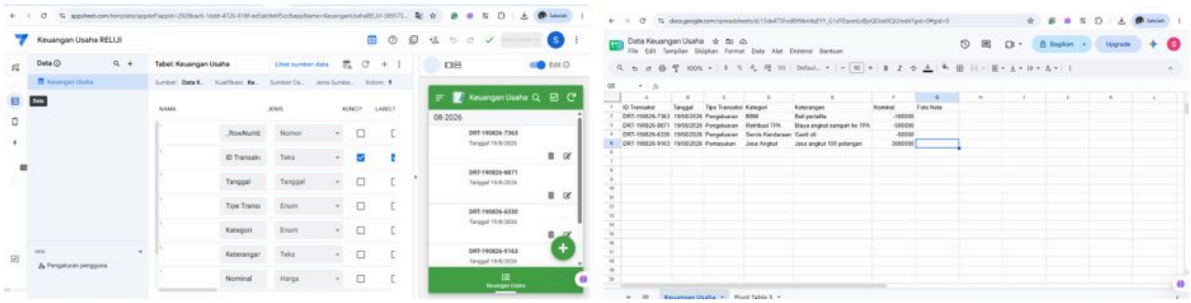

Figure 6. "AppSheet" application for recording the income and expenses of the waste processing business.

A tangible solution to untangling the bureaucratic complexities of partners' conventional bookkeeping lies in the adoption of the AppSheet digital platform. The fact that partner administrators achieved a 100 percent adoption rate within a short period demonstrates the software's high practicality and ability to resolve confusion regarding field-level record-keeping. This digital implementation directly eliminates daily administrative inefficiencies while enhancing partners' organizational governance capacity, an intervention proven effective at the grassroots level (Fatimah & Ema, 2024). Beyond merely shifting record-keeping from paper to digital screens, this digital support serves as a concrete step that enables partners to transition from an informal business ecosystem to formal sector governance standards. With transaction records securely stored in a spreadsheet database, partner managers can now practically calculate the Cost of Goods Sold (COGS) and precisely evaluate the efficiency of their transport fleets. Implementing this app-based management information system represents a fundamental empowerment measure, enabling village-level institutions to compile transparent financial statements and ultimately opening doors to access capital from external financing agencies (Siahaan et al., 2025).

The effectiveness of the aforementioned governance improvements can be quantitatively evaluated using partner business financial records. Figure 7 illustrates the weekly cash flow trends for the "Religious-Based Waste Processing" business unit over a full six-week monitoring period. An analysis of the data reveals highly dynamic yet realistic financial activity for communal environmental management businesses. During the initial two weeks (Weeks 1 and 2), revenue surged to its peak, reaching Rp3,400,000 and Rp3,100,000, respectively. This high liquidity early in the period was driven by two key factors: the robust collection of sanitation service fees from residents and strong market uptake resulting from bulk purchases of solid organic fertilizer by local farmer groups preparing their land. In the subsequent phase (weeks 3–6), the revenue trend leveled off, stabilizing at approximately Rp2,700,000 per week. Income during this mid-to-late-month period was primarily driven by daily fee collections and retail sales of Liquid Organic Fertilizer (LOF). A complete graphical representation of these weekly cash flow trends is shown in Figure 7.

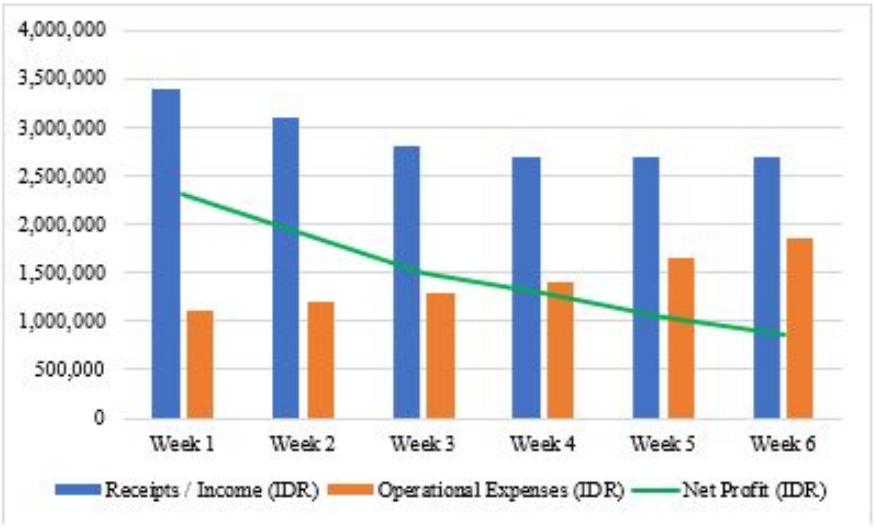


Figure 7. Weekly cash flow graph of the partner business "Pengolahan Sampah Reliji"

Conversely, the operational expenditure curve displays a gradual escalation trend. The cost burden, which was initially only recorded at IDR 1,100,000 in Week 1, continued to increase until it reached its peak point at IDR 1,846,000 at the end of monitoring in Week 6. The increase in expenses at the end of this month was not a managerial anomaly but rather an accumulation of two mandatory cost factors. First, there is an obligation to pay a final levy for the disposal of the remaining residue at a regional landfill facility. Second, the inclusion of a regular mechanical maintenance schedule (preventive maintenance), which includes repairs to diesel engine instruments and shopping for spare parts for operational vehicles, which are routinely replaced at the end of every month.

The dynamics of increasing equipment maintenance costs certainly had an impact on the erosion of the business profit margin ratio, which decreased sharply from 67.65% in Week 1 to 31.68% in Week 6. However, the partner institution demonstrated commendable capability in maintaining positive margin stability and recording a net profit (net positive cash flow) throughout the monitoring period without incurring any deficit. To determine financial health, profitability was calculated using the standard profit margin formula:

By applying this calculation cumulatively, the entity successfully recorded a total net profit of IDR 8,904,000, which yielded a healthy average profitability percentage of 51.17%. This comprehensive achievement serves as valid, real-world evidence of the financial resilience offered by implementing a circular-based waste processing model at the community level. The massive liquidity surplus accumulated at the beginning of the month practically functioned as a strategic safety cushion, enabling the partners to independently cover and finance the sudden surge in technical maintenance costs at the end of their operational cycle

***3.4 Economic Sustainability Strategy (Downstreaming) and the Realization of a Circular Economy***

The ultimate achievement marking the success of this community service program is the establishment of a downstreaming ecosystem (supply chain end-point). The implementation team fully recognized that massive production capacity had to be matched by guaranteed market absorption. Consequently, a strategic step was taken by signing a Memorandum of Understanding (MoU) that legally bound the waste management partner to end-user entities, specifically representatives of local farmer groups and ornamental plant growers (Shapiro et al., 2023). The pivotal moment in formalizing this commercial partnership is illustrated in Figure 8. The signing ceremony was not merely symbolic; it served as a milestone in establishing a permanent off-taker system in the project. To ensure operational sustainability beyond the program's conclusion, the team also handed over comprehensive Standard Operating Procedures (SOPs) covering both mechanical maintenance protocols and the associated managerial procedures.

Figure 8. Signing of a Memorandum of Understanding (MoU) between the waste management partner and farmer groups/buyers.

From the perspective of sustainability management, the availability of technological infrastructure and an abundant supply of raw materials often holds little significance for the viability of social enterprises if they fail to secure buyers (Taylor & Rosca, 2023). The lack of market certainty is a systemic obstacle that frequently triggers marketing bottlenecks in waste management initiatives across Indonesia. The offtaker contract scheme implemented in this program has proven to be effective in resolving this impasse. Feasibility analysis indicates the creation of a mutually beneficial arrangement, a "win-win solution," that is highly advantageous from a commercial standpoint. On the one hand, farmer groups gain a guaranteed, continuous supply of high-quality organic fertilizer at very affordable prices, thereby reducing their agricultural input costs. On the other hand, the partner business unit secures a guarantee of stable monthly cash flow without the burden of struggling to find retail buyers in a volatile market environment.

Furthermore, the practical realization of this downstream processing demonstrates that the Circular Economy is not just a theoretical concept but a fully operational daily practice in Mendalo Indah Village. Unlike the extractive linear models of the past, this community service intervention successfully restructured the material cycle. Piles of organic household waste, originally mere sources of environmental pollution and generators of toxic leachate, have been directly transformed into soil-conditioning commodities that replenish the surrounding agricultural land. This tangible transformation proves that providing direct institutional capacity building combined with cross-sector collaboration, specifically by securing an off-taker, acts as a powerful real-world catalyst for improving local economic conditions and empowering rural communities (Puspaningrum et al., 2025).

In conclusion, the successful implementation of this empowerment program offers a concrete and replicable blueprint rather than mere theoretical literature. The practical combination of physical infrastructure assistance ("hardware") and intensive managerial mentoring ("software") proved directly capable of establishing an independent grassroots green enterprise. The integrated solution demonstrated in this program, encompassing communal waste sorting systems, mechanical aerobic decomposition processes, digitized financial reporting, and market-securing downstream agreements (MoUs), is highly recommended for policy makers. It serves as a proven, ready-to-use reference for local governments and Village-Owned Enterprises (BUMDes) to solve the waste management crisis in other peri-urban areas across Indonesia.

## 4. Conclusions

### *4.1 Conclusion*

Overall, this community service program has achieved measurable success in fulfilling its primary mission: transforming conventional household waste management into an autonomous institutional entity focused on producing valuable organic fertilizers. This success is empirically evidenced by the

achievement of key performance indicators across several major output areas. Regarding physical engineering efficiency, the introduction of a 7-HP shredder integrated with drum composting units reduced the volume of residual waste sent to the final disposal site (TPA) by 30 percent. Furthermore, the facility has successfully achieved a monthly production rate of 1,500 kg of solid organic fertilizer and 150 liters of liquid organic fertilizer. In terms of managerial modernization, the transition to a cloud-based digital recording system using the AppSheet application was fully adopted (100%) by the management team. Digitalization has directly eliminated bureaucratic inefficiencies, enhanced transaction transparency, and facilitated real-time inventory monitoring. Ultimately, these operational successes have led to financial self-sufficiency and the realization of a circular economy. A cash flow analysis of the business unit confirmed robust profitability, with an average profit margin of 51.17%. This financial resilience is underpinned by guaranteed market uptake secured through off-take contracts with local farmer groups. Conceptually, these findings offer both theoretical and practical contributions, affirming that the fusion of hardware innovation ("hard innovation") and digital governance improvements ("soft innovation"), achieved through a participatory approach (PTD), serves as a highly effective catalyst for accelerating the adoption of green technology in urban fringe areas.

### *4.2 Research Limitations*

Despite achieving a series of positive outcomes, the implementation of this community service program faced certain operational and methodological limitations, which constrained the scope of the analysis. The first limitation is the brief evaluation timeframe. The monitoring period for equipment efficiency and cash flow dynamics covered a relatively short cycle, comprising four months of mentoring and six weeks of intensive administrative record keeping. This duration was insufficient to capture financial balance fluctuations associated with specific seasonal patterns, such as the agricultural lean season or extreme weather events that could affect daily material supply volumes. The second limitation relates to the suboptimal scale of raw material intakes. The supply chain for sorted waste remains concentrated within the immediate neighborhood units (RT/RW) of the partner organization and has not yet expanded fully to the village level; consequently, the composter's production capacity has not yet been maximized. Third, there is a high level of reliance on specific personnel for application management. The digital data recapitulation process currently relies heavily on two or three trained key operators. This situation creates a risk of administrative bottlenecks should there be future restructuring of the management team or turnover of operational staff within the partner organization.

### *4.3 Suggestions and Directions for Future Research*

Based on the mapping of findings and an analysis of existing limitations, several strategic recommendations can be considered for the future development of this community-service program. The first crucial step is scaling up the commodity supply chain. Subsequent support initiatives should aim to expand the organic waste sourcing network to include local commercial sectors near the village, such as traditional markets or restaurant hubs, thereby securing a continuous supply of raw materials in greater volumes. The second strategic recommendation focuses on integrating advanced technological innovations. Composting reactor units can be enhanced by installing automated IoT-based sensors to monitor temperature fluctuations, humidity levels, and pH values. On the software front, the AppSheet system requires further development through the integration of e-commerce features to broaden the market reach of the fertilizer product. Finally, to ensure the program's sustainability, advocacy efforts are needed to integrate the waste management business unit into the Village-Owned Enterprise (BUMDes) structure. Operating under the BUMDes legal framework would not only provides the entity with regulatory protection from the local government but also unlocks opportunities to access financing through village fund allocations.

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