# Reduction of waste in biodiesel production with Value Stream Mapping (VSM)

*Sianturi,* Ruth Indah[1*], *Singgih,* Moses Laksono[1]

[1]Institut Teknologi Sepuluh Nopember, Indutrial Management, 60115, Surabaya

**Abstract.** Currently, the biodiesel industry in Indonesia presents significant opportunities within the broader industrial sector. However, competition within this field has intensified, leading to higher price offers. This situation may be caused by inefficiencies in the production floor. The application of Lean Manufacturing is implemented to map all activities involved in biodiesel production. A questionnaire method is employed to identify the inefficiencies. After assessing the current state, the root causes are analyzed using the 5W method, followed by a production gemba walk. This research is then carried out through process activity mapping to evaluate time utilization on the production floor. The steps undertaken include creating a future state map plan, which provides a design for improvements and the implementation of continuous improvement in biodiesel production, ultimately leading to cost savings. The results of this study indicate a production savings margin of IDR 1,870,726,000 per year, and the application of continuous improvement at the Biodiesel Plant successfully reduced the total time required by 3,920 hours.

## 1 Introduction

Currently, the level of competition in the biodiesel industry is influenced by the developments in the business environment. This is evident not only in the competition over quality but also in the competition regarding the technologies employed, delivery systems, and the value of the products offered. Manufacturers adopt various methods to meet the expectations of the products produced, as well as the costs presented to consumers. The competitive advantage of an industry can be maintained through efficient and effective work systems, which become the responsibility of companies to continuously improve and develop. This can be achieved if the company has undergone a revolution in its manufacturing system through the implementation of lean manufacturing across the entire supply chain to address issues such as reducing the time required for new product production, enhancing labor productivity, minimizing time consumption in mass production, and addressing product defects. On the other hand, the application of lean manufacturing can minimize waste and improve the workflow throughout the company's production processes (Andy, 2018).

The Biodiesel Plant is a company that focuses on processing palm oil derivatives with an annual processing capacity of 420,000 MT and has been established for 15 years. The company faces several issues, including high process downtime, which leads to high production costs (chemical and operational), bottlenecks, waste motion, and product defects. The biodiesel production process itself is divided into five major stages: oil drying, transesterification, separation, double washing, and final drying.

As shown in Figure 1, the average downtime of biodiesel production from 2016 to 2020, before improvements were implemented, was 92 hours. This high downtime occurred due to activities on the production floor that did not add value, primarily caused by the emulsification of raw materials during the double washing process in the centrifugal separator unit. From 2021 through 2023, downtime significantly decreased following improvements made on the production floor, with an average downtime of 7.6 hours, representing a reduction of 92%. The high production downtime also led to significant production margin losses, which can be observed in Figure 2.

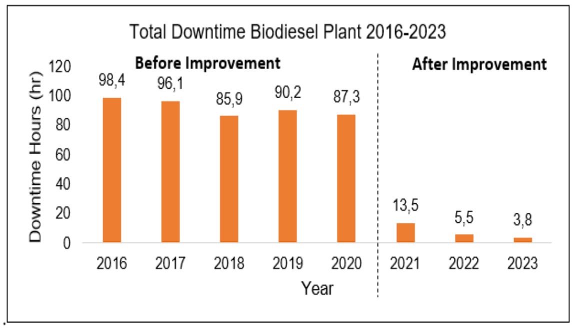


**Fig. 1.** Total Downtime Biodiesel Plant 2016-2023.

* Corresponding author: sianturiindahruth@gmail.com

Figure 2 illustrates the production margin loss of biodiesel during the downtime period from 2016 to 2023. This is directly correlated with the high levels of production downtime and margin loss. In the period from 2016 to 2020, the average production margin loss was IDR 1,291,735,900, while for the period from 2021 to 2023, the margin loss decreased to IDR 107,198,000, representing a reduction of 92%. The high downtime is attributed to the methods used in material handling that do not meet standards, leading to extended setup durations. Additionally, inefficiencies in labor utilization, where actual working hours exceed the planned hours, and suboptimal resource usage, especially when considering bottlenecks occurring on the production floor, further exacerbate the issue. These factors result in higher production costs. Therefore, there is a need for strategies to minimize production costs by optimizing resources, with a focus on continuous improvement and production activities to enhance productivity.

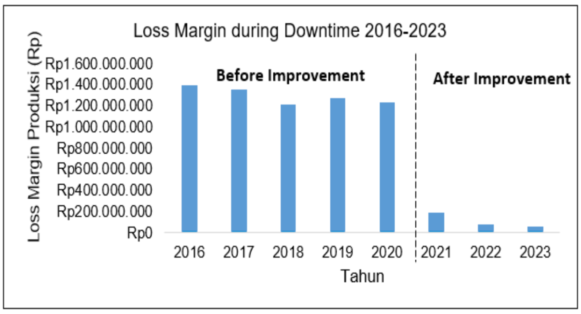


**Fig. 2.** Lost Margin during Downtime 2016-2023.

Lean manufacturing is a production system aimed at maximizing production flow and minimizing waste. This system is associated with increasing awareness of waste at the production level and implementing measures to eliminate it. In the Toyota Production System (TPS), there are seven types of waste, including defects, unnecessary motions, excess inventory, improper processes, inefficient transportation, waiting, and overproduction (Rüttimann & Stöckli, 2016). Waste is defined as activities that do not add value but consume space, resources, and time at any stage of production. The application of lean manufacturing focuses on minimizing resource consumption and time. This approach aims to improve quality through quality control systems, which in turn helps reduce production costs by limiting non-value-adding activities. Inventory is minimized through improved production flow, while a tidy and organized work environment is achieved through the implementation of the 5S method, which also helps in identifying problems and enhancing worker comfort and safety.

The issues related to waste reduction in biodiesel production are as follows:

1. How can the concepts of Lean Manufacturing and Value Stream Mapping (VSM) be utilized to identify effectiveness and provide improvements in the processes and resource consumption in biodiesel production?
2. What methods can be implemented to improve the biodiesel production process in order to reduce lead time, lower production costs, and minimize production waste?

The research contributes to individuals, companies, and the academic world. The following are some of the key benefits of research activities:

1. Practitioners
   • Proposal planning to improve and minimize the burden on the production floor.
   • Control of previously established costs.
   • Providing input to management for improving stages on the production floor.
2. Scientific Development
   Serving as a reference for further research in the field of Lean Manufacturing with Value Stream Mapping.

## 1.1 Lean Manufacturing

### *1.1.1 Lean Thinking Principles*

Lean manufacturing is a popular means of continuous improvement that has transformed manufacturing processes, practices and principles globally. Originating in the automotive industry, this approach has been widely used in the manufacturing sector since the 1990s. Lean manufacturing basically rests on the philosophy of systematically improving performance which can result in waste on the production floor. Lean thinking was introduced to expand the concept from the manufacturing floor to the business operations level (Smith A, 2015). Lean thinking (LT) has 5 main principles that were introduced to overcome challenges between or within business units due to management thinking stages and differences in business culture. The five principles can be reviewed in Figure 3.

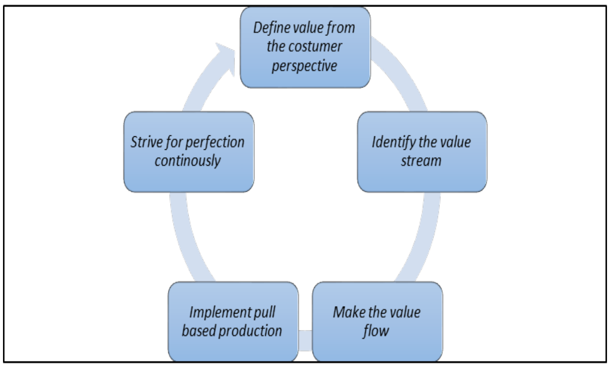


**Fig. 3.** Five Key Principles of Lean Thinking.

### *1.1.2 Seven Waste*

Waste is anything that does not contribute added value in the input to output transformation stage throughout the VSM. Waste can take the form of work area, energy or time, it is not limited to wasted materials. This was not expected because lean focuses on eliminating waste, so classifications are made to make it easier to identify types of waste.

### 1.2 Biodiesel Plant

Biodiesel is a fuel made from vegetable oil which has been reacted with methanol using a catalyst to produce methylester and glycerine. In general, the reaction in making biodiesel is divided into two methods, namely esterification and transesterification. The choice of method applied to the Biodiesel Plant is based on several aspects such as: FFA content in the oil, side products, type of oil, type of catalyst, and production yield. The differences between these two reactions can be seen in Table 1 below.

**Table 1.** Different between Transesterification and Esterification Reaction.

| Component | Esterification | Transesterifikation |
|---|---|---|
| %FFA | >0,2% | Max 0,2 |
| Type of catalyst | Acid Catalyst (HCl, $H_2SO_4$) | Base Catalyst (KOH, NaOH) |
| Side Product | Water | Crude Glycerine |
| Type of Oil | Carboxylate acid | Triglyceride |
| Yield | <100% | Max 100% |

## 2 Methodology

This study was carried out through stages arranged systematically in order to obtain maximum and structured results. This stage is described in the research method which includes the steps and stages carried out to obtain the objectives of this research. Based on the scope of the topic used, the object of this research is in the biodiesel production stage to calculate the costs incurred by calculating the budget required for making biodiesel then analyzing the production process and eliminating waste through VSM so that it can be in a lean manufacturing condition.

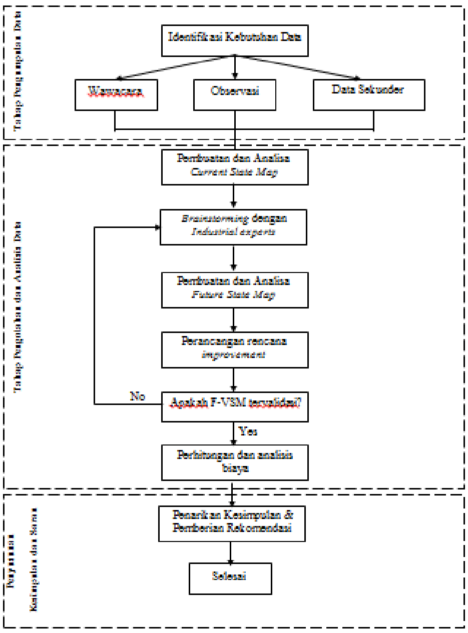


**Fig. 4.** Flowchart of Research Methodology.

## 3 Result and discussion

The stages of biodiesel production can be calculated from the arrival of raw materials until shipment at the finished goods location. This activity begins with the arrival of raw material oil from the Refinery Plant by looking at suitability in terms of quality and quantity. If fulfilled, it will continue with storing raw material oil in the tank farm unit. Material storage is adjusted to the production plan that has been arranged by the PPIC department. The raw material oil delivery process uses a Refinery unit transfer pump to Biodiesel Plant. Next, the raw material oil from the Refinery will continue with the biodiesel manufacturing process. Generally, this stage is divided into 5 major processes, namely reaction, separation, washing, drying and cold filtration processes.

The biodiesel industry is a manufacturing industry with complex production processes and labor requirements. Based on problems that arise because the operator's needs become uncertain due to long working hours. High downlime rate, resulting in loss through put. This cannot be separated from activities that do not have good added value at the construction stage. Work operational standards, as well as methods applied and implemented by the company. So it is necessary to identify the ongoing stages and carry out planning so that waste can be eliminated

In order to identify more waste, students are asked questions related to ongoing waste: 15 people with the following detailed positions: a production manager, a PPIC manager, a biodiesel unit superintendent, 4 biodiesel unit shift supervisors, 5 team leaders, 1 accounting manager, 2 QC staff. The basis of this lean approach is a philosophy in reducing waste so that the questionnaire is related to 7 wastes that may occur in production as well as providing waste in identifying waste that occurs. The results of the recap of questionnaire distribution data can be reviewed in Table 2.

**Table 2.** Results of the Questionnaire Distribution Data Summary.

| No | Jenis Pemborosan | Responden | | | | | | | | | | | | | | | Total | Rata-rata |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | | |
| 1 | *Over Production* | 1 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 11 | 0.73 |
| 2 | *Waiting* | 4 | 4 | 4 | 3 | 3 | 5 | 5 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 53 | 3.53 |
| 3 | *Transportation* | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 13 | 0.87 |
| 4 | *Inappropriate Processing* | 3 | 4 | 4 | 3 | 5 | 4 | 4 | 4 | 3 | 3 | 3 | 5 | 5 | 4 | 4 | 58 | 3.87 |
| 5 | *Inventory* | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 8 | 0.53 |
| 6 | *Motion* | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 4 | 3 | 2 | 3 | 3 | 3 | 1 | 2 | 43 | 2.87 |
| 7 | *Defect* | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1 | 1 | 16 | 1.07 |

From Table 2, it can be observed that the weighting achieves a score of 0, representing the lowest value when no waste occurs, and a score of 5 for the highest value. The highest total score is found in the type of waste categorized as inappropriate processing, with a score of 58. To facilitate the analysis of waste in the Biodiesel Plant, the identified wastes are ranked. Three of the largest wastes identified are caused by improper processes, waiting, and unnecessary movements. After identifying the wastes on the production floor using a questionnaire, a gemba walk was conducted to directly review the stages on the production floor, which facilitated the discovery of solutions and made the waste analysis easier. The solutions found are related to eliminating waste that occurs during the production stages, from the arrival of materials to the finished product. In the material handling stage, particularly during the double washing separator process, a common issue is the emulsification of FAME (Biodiesel) product, which makes it difficult for the production operators to handle the separator unit and return it to its normal position. This issue leads to improper processing, disrupting the general process flow, causing high downtime and product defects, rendering it unusable for the subsequent processes. This is due to the absence of a circulation path in the FAME buffer tank and the lack of dosing of chemicals to the feed buffer tank of the centrifugal separator. The same issue occurs in the subsequent stage after the centrifugal separator unit is operating normally. A significant amount of time is needed to adjust the formula and normalize the reaction process in the transesterification unit. This creates a challenge for the production operators, who experience long waiting times to align the chemical requirements with the raw material oil when entering the transesterification process. Additionally, there are many activities that do not align with the process, leading to unnecessary movements, such as temporary hose connections, loading citric acid, and flushing the separator.

**Table 3.** Process activity mapping table before improvement.

| Aktivitas | Waktu (Jam) | Persentase |
|---|---|---|
| Operasional | 17252 | 84.8% |
| Transportasi | 816 | 4,0% |
| Inspeksi | 48 | 0.2% |
| Menunggu | 1440 | 7.1% |
| Menyimpan | 792 | 3.9% |

After analyzing the process activity mapping, it becomes clear that the operational time stage is the largest activity in biodiesel production. However, there are other activities that should be minimized, such as the waiting activity, which typically occurs during the shipment process. This is caused by the mismatch between the arrival time of the ship and the schedule planned by the PPIC team, leading to tank shortages and resulting in the stoppage of production operations. Therefore, improvements must be made based on the appropriate work processes to minimize waiting time, ensuring that operations can proceed efficiently.

Figure 5 shows the piping design sketch for the chemical dosing line and circulation path of the vessel, aimed at accelerating the breakdown of the emulsion. This is intended to reduce downtime at the Biodiesel Plant caused by the biodiesel emulsion, which requires time to normalize the reaction. The design process involved a more in-depth analysis by the process engineer, mechanical engineer, and fabrication engineer to maintain process efficiency and not disrupt the production flow. The piping is made of stainless steel SS316L, which was chosen based on the fluid to be pumped. In addition to the piping design, an efficiency analysis was also conducted on the concentration of citric acid solution used, evaluating the impact of concentration on the biodiesel emulsion breakdown time. The impact of the piping modification installation can be observed in the results of the process activity mapping after the improvements, as shown in Table 4.

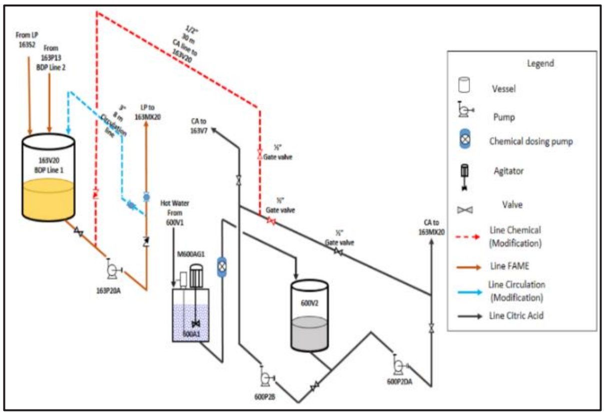


**Fig. 5.** Sketch and Piping Modifications.

**Table 4.** Process activity mapping table after improvement.

| Aktivitas | Waktu (Jam) | Persentase |
|---|---|---|
| Operasional | 17160 | 91.1% |
| Transportasi | 624 | 3.3% |
| Inspeksi | 36 | 0.2% |
| Menunggu | 288 | 1.5% |
| Menyimpan | 720 | 3.8% |

From Table 4, it can be observed that after reviewing the process activity mapping, there is a reduction in the storage time used during the storage stage, which can be minimized. To make the differences before and after the improvements more apparent, they can be reviewed through Table 5.

**Table 5.** Process Activity Mapping Table Before and After Improvement

| Aktivitas | Waktu (Jam) | | Persentase |
|---|---|---|---|
| | Sebelum | Sesudah | Perbaikan |
| Operasional | 17252 | 14760 | 14.4% |
| Transportasi | 816 | 624 | 23.5% |
| Inspeksi | 48 | 36 | 25% |
| Menunggu | 1440 | 288 | 80% |
| Menyimpan | 792 | 720 | 9.1% |

Table 5 shows that process improvements have resulted in a reduction in the operational time for several activities. Starting with the reduction in the working hours required to meet demand, which can subsequently impact the number of workers and the resources needed. On the other hand, the improvement plan also affects transportation activities, with a reduction in time allocation compared to the previous state. This change is influenced by the future state map, which eliminates activities considered wasteful, such as the integration of chemical dosing with circulation, thereby reducing inspection processes, transportation, and waiting activities.

## 4 Conclusion

Through the conducted study, the conclusion obtained is that during biodiesel production, waste in the form of waiting and inappropriate processing was observed. As a result, the future state map was improved by redesigning the piping system to create a more efficient layout and facilitate the workflow by balancing the processes, allowing non-value-added activities to be eliminated. The improvements led to a reduction in the time required to produce 420,000 MT of biodiesel, decreasing from 20,348 hours to 16,428 hours. Additionally, the improvements minimized production costs; previously, during downtime, the company incurred a margin loss of IDR 2,029,180,000. After the improvements, the margin loss was reduced to IDR 168,454,000, resulting in a margin saving of IDR 1,870,726,000 per year. To assess the success of using the VSM method in this study, it can be seen in the following figure.

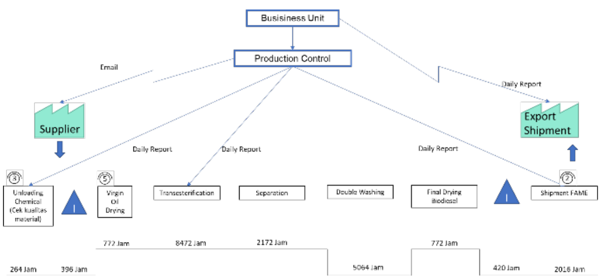


**Fig. 6.** Current State Map.

The total time required to produce 420,000 MT of biodiesel is 20,348 hours.

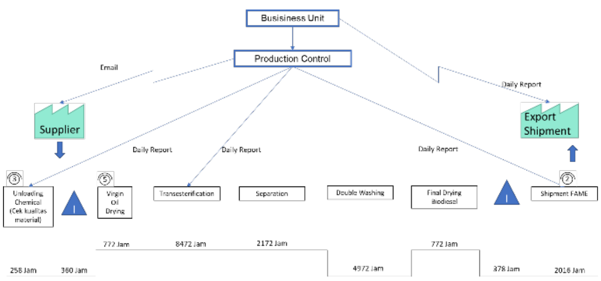


**Fig. 7.** Future State Map .

The total time required to produce 420,000 MT of biodiesel is 16,428 hours.

## References


1. Andy, R. A., Perancangan Lean Production System Dengan Pendekatan Cost Integrated Value Stream Mapping Pada Industri Alas Kaki. Institut Teknologi Sepuluh Nopember (2018)
2. Hines, Peter., & Taylor, David, Going lean : a guide to implementation. Lean Enterprise Research Centre (2000)
3. Lodgaard, E., Ingvaldsen, J. A., Gamme, I., & Aschehoug, S., Barriers to Lean Implementation: Perceptions of Top Managers, Middle Managers and Workers. Procedia CIRP, **57**, 595–600 (2016), https://doi.org/10.1016/j.procir.2016.11.103
4. Manjunath Muniyappa. (n.d.). https://www.researchgate.net/publication/262014857
5. Nash, M., & Poling, S. R., Value Stream Mapping: The Complete Guide to Production and Transactional Mapping (1959)
6. Rohac, T., & Januska, M., *Value stream mapping demonstration on real case study*, Procedia Engineering, **100** (January), 520–529 (2015), https://doi.org/10.1016/j.proeng.2015.01.399
7. Rüttimann, B. G., & Stöckli, M. T., *Going beyond Triviality: The Toyota Production System—Lean Manufacturing beyond Muda and Kaizen*, Journal of Service Science and Management, **9**, 2, 140–149 (2016), https://doi.org/10.4236/jssm.2016.92018
8. Smith A, T. Y., Lean Thinking: An Overview. Industrial Engineering and Management, **4**, 2 (2015) https://doi.org/10.4172/2169-0316.1000159
9. Tavana, Shaabani, & Valaei, A., An Integrated Fuzzy Framework for Analyzing Barriers to the Implementation of Continuous Improvement in Manufacturing (2020)
10. Tavana, M, Shaabani, A and Valaei, N, *An Integrated Fuzzy Framework for Analyzing Barriers to the Implementation of Continuous Improvement in Manufacturing*, International Journal of Quality and Reliability Management. An Integrated Fuzzy Framework for Analyzing Barriers to the Implementation of Continuous Improvement in Manufacturing (2020), http://researchonline.ljmu.ac.uk/id/eprint/12448/Articlehttp://researchonline.ljmu.ac.uk/