Implementation of Lean Six Sigma to Reduce Waste and Improve Quality: A Case Study of Asphalt Drum Production

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Abstract. In today's competitive business environment, companies must continuously enhance production effectiveness by minimizing waste and maintaining quality to ensure sustainability. However, an asphalt production company in Indonesia continues to face inefficiencies in process time and defects in its drum fabrication process. In 2024, the reject rate reached 11,16% out of 555,070 produced units, resulting in an estimated financial loss of IDR777,711,482. Initial analysis showed a DPMO of 21,857.3 and a sigma level of 3.5, indicating significant quality issues. A Value Stream Mapping (VSM) analysis revealed a total lead time of 3,891.05 minutes in the drum production process, with only 75.60% classified as value-added activities (VA). This study aims to identify critical waste, analyze root causes, propose improvement actions, raise the sigma level, and reduce financial losses. The Lean Six Sigma (LSS) methodology was applied using the DMAIC (Define, Measure, Analyze, Improve, Control) framework, supported by various improvement tools. Key corrective actions included revising incoming material inspection standards, implementing scheduled machine maintenance, establishing Standard Operating Procedures (SOPs), and optimizing the production facility layout. As a result, the VA increased from 2,880.2 to 2,941.93 minutes, the sigma level improved to 4.04, and the DPMO was reduced to 6,210. The Process Cycle Efficiency (PCE) rose to 76.66%, and potential losses were successfully reduced by 38%.

Keywords: Six Sigma, DMAIC, Drum Fabrication, DPMO, Sigma Level, VSM, Control Chart.

1 Introduction

In the development of the industrial world, each company will continue to compete to improve its production system, quality, and products in order to maintain customer satisfaction in order to maximize existing profits and achieve competitive advantage. The business strategy to achieve competitive advantage is the successful implementation of a quality management system [1]. The implementation of quality management and quality improvement programs in an organization has several advantages, including increasing customer satisfaction, increasing employee awareness of quality, improving organizational performance, and achieving organizational effectiveness. In an era of

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competition like today, without quality management, companies will not be able to survive in a competitive business environment and are bound by various regulations that apply today [2]. Companies must also be able to increase production effectiveness by reducing waste by creating better business processes is the most important task for companies to maintain their existence. Talking about productivity, the production process must contribute fully to activities that provide added value and minimize activities that do not provide added value, such as idle time, delays, arrangement, loading and unloading processes, and material handling [3].

In production activities in the company there are non-value-added activities or waste that result in the use of resources ranging from energy, human resources and time that are increasingly high, so that the production process becomes inefficient. As a result, many companies are always trying to continuously make improvements and create effective and efficient business processes. The production system is the focus of the main research study that has a major influence on sales and production growth. The value chain approach is a framework used in compiling activities ranging from procurement of raw materials to delivery of products to customers which shows the company's consistency in maintaining the quality and quality of production.

PT XYZ focuses on receiving asphalt (receiving storage), distributing asphalt drums, distributing bulk asphalt via trucks and ships, and drum fabrication. The following is a description of the production flow at the PT XYZ.

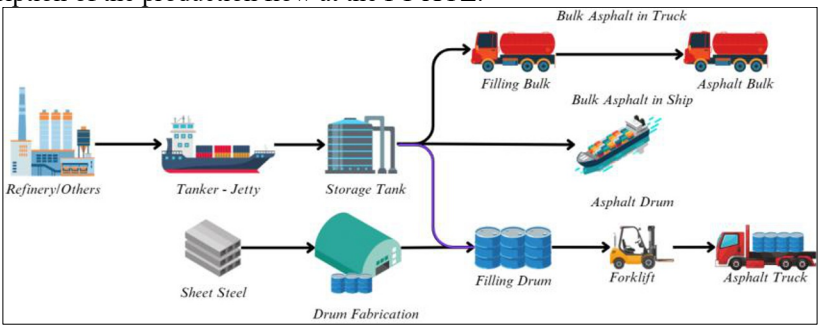

Fig. 1. PT XYZ Production Flow

Asphalt is obtained from Indonesia's refinery and imports, which are sent via ship mode to then be distributed via pipes until they enter the storage tank at the PT XYZ (receiving and storage). The asphalt received will be kept at a temperature so that it does not freeze, for high-quality asphalt (according to customer requests) additives will be added and mixed before being packaged into several media, including bulk filler asphalt and filler drums. Bulk filler asphalt can be distributed by truck or ship, while for filler drums using drum media and distributed via truck (distribution). The drums used to package asphalt are produced independently at the PT XYZ which is known as the drum fabrication process. The distribution of bulk asphalt via truck and ship modes, it is known based on historical data, the total demand per year in 2023 reached 44% with a total shipping frequency of 19 times in one year. Bulk truck distribution can accommodate asphalt demand in East Java, Bali, and Nusa Tenggara, while bulk ship asphalt distribution can accommodate customer demand for all regions of Indonesia that have supply

points via docks. Distribution of asphalt drums using drum-shaped packaging is the type of asphalt distribution with the highest sales rate, reaching 56% based on 2023 data. This is because asphalt drum production is easier to distribute to meet customer demand throughout Indonesia.

PT XYZ applies a make-to-stock strategy, which requires accurate demand forecasting to avoid overproduction and manage inventory efficiently. The main aspects that need to be considered in managing a supply chain operating in a make to stock environment are determining how much and where the final product inventory should be stored, as well as the mechanism or rules for sending finished products to marketing locations [4]. The performance measures of the MTS process include the percentage of orders filled from inventory. This is called the service level or fill ratio and is usually targeted in the range of 90 to 99 percent. Other measures are the length of time it takes to replenish inventory, inventory turnover, capacity utilization, and the time it takes to fulfill backlog orders. The goal of the MTS system in the context discussed is to ensure the fulfillment of customer demand through optimally managed inventory at efficient costs, which is achieved through inventory replenishment policies based on projected demand [5].

The drum manufacturing process begins with the rolling stage, at this stage the metal plate is formed into a cylinder using a roll machine, the inside of the metal cylinder is connected by a welding process. After that, the end of the cylinder will be folded to facilitate the installation of the cover (top and bottom covers) and increase the strength of the drum structure; this process is called flanging [6, 7]. The outer wall of the cylinder is then curved or wavy to increase the strength and rigidity of the drum, which is useful for helping the drum withstand internal and external pressure. Next, the top and bottom covers are installed at both ends of the cylinder, where the top cover of the drum is equipped with holes or openings for filling and removing the contents of the drum. To lock or seal the top and bottom covers with the drum wall through the double seamer process. At the finishing stage, a leak test needs to be carried out on the drum, drums that pass the leak test will be painted and dried with an oven machine. In order to continue to reap profits and maintain good relationships with customers, special attention is needed to the quality of the drum and asphalt. Based on the recapitulation data of drum production at the PT XYZ throughout 2024, the total reject percentage was 11,16%.

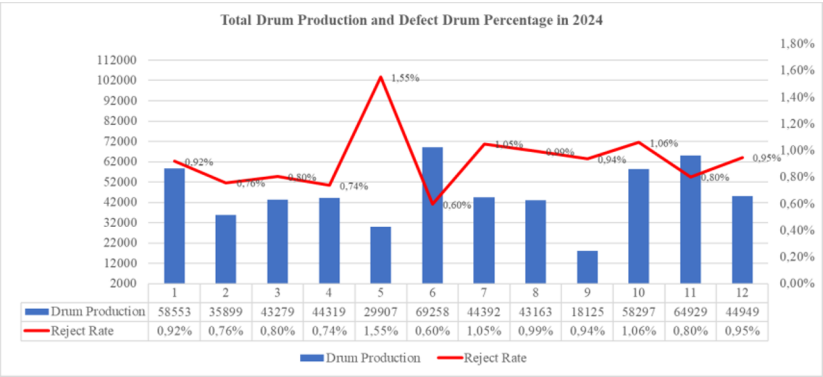

Fig. 2. Total Drum Production and Defect Percentage 2024

It is known that the average percentage of rejects in drum production throughout 2024 was 0.93% with the highest reject contribution in the welding process between the sheet and the drum top cover. The welding process often results in high reject rates and process variations due to several critical factors. First, the material used in the drum tends to be thin and easily deformed due to heat. Second, the drum top cover has a wide surface shape so that it requires consistent welding along the surface, which is difficult to achieve with high precision manually. Sheet metal with not ok status will be reworked by manual welding. Meanwhile, defects that occur in the finished goods drum will be checked first by the drum fabrication operator team, if it is possible to be reworked, it will be reworked if it is not possible with rework, the drum will be processed to be destroyed or rejected which is then identified as a loss for PT XYZ.

Based on the data in Figure 2, it shows that the more rejects that occur, the more new losses the company will experience in terms of costs and can cause customer complaints. The DPMO value throughout 2024 reached 21,857.3 with a sigma level of 3.5 which is still far from the 6-sigma target. This shows that the current production process still has many opportunities for improvement, especially in reducing variation and the number of defects that occur. Therefore, the application of the Lean Six Sigma method in this study is a very important strategic step to identify the main causes of defects, reduce the reject rate, and encourage overall quality and efficiency improvements in the drum fabrication process.

The Lean Six Sigma model developed by Crawford (2004) describes an approach where Six Sigma is used first to improve process effectiveness, followed by Lean to improve system efficiency. However, the use of both methods simultaneously is considered more effective in achieving comprehensive integration [8, 9]. To successfully integrate Lean and Six Sigma, organizations need to implement a holistic improvement method, where both approaches support and strengthen each other. This integration approach involves several important steps, such as the use of VSM (Value Stream Mapping) as a container for implementing tools from Six Sigma and Lean, adjusting process parameters with Six Sigma tools, implementing Lean techniques into the DMAIC (Define, Measure, Analyze, Improve, and Control) framework, and utilizing VSM to redesign the process structure [10]. With this integration, various shortcomings of each method can be overcome. The combination of Lean and Six Sigma allows companies to achieve zero defects, optimize production performance, improve product quality, and reduce shipping costs [11, 12]. Furthermore, the implementation of these two methods is expected to help organizations exceed customer expectations in the future [13].

Several previous studies have discussed Lean Six Sigma in various industrial sectors. For example, Widiwati et al. [14], who implemented Lean Six Sigma to minimize waste in food manufacturing [14]. The company managed to increase the Process Cycle Efficiency (PCE) level from 66.19% to 70.98%. Reduced the total production cycle time from 0.498 seconds/pcs to 0.486 seconds/pcs. The loss time level in conditions before implementing Lean Six Sigma was 194 minutes, significantly decreasing to 87 minutes, and the production loss level decreased from 25,146 pcs to 12,508 pcs. Lean Six Sigma

can help companies save costs, according to research by Adeodu et al. [13], which managed to control overstaffing in the inventory area from 33 people to 16 people [13]. In addition, the Process Cycle Efficiency (PCE) level increased from 23.4% to 40% by implementing Kaizen and work standardization. Production lead time decreased to 25,115 seconds, where before the improvement the production lead time was 43,200 seconds. Downtime before implementing LSS was 32.65% and with the implementation of LSS significantly reduced the percentage of downtime to 10.9%.

In the study Nopri Andi & Basri the implementation of LSS also helped increase production capacity in manufacturing companies to 528,000 units in 2023, where the production results before the implementation of LSS were 508,000 units. After the implementation of LSS, the company was able to exceed its production target by more than 20%. The results of Cp quality control decreased to 2.06 where the Cp value before the implementation of LSS was 3.36, in addition the Cpk value decreased to 1.12 where it was originally 1.47. The potential for the DPMO value to decrease from 7325 to 57 [15].

2 Research Methods

There are two data collected, namely primary data and secondary data. Primary data consists of types of drum production defects, time data and drum fabrication process flow, recapitulation of production results and drum reject rates taken through direct data collection. Furthermore, secondary data collection conducted is an interview related to the sequence of the drum fabrication process, the length of time required for each drum fabrication process station, and other supporting data. In this study, sigma calculations were carried out for existing conditions. The sigma level is an indicator that provides an overview of the level of process capability achieved through the application of Lean Six Sigma tools [11]. This study follows the Lean Six Sigma stages commonly known as DMAIC. DMAIC is an abbreviation of five stages, namely Define, Measure, Analyse, Improve, and Control [10].

Lean six sigma is a combination of lean with six sigma as a business philosophy, a systematic approach in identifying and eliminating waste in the form of activities that do not provide added value (non-value-added activities) through continuous improvement continuously to achieve the six sigma work level, by flowing products (materials, work in process, output) from internal and external customers to pursue excellence and perfection in the form of producing only 3.4 defects for every one million opportunities or operations (3.4 DMPO) [16].

The Define stage is the first operational step in the Six sigma quality improvement program, where at this stage potential projects are identified, the roles of people involved in the Six sigma project are defined, key quality characteristics (CTQ) are identified that are directly related to specific customer needs and determine objectives. CTQ (Critical to Quality) is something that needs to be defined based on customer input on the desired quality of the product [17, 18, 19]. The defined stage can be explained with a project charter, SIPOC diagram, Pareto diagram, process flow, Voice of Customer (VOC), and others.

Measure is the second operational step in the Six Sigma quality improvement program, there are several main things that must be done, namely:

1. Conduct and develop a data collection plan that can be done at the process level, and/or output.
2. Measure current performance to be set as a performance baseline at the beginning of the Six Sigma project.

Measure in Six Sigma in the form of statistical tools (Statistical Process Control) as well as DPMO calculations and Sigma values measure the performance baseline. At the analysis stage, the results of the measurements carried out in the previous stage are analysed, and the root causes of the key CTQs are also determined using the tools of cause-and-effect diagrams (fishbone), 5-Whys, control charts, capability and reliability analysis, fishbone diagrams and others. The improvement step is carried out after the sources and root causes of quality problems have been identified. At this stage, an action plan is established to implement six sigma quality improvements. At the control stage, procedures and quality improvement results are documented to be used as standard work guidelines to prevent the same problems or old practices from recurring, and are expected to be applied to all areas relevant to the proposed improvements [20].

3 Result and Discussion

3.1 Analyze

Improvement Analysis on CSM

Several work stations identified as the main sources of waste are the painting station, which has the highest NVA of 108.33 minutes, as well as the leakage test and cutting press lid cover which each contribute NVA of 86.67 minutes and 65 minutes. In addition, the welding station recorded the highest cycle time of 418.33 minutes with an NVA of 35 minutes, which also increases the total process time and indicates the potential for a bottleneck. The production process in general also still contains waiting activities and transfers between stations that are not yet efficient. To clarify the changes that occur between existing and proposed conditions, see **Table 1** the following.

Table 1. Comparison of Total Time of Existing and Proposed Conditions

	Existing Conditions	**Proposed Conditions**
Total Lead Time	3891.05 minutes	3757 minutes
Total Cycle Time	3560.27 minutes	3457 minutes
Total Waiting Time	330.78 minutes	300 minutes
Total Value Added	2941.93 minutes	2880.2 minutes
Total Non-Value Added	448.3 minutes	423.8 minutes
Total Not Necessary Value Added	169 minutes	153 minutes
% VAR	75.60%	76.66%

The bottleneck problem is also exacerbated by the length of the conveyor track between the double seamer station and the leak tester station, which reaches six meters. With

only one operator with a manual process type of work, there is often a pile-up of drums (waiting) along the track due to the testing capacity being unable to keep up with the production rate of the previous station. This causes a waste of time. As part of the VSM proposal, BPG can consider increasing the number of operators at the leak tester station to two people. This decision is based on an evaluation of the current production volume, most of which is produced by Line 1, so that the addition of operators can be focused on accelerating throughput at the bottleneck point. Adding two operators for the painting booth can reduce the total non-value added (NVA) time from 108 minutes to 97.5 minutes. This is necessary because the operator needs to herd and push the drums to cross and enter the drying booth.

Identify Root Cause Analysis with Fishbone

This sub-chapter discusses the application of root cause analysis using the Fishbone Analysis method to explore the deep causes of problems that occur from the three types of defects, inconsistency welding, over/short hook, and rejected sheets.

Attached Figure 3 is the result of the analysis of the types of inconsistency welding defects that occurred at the seam welding machining station.

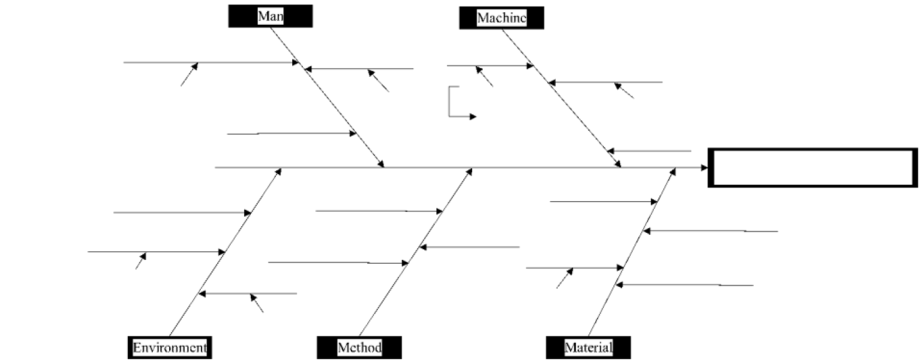

Fig. 3. Fishbone Analysis Inconsistency Welding Drum

This diagram analyzes the main causes of inconsistency welding on the drum wall by identifying factors in the categories: human, machine, method, material, and environment. The main causes include lack of ongoing training for operators, broken and unscheduled machine maintenance, irregular raw material thickness, and lack of control of the work environment. Attached Figure 4 is the result of the analysis of the type of over/short hook defects on the cover and bottom drum that occurred at the seam welding machining station.

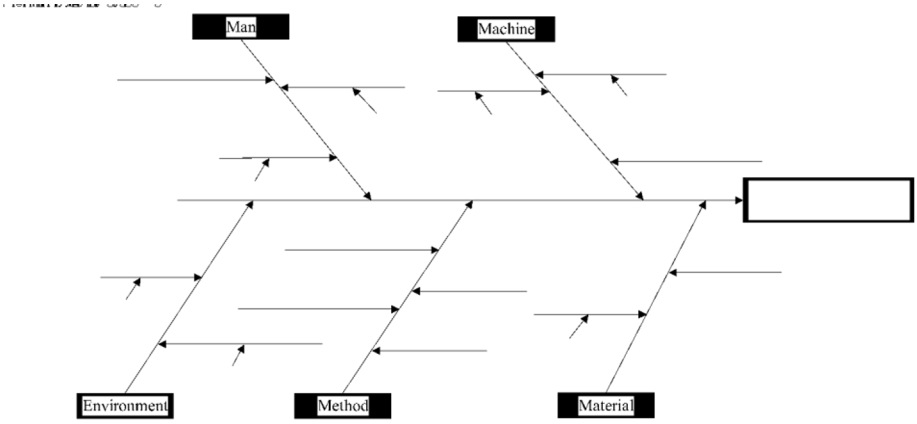

Fig. 4. Analysis of Fishbone Over/Short Hook Cover and Bottom Drum

This diagram analyzes the causes of over & short hook on the double seamer machining station. The main cause lies in human factors such as incorrect placement of material positions due to the absence of work instructions for placing materials on the press cutting machine. In terms of machine factors, problems such as machine instability and blunt cutting dies contribute to the emergence of quality issues. On the method side, poorly documented work procedures cause operator subjectivity which causes variations in cutting results. Meanwhile, from the material and environmental side, such as the non-uniform thickness of the plate used and the work area exposed to scrap are supporting factors for the emergence of defects.

Attached Figure 5 is the result of the analysis of the types of reject sheet defects that occur at the rolling machine station.

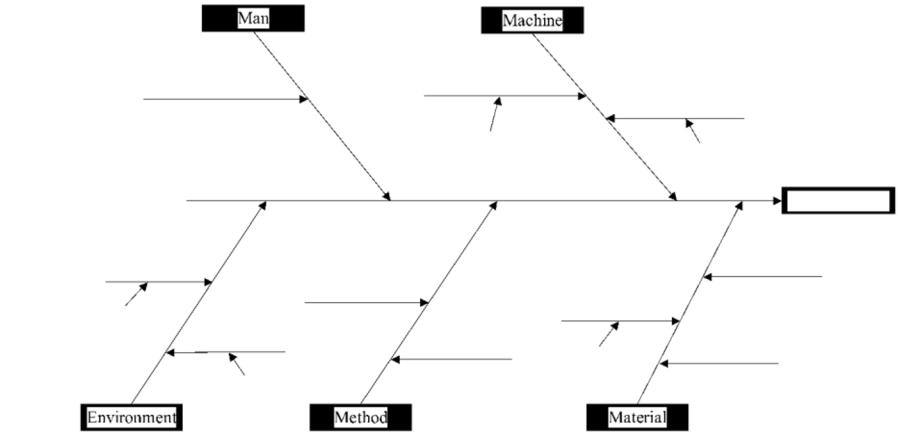

Fig. 5. Fishbone Sheet Analysis Rejection

The main cause of rejected sheets is human factors such as lack of training and refreshment for operators. From machine factors, problems such as inconsistent motor pressure, and wavy machine rollers often arise due to lack of attention and routine maintenance schedules at the PT XYZ. Furthermore, poorly documented work procedures are the root cause of problems from the method aspect. On the material and environmental side, the root of the problems that arise is the presence of non-uniform plate thickness and the work area is exposed to scrap.

3.2 Improve

Future State Map

The proposal describes the proposed process flow by reducing non-value-added activity and waiting time. The improvement proposal is made by analyzing the types of activities that occur in the entire machining process and reducing non-value-added activities. Some prominent NVA activities include the activity of positioning the drum into the belt conveyor at the painting station for 108.33 minutes at the painting station and moving the leaking drum to the quarantine area at the leak tester station for 87 minutes. To reduce this time, manpower assistance is provided to speed up the placement of the drum so that the positioning time can be reduced to 97.5 minutes. In the leak tester process, reducing NNVA time can be done by adding an assistant operator for the leak tester is the most appropriate recommendation considering that the operator needs precision to observe leak points in the welding area, with activities carried out manually, such as applying a brush that has been moistened with soapy water, and separating the checked drum to the side of the station as a quarantine area for leaking drums that will be moved to the rework station, or moving and placing the drum on the conveyor to be continued to the next machining station.

Meanwhile, in the NNVA category, the painting and drying machine set up activities take 30 minutes and 20 minutes respectively. If the preparation is done after the closing shift, the painting set up time is reduced to 20 minutes. By integrating maintenance activities and spare part inspections, the drying process set up time can be reduced to 15 minutes. Increasing the number of painting operators is also recommended to speed up the drum positioning process into the drying station belt.

Based on the results of the process activity map classification, the process cycle efficiency (PCE) can be calculated. The results of the PCE calculation obtained in the production of asphalt drums at the PT XYZ are as follows:

$$\text{PCE (\%)} = \text{x } 100\% \frac{Total\ Value\ Add\ Time}{Total\ Lead\ Time}$$

$$\text{PCE (\%)} = \text{x } 100\% \frac{2880{,}2\ minutes}{3778{,}67\ minutes}$$

$$\text{PCE (\%)} \approx 76.22\%$$

Improvement Recommendations for Pareto Machining Stations

Inconsistency Welding

The proposed improvements to the problem of inconsistent welding quality on the drum walls are as follows.

Table 2. Proposed Improvements for Welding Inconsistency

Waste	*Root Cause*	Recommendations for Improvement
Inconsistency Welding on Drum Walls	High intensity of machine use without routine spare part replacement There is no routine maintenance schedule	Implementation of preventive maintenance system, maintenance schedule and spare part replacement schedule based on time and usage cycle
	Operators do not receive regular training	Conduct refreshment programs (for old employees) and training (for new employees) periodically based on competency and periodic evaluations.
	Poor air circulation	Improve the layout of work area ventilation and install air insulation in accordance with K3 standards so that temperature and humidity are controlled.
	The quality control procedure is limited to administrative completeness only.	Adding a physical checklist based on technical parameters and adding supporting facilities for technical data collection (vernier calipers)
	Does not implement inline checking	Standardization of inline inspection procedures as part of production SOPs with clear frequencies, technical parameters and quality operator responsibilities.
	Production scheduling without considering machine capacity	Implementation of the capacity requirement planning approach and integration with the production scheduling system based on machine performance (OEE - overall equipment effectiveness)
	No collaboration with QLT team	Formation of cross-functional teams between production, engineering, and quality for regular and continuous quality issue evaluation (CAPA) (Gemba)

Over & Short Hook-on Cover and Bottom Drum

The proposed improvements to the quality problems of over and short hooks on the cover and bottom drum are as follows.

Table 3. Proposed Improvements Over and Short Hook

Waste	*Root Cause*	Recommendations for Improvement
Over& Short Hook-on	There is no routine maintenance schedule	Implementation of preventive maintenance system, maintenance schedule and spare part

Cover and Bottom Drum	High intensity of use without routine spare part replacement	replacement schedule based on time and usage cycle
	Operators work based on production targets without WI and SOP standards Does not implement inline checking	Compiling and implementing standard WI and SOP in drum production machining process, especially double seamer and cutting press process. Standardization of inline inspection procedures as part of production SOPs with clear frequencies, technical parameters and quality operator responsibilities.

Sheet Rejected

The proposed improvements to the problem of reject sheet quality are as follows.

Table 4. Proposed Improvements to the Rejection Sheet

Waste	*Root Cause*	Recommendations for Improvement
Sheet Rejected	There is no routine maintenance schedule High intensity of use without routine spare part replacement	Implementation of preventive maintenance system, maintenance schedule and spare part replacement schedule based on time and usage cycle
	No operator refreshment	Conduct periodic refresher training for operators regarding process and quality standards.
	Incoming check material without measuring plate thickness	Added plate thickness measurement procedure during incoming material check

DPMO Calculation Result and Proposed Condition Sigma Level

The calculation of DPMO and sigma level in the proposed condition shows a significant decrease compared to the existing condition, along with the increase in sigma level from 3.63 to 4.04. This indicates that the drum production process is more stable and of higher quality, marked by a reduced number of defects. Figure 6 below explains the results of the calculation of DPMO, process DPMO, Sigma, and Process Sigma in the proposed condition.

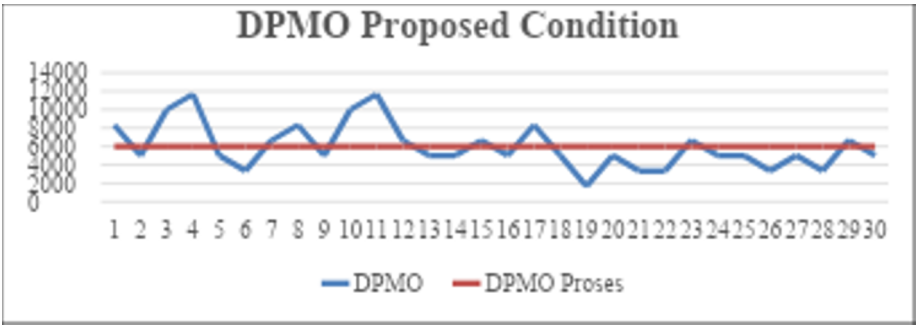

Fig. 6. DPMO Graph Proposed Conditions

From the graph, it can be seen that the DPMO value is generally below the process DPMO limit, indicating that the defect rate per million opportunities in the drum production process has decreased significantly. The relatively stable DPMO fluctuation indicates better process control than the previous condition. This decrease in DPMO indicates the effectiveness of the implementation of improvements that have been made, so that the production process becomes more consistent and of higher quality.

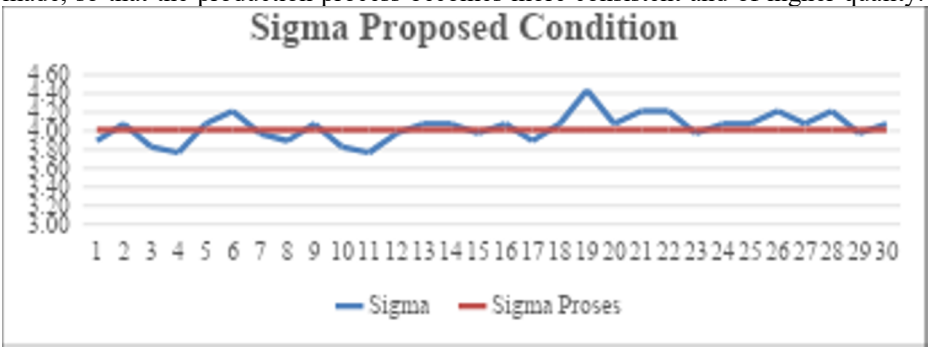

Fig. 7. Proposed Condition Sigma Chart

The process sigma value at the proposed condition shows a stable trend with an average of around 4.0 which is above the specified process sigma level. This increase in sigma reflects an increase in process quality with a significant decrease in the number of defects. A process with high sigma shows a low level of variation and better control over defects, thus strengthening the stability and performance of drum production at the PT XYZ.

Potential Loss Calculation Based on Proposed Condition

The calculation of potential loss is calculated based on the reduction in drum defects that occur after the implementation of several proposed strategies to minimize the number of drum variations in existing conditions. With a total production volume of March-April 2025 of 35,204 units with a reject rate of 1.32%, and a drum reject cost per kg of IDR 13,100, the total cost of losses that occurred in March-April 2025 was IDR

29,432,032. When compared to the total cost of the reject rate in January-February 2025, there was a decrease in potential loss of 38%. The details of the loss calculation are attached in Table 9 below.

Table 5. Calculation of Proposed Condition Loss

Average Production Volume January - February 2025	16000
Reject Rate Jan-Feb 2025	2.27%
Average Production Volume March-April 2025	17000
Reject Rate Mar-Apr 2025	1.32%
Cost per Kg Reject	13100
Losses Jan-Feb 2025	Rp47,695,659
Losses Mar-Apr 2025	Rp29,432,032
Potential Loss (Defect) Reduction	38%

3.3 Control

The control stage is the final phase in the Lean Six Sigma approach with the DMAIC method. The main objective of this stage is to ensure that all improvements that have been implemented can be maintained consistently and sustainably. In the context of the asphalt drum production process, this stage includes a control map of the results of recommendations on the proposed conditions and the creation of SOPs for Pareto machining stations including rolling stations, welding stations, press cutting stations, and leak tester stations.

Control Chart Result C Proposed Condition

Sampling and checking of defects that occur in drums are carried out as a result of the implementation of repair recommendations at several machining stations (maintenance), work SOPs and cross-functional collaboration of management including quality, production, and technical. Implementation of machine maintenance every 6 months, and checking spare parts every 3 months, and the addition of incoming material check procedures using calipers. During the inspection process of 30 samplings, each of 200 units, a total of 108 defects of various types were found.

It is known that there was a decrease in the findings of the type of inconsistency welding defect samples by 80%, over/short hook by 76%, the findings of rejected sheets decreased by 69%, and the type of rejected drum defects decreased by 27% between the conditions before and after the repair. This decrease shows that the corrective actions that have been implemented both in terms of technical, quality control, and work process standardization have had a significant impact on improving production quality. This is also an indicator of the success of efforts to increase efficiency and sustainable quality control, so it is recommended to carry out routine monitoring to ensure that the improvement trend remains consistent. The control chart C for the proposed conditions is explained in Figure 8 below.

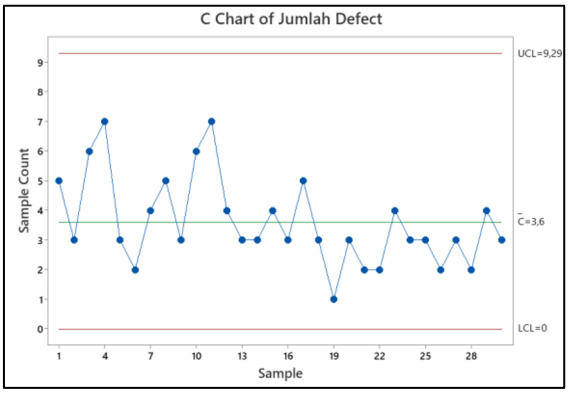

Fig. 8. Control Chart C Proposed Conditions

Based on the results of the C control chart graph per sample in the production process by taking 30 samples, it is known that all points are below the upper control limit and the lower control limit, which indicates that the process is in statistical control. This process is relatively stable with an average defect of around 3.6 per sample and shows no signs of significant process disruption. Fluctuations in the number of defects occur naturally within acceptable control limits.

Standardization of Proposed Improvement in SOP

As part of the control phase, standardization of work procedures is a crucial step to maintain consistency in the implementation of improvements. In this sub-chapter, Standard Operating Procedures (SOP) are prepared as formal documents that regulate the procedures for implementing activities, especially in areas that have been improved. The SOP draft is attached as follows. Standard Operating Procedures were developed for the rolling, welding, press, and leak testing stations. These SOPs include detailed work instructions, safety protocols, and maintenance checklists to ensure sustained quality control.

4 Conclusion

The identification and analysis of critical waste in the asphalt drum production process have highlighted key areas for improvement, particularly in the categories of defects, waiting, and over-processing. Through Pareto analysis, it was established that inconsistent welding, excessive/short hooks, and rejected sheets were the primary contributors to defects, accounting for significant proportions of overall waste. The Value Stream Mapping revealed that the painting machine setup and double stitching processes were the most time-consuming non-value-added activities, indicating opportunities for efficiency gains. Following a thorough investigation using fishbone and five whys analysis, it became clear that addressing irregular maintenance, enhancing training, and improving the quality control system are crucial to mitigating these defects.

Implementing structured recommendations, such as optimizing work areas and reinforcing maintenance protocols, has led to substantial reductions in defect rates and setup times, alongside a notable improvement in process capability as evidenced by the increase in sigma level. Overall, these targeted improvements not only enhance production efficiency but also ensure higher quality outcomes in asphalt drum manufacturing.

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