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The Use of Lean Six Sigma Methodology to Improve Efficiency in Waste Bank Operations and Its Contribution to The Circular Economy

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ABSTRACT

Waste banks are innovative solutions in community-based waste management that support circular economy principles. However, many waste banks face various operational constraints such as process inefficiency, waste of resources, and low utilization of technology. This research aims to apply the Lean Six Sigma methodology to improve the operational efficiency of waste banks and analyze its contribution to the circular economy. With the DMAIC (Define, Measure, Analyze, Improve, Control) approach, the study was conducted through field observations, interviews, and process efficiency analysis at waste banks in South Sumatra Province. The results show that Lean Six Sigma is able to identify points of waste and improve efficiency indicators such as process time, space utilization, and sorting quality. This efficiency has a positive impact on increasing the recycling volume and economic value of waste products. This study shows that Lean Six Sigma integration supports the transition to a more sustainable waste management system.

Keywords: *Waste Bank, Lean Six Sigma, Circular Economy*

Introduction

Waste management is a complex and urgent global issue, especially in developing countries such as Indonesia. Waste banks are present as an innovative solution to overcome waste problems by involving the community in community-based waste management. However, many waste banks experience obstacles in their operations, such as process inefficiency, lack of resources, and suboptimal management [1].

According to [2], there are more than 11,000 waste banks spread throughout Indonesia. Regions such as East Java, Yogyakarta, and DKI Jakarta are pioneers in the management of structured waste banks, with the support of technology, digital recording systems, and industrial partnerships. Meanwhile, areas outside Java, such as South Sumatra, show slower growth, generally still using manual methods, both in sorting, recording, and distributing waste. In fact, the potential for waste management through waste banks is very large. In addition to being able to reduce the burden of landfills, waste banks can also create new economic value for the community. However, to achieve maximum impact, a quality management approach and process efficiency such as Lean Six Sigma, which is proven to be able to identify and eliminate waste, as well as systematically increase productivity [3], [4], [5], [6].

Lean Six Sigma is a methodology that combines the principles of Lean and Six Sigma to improve process efficiency and quality by identifying and eliminating waste and reducing variety. Application Lean Six Sigma has proven effective in various sectors, including banking and manufacturing, to improve service quality and operational efficienc [7], [8]. In addition to improving operational efficiency, the implementation of *Lean Six* Sigma Waste banks also contribute to the circular economy. A circular economy is an economic model that emphasizes resource reuse and waste reduction, in contrast to traditional linear economic models. By optimizing the waste processing process through Lean Six Sigma, waste banks can increase recycling capacity, reduce waste ending up in landfills, and produce value-added products from recycled materials. This is in line with a study by [9], [10], which indicates that integration Lean Six Sigma In manufacturing practice can promote sustainability and resource efficiency, which is a key principle in the circular economy[11].

Although waste banks play an important role in the circular economy and waste management in Indonesia, there are still various challenges in their operations. To understand the real conditions faced by Indonesian waste banks in South Sumatra Province, researchers conducted a direct survey of several waste bank operational locations [12], [13].

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Figure 1. 1 Observation of the Waste Bank

From the results of observations and interviews with managers and workers at waste banks, several main problems were found: inefficiencies in the waste collection and sorting process, which are often done manually without effective standard procedures, lack of data and information management systems, making it difficult to monitor performance and data-based decision-making, limited storage capacity causing waste accumulation to be poorly organized and slow down distribution process to the recycling industry, lack of public awareness and active participation in waste management, which has an impact on the low volume of recyclable waste [14], [15].

To overcome these problems, the implementation of Lean Six Sigma can be an effective solution. Through this approach, waste banks can identify and eliminate waste, improve efficiency in waste management, and optimize available resources. Some of the main strategies in the application *of Lean Six Sigma* in waste banks include: The use of DMAIC (Define, Measure, Analyze, Improve, Control) methods to analyze and improve waste management processes [16], [17], [18], [19].

Previous research has shown that Lean Six Sigma has succeeded in improving efficiency in various sectors, including waste management. Research [20], [21], found that the implementation of *DMAIC* In waste management, it can increase process efficiency by up to 40%.

Through this research, the researcher hopes that waste banks can improve their efficiency in managing waste, speed up the recycling process, and make a greater contribution to the circular economy. In addition, the results of this research can be a recommendation for local governments and stakeholders in formulating policies that support more effective and sustainable waste management. Thus, this research not only has a positive impact on the waste bank, but also on the environment and the welfare of the community as a whole [22], [23].

Research Methods

This type of research is applied research with a quantitative-descriptive approach. The research was conducted on the Indonesian Waste Bank in the South Sumatra region located in Palembang City. The research period lasted from February to July 2025.

The target of this research is all operational activities of waste banks which include the process of collecting, sorting, recording, and distributing waste. The research subjects consist of managers, workers, and several active waste bank customers.

The research procedure follows the DMAIC stages in the Lean Six Sigma methodology [24], [25], [26], [27], [28], [29], [30], [31]:

- **Define**: Identify the main problems in waste bank operations such as long processing time, waste of space, and labor inefficiency.
- **Measure**: Measurement of process performance indicators prior to repair, including collection, sorting, and recording times.
- **Analyze**: Analyze the root causes of waste with tools such as fishbone and Pareto charts.
- **Improve**: Implementation of solutions such as digitization of records, improvement of warehouse layouts, and training of sorting SOPs.
- **Control**: Evaluate the results of improvement and establish work standards to maintain the performance that has been achieved.

The research instruments are in the form of observation sheets, semi-structured interview guides, and documentation of historical data on waste bank operations. The data analysis techniques used are quantitative descriptive analysis and visualization of change graphs before and after improvement [32], [33], [34], [35], [36].

Results

The research was conducted on the Indonesian Waste Bank in the South Sumatra Region which experienced various operational constraints, including slow processing times, manual sorting processes without SOPs, non-digital recordings, and low customer involvement. After the implementation of Lean Six Sigma using the DMAIC approach, the improvement results showed significant improvements in various aspects of operations.

1. Define

The main problems identified in this phase are low operational efficiency which has an impact on the low volume of waste that can be processed and the lack of contribution to the circular economy. Some of the specific problems found are:

- Manual sorting process without standard procedures.
- High rate of waste misclassification (>20%).
- An inefficient workplace layout and causes bottlenecks.
- Reliance on manual logging.
- Public participation is still low (20–30 active customers).

The improvement goals set are to reduce sorting time, reduce sorting errors, increase processing volume, reduce operational costs, and encourage community participation.

2. Measure

Initial condition measurements were carried out to determine the baseline of waste bank performance, through direct observation and interviews. The results of the preliminary measurements showed:

- Sorting time of 1 kg of waste: ±10 minutes.
- Number of workforce: 8–10 people.
- Sorting error rate: >20%.
- Processing volume per day: ±150 kg.
- Operating fee per month: ±IDR 5,000,000.
- Income from waste sales: ±IDR 2,000,000.
- Community participation: ±30 active customers.
- Recovery rate: ±40%.

3. Analyze (Root Cause Analysis)

To find the root cause of the inefficiency, tools such as the Fishbone Diagram are used. Here is a troubleshooting based on the Fishbone Diagram (Ishikawa) that identifies the main causes of waste in waste bank operations, as well as proposed solutions based on *the Lean Six Sigma* approach:

Table 1 Fishbone Diagram Troubleshooting

Cause Category (Fishbone Diagram)	Main Problems (Consequences)	Lean Six Sigma Solutions (*DMAIC Approach*)
People	• Sorting errors due to lack of training • Lack of awareness and community participation	• Improve: Regular training, SOP creation, and implementation of a reward system for good performance

Cause Category (Fishbone Diagram)	**Main Problems (Consequences)**	**Lean Six Sigma Solutions (*DMAIC Approach*)**
		• Define & Control: Intensive socialization and economic incentives through waste savings programs
Method	• The sorting process does not have a standard procedure • No fixed transportation and distribution schedule	• Define & Standardize: Create and implement SOPs for waste sorting and collection • Measure & Improve: Create distribution route schedules and use an app-based logistics system
Machine	• No aids (press machine, digital scale) • Transaction recording errors due to manual system	• Improve: Investment in presses, digital scale, and sensor-based sorting tools • *Control*: Digitize records with online dashboards
Material	• The waste mixture is not properly sorted	• Measure & Improve: Color/label-based initial classification system for easy sorting
Environment	• Storage warehouses are full and disorganized • Waste accumulates due to slow distribution	• Improve: Optimization of warehouse layout and the use of compactors • Control: Regular monitoring of distribution and route performance
Measurement	• No performance data for evaluation	• Measure & Control: Collect data on inbound/outbound volume, runtime, and error rate

4. Improve

Improvements are made by applying the 5S principles, sorting SOPs, staff training, and the use of digital tools. Details of the improvements include:

- Implementation of SOPs for waste sorting and recording.
- Retraining for workers and volunteers.
- Rearrange the workplace layout to make the process flow smoother.

- Digitize records with automated spreadsheets.
- Implementation of a simple operational dashboard.

Results after implementation:

- The time of sorting 1 kg of waste drops to ±4–5 minutes.
- The number of workers required is 5–6 people.
- Sorting error rate <5%.
- The volume of processed waste increased to 300 kg/day.
- Operating costs decreased ±IDR 3,500,000/month.
- Revenue from waste sales increased to ±IDR 4,500,000.
- Participation increased to 50–70 active customers.
- The recycling rate reaches ±75–85%.

5. Control and Monitoring

After the repair process is carried out, quality control is carried out through:

- Weekly monitoring by the field coordinator.
- Monthly performance evaluation using efficiency indicators.
- Periodic audit of SOPs and ongoing training.

Real-time digital data logging to support data-driven decision-making.

6. Waste Bank Operational Efficiency Indicators: Before and After Lean Six Sigma

Table 1 Before and After Lean Six Sigma

Efficiency Indicators	Before Lean Six Sigma	After Lean Six Sigma	Information
Sorting process time per kg	± 10 minutes	± 4–5 minutes	Layout and SOP improvements → time waste reduction (Lean)
Number of manpower required	8–10 people	5–6 people	The existence of sorter technology and 5S → reduce workload
Sorting error rate	>20% (misclassified waste)	<5%	DMAIC is used for root cause analysis and retraining
Volume of waste that can be processed per day	± 150 kg	± 300 kg	Increased throughput efficiency (double output at the same time)
Operating costs per month	± IDR 5,000,000	± IDR 3,500,000	Lean waste elimination
Revenue from waste sales (per month)	± IDR2,000,000	± IDR 4,500,000	Recycling increases, product quality is better, selling value increases.
Community participation rate	Low (20–30 active customers)	Higher (50–70 active customers)	Operational efficiency fosters public trust and enthusiasm
Waste recycling rate (recovery rate)	± 40%	± 75–85%	Waste sorted better and more accepted by the processing industry

Discussion

The increased operational efficiency generated by the Lean Six Sigma approach shows that this method is highly adaptive for community-based waste management. The implementation of DMAIC is able to identify activities that are not value-added and replace them with a more streamlined and standardized process.

These results are in line with the findings [37] that the reduction of wasted time, labor, and overprocessing processes can significantly improve efficiency. Fishbone Diagram used in the Analysis successfully uncover the root of the main problem, such as lack of training and suboptimal work layout.

From a social and economic perspective, the increase in customer participation and income from the sale of recycled products reflects a positive shift towards a circular economy system. Waste that was previously considered waste now has a clear and measurable economic value. Community involvement has also become more active thanks to incentives and better process efficiency.

The application of technology such as digital recording systems and operational dashboards is an important key in the Control process. With this system, waste bank management can make data-driven decision-making, which is an important foundation for long-term operational sustainability.

Thus, this study not only shows technical improvements in waste management, but also emphasizes the importance of integrating quality management approaches with circular economy principles.

Conclusion

The implementation of Lean Six Sigma has been proven to be able to significantly increase the operational efficiency of waste banks. The sorting process becomes faster, error rates decrease, operational costs are reduced, and processing volumes are increased. The DMAIC methodology is able to identify the root of the problem and design appropriate solutions, supported by training, SOPs, and process digitization.

Directly, this increase in efficiency contributes to the strengthening of the circular economy. The volume of recycling increases, the economic value of waste increases, and community involvement becomes higher. This research confirms that the Lean Six Sigma approach is not only relevant in the context of the manufacturing industry, but also highly applicable in sustainable community waste management.

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