

LEAN SIX SIGMA APPROACH TO INCREASE PROCESS CYCLE EFFICIENCY IN PALM OIL PROCESSING AT PT. X

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Abstract

The Indonesian palm oil industry, a global leader in production, faces increasing challenges in maintaining efficiency and quality. This study aims to apply the Lean Six Sigma methodology to enhance production processes by integrating Lean Manufacturing principles with the systematic, data-driven approach of Six Sigma. Using the Define-Measure-Analyze-Improve-Control (DMAIC) framework, the research identifies and mitigates inefficiencies in key stations of a palm oil mill. Novelty lies in the application of Lean Six Sigma to the palm oil industry, demonstrating significant improvements: a 16% increase in process cycle efficiency, a reduction of 70.5 kg in daily fresh fruit bunch (FFB) losses, and a decrease in associated costs by IDR 176,750 per day. The findings underscore the potential for continuous improvement in the industry through the systematic application of Lean Six Sigma.

Abstract

Industri kelapa sawit di Indonesia, sebagai pemimpin global dalam produksi, menghadapi tantangan yang semakin meningkat dalam menjaga efisiensi dan kualitas. Penelitian ini bertujuan untuk menerapkan metodologi Lean Six Sigma guna meningkatkan proses produksi dengan mengintegrasikan prinsip-prinsip Lean Manufacturing dengan pendekatan Six Sigma yang sistematis dan berbasis data. Dengan menggunakan kerangka kerja Define-Measure-Analyze-Improve-Control (DMAIC), penelitian ini mengidentifikasi dan mengurangi ketidakefisienan di stasiun-stasiun kunci di pabrik kelapa sawit. Kebaruan penelitian ini terletak pada penerapan Lean Six Sigma di industri kelapa sawit, yang menunjukkan peningkatan signifikan: peningkatan 16% dalam efisiensi siklus proses, pengurangan kehilangan Tandan Buah Segar (TBS) sebesar 70,5 kg per hari, dan penurunan biaya terkait sebesar IDR 176.750 per hari. Temuan ini menekankan potensi peningkatan berkelanjutan di industri melalui penerapan Lean Six Sigma yang sistematis..

Kata Kunci: Lean Six Sigma, industri kelapa sawit, efisiensi produksi, DMAIC, peningkatan proses, pengurangan limbah.

INTRODUCTION

In recent years, the Indonesian palm oil industry has emerged as one of the most pressing issues faced by the global community [1]. Palm oil plantations in Indonesia have expanded from North Sumatra, Aceh, Riau, Kalimantan, and other regions[2][3]. Indonesia has solidified its position as the world's largest palm oil producer, with remarkable growth in this industry. In 2022, Indonesia produced 46.50 million tons of palm oil, increasing to 47.7 million tons in 2023, with a production yield of 144.682 thousand tons. This significant production, accounting for 59% of global CPO output, is supported by an extensive expanse of palm oil plantations covering 16.83 million hectares in 2023. The proliferation of palm oil mills in Indonesia has further facilitated this growth, demonstrating the country's dominance in the palm oil market.[4][5].

In today's competitive industrial landscape, companies strive to enhance production efficiency and quality to maintain their competitive edge [6]. The Lean Six Sigma methodology, a combination of Lean and Six Sigma principles, has proven effective in achieving these objectives by identifying and eliminating waste in production processes [7]. By reducing waste such as defects, excess inventory, and delays, companies can significantly improve production efficiency and deliver higher-quality products to meet customer expectations.

Lean Six Sigma is a continuous improvement endeavor that combines two complementary methodologies, namely Lean manufacturing and Six Sigma [8][9]. The former seeks to eradicate or minimize waste and boost the added value of products (goods or services) [10]. Six Sigma, on the other hand, is a method of problem-solving that uses the Define-Measure-Analyze-Improve-Control (DMAIC) phases to measure results comprehensively and systematically. Businesses can improve the "quality" of the Six Sigma idea and the "efficiency" of the Lean concept by integrating these two approaches. Various tasks will be completed at each level in

accordance with the circumstances that arise throughout the production process [11].

Lean Six Sigma is the integration of two mutually supportive methodologies: Lean Manufacturing and Six Sigma [12]. Lean Manufacturing aims at continuous improvement efforts to eliminate or reduce waste and enhance the value added to products (goods or services) [13]. On the other hand, Six Sigma is a problem-solving method that is systematically and quantitatively driven, utilizing the Define-Measure-Analyze-Improve-Control (DMAIC) phases [14]. By combining these two methods, a company can enhance the "efficiency" inherent in the Lean concept and the "quality" associated with Six Sigma. In each phase, different activities are undertaken based on the specific conditions present during the production process[15].

RESEARCH METHODS

In this research, the lean six sigma approach was carried out by incorporating lean concepts at each systematic stage of six sigma, namely Define-Measure-Analyze-Improve-Control (DMAIC) [16]

Define:

At this stage, problem identification will be carried out to clearly understand the focus of the problem area to be resolved. For this reason, a SIPOC (Input-Process-Output-Customer) diagram can be created.

Measure:

After knowing the research focus based on the SIPOC diagram, a Process Activity Mapping (PAM) table is then created, which is used to determine and measure each activity consisting of value-added activities (VA), non-value-added activities (NVA), and necessary but non-value-added activities (NNVA). Process activity mapping will provide an overview of the physical and information flow, the time required for each activity, the distance traveled, and product inventory levels at each stage of the production process. Ease of identification of activities occurs due to the classification of activities into five types, namely: operations, transportation, inspection, storage, and delay.

Operations and inspections are value-added activities. Transportation and storage are important but non-value-added activities. Meanwhile, delay is an activity that does not add value, so it must be avoided.

Based on process activity mapping, several process performance measurements were carried out before improvement as a basis for comparison to determine performance improvements after the process was analyzed and improved. The measurements carried out include:

- Measurement of Process Cycle Efficiency with the Formula: $PCE = \frac{\text{Value added time}}{\text{Total lead time}}$
- Measurement of material loss, based on the amount of material lost in production activities.
- Measuring the cost of losses due to material losses.

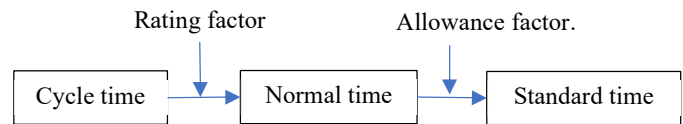
The measurement results are then depicted in Current Value Stream Mapping (C-VSM) to provide an overview and information related to the flow of resources, such as materials and activities carried out.

Analyze:

At this stage, analysis is carried out based on the previous stage. Analysis can be carried out based on direct observation of existing processes and data or using supporting tools that are appropriate to the problem that occurs.

Improve:

At this stage, improvements are made by considering the analysis carried out in the previous stage. Improve aims to eliminate or reduce the waste that occurs. The time for activities carried out by workers will be completed using standard time determination. Standard time is the average time required for a worker to complete a job reasonably within a work system, considering adjustments and providing additional allowances [17]. The stages for calculating standard time can be seen in Figure 1 below.



Figur 1. Steps for Standard Time Calculation

Standard time can be calculated by first calculating cycle time and normal time. Cycle time is the time required to complete one work process, or the amount of time for each element in a job [18]. Normal time is the average time needed for a worker to complete a job fairly within an adjusted work system design [19]. The rating factor value can be determined based on the adjustment factor in the Westing House method. The allowance value can be determined based on the values in the table 'determination of the amount of allowance based on influencing factors [20]. The formula used to calculate standard time is:

- $Cycle\ Time = \frac{\text{total cycle time}}{\text{amount of data}} = \frac{\sum X_i}{N}$
- $Normal\ Time = Cycle\ Time \times (1 - Rating\ factor) = CT \times (1 - Rf)$
- $Standard\ Time = Normal\ Time + (Normal\ Time \times Allowance) = NT + (NT \times All)$

Control:

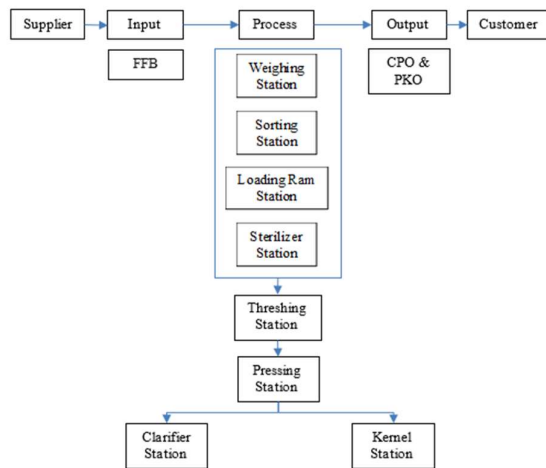
The control stage focuses on efforts to maintain and control the improvement proposals that have been prepared in the previous stage.

RESULTS AND DISCUSSION

The explanation for results and discussion follows the five stages of Six Sigma, namely define, measure, analyze, improve, and control.

Define

At this stage, a SIPOC diagram is created to determine the location of the source of the problem that is the focus of the research, as shown in Figure 2.



Figur 2. SIPOC Diagram

Based on the SIPOC diagram in Figure 2, it was decided that the main problem occurred in the process, namely at the weighing station, sorting station, loading ram station, and sterilization station. For this reason, the research focuses on these four stations.

Measure

Each activity that is the focus of research is measured, and the type of activity is identified. Activities consist of value-added (VA) activities, non-value-added (NVA) activities, and necessary but non-value-added (NNVA) activities. The measurement and identification results are then entered into the activity mapping process table, as can be seen in Table 1 below.

Table 1. Current Process Activity Mapping

No	Station	Activity	Tools	Type of activity	Distance (m)	Worker	Times (minute)	Losses (kg)	Process VA/NVA/NNVA
1	Weighing	Weighing raw materials (FFB)	Avery	√	-	1	1.39	-	The truck driver gives a letter of introduction to the weighing operator, and then the operator carries out the weighing. (VA)
					√	-	0.63	-	Activities other than those that are supposed to be carried out. (NVA)
		Queue to unload FFB at the weighing station	Truck	√		1	34.54	-	Waiting in line to load FFB at the sorting station, because there are still trucks being loaded and the FFB is still piling up at the sorting station. (NVA)
2	Sorting	Bringing FFB to sorting station	Truck	√	100		7.25	-	Bringing FFB to sorting station
		Unloading FFB from the truck	Tojok	√ √	-	3	79.93	-	Unloading FFB from the truck and sorting FFB that is suitable and that is not suitable. (VA)

	Loading inappropriate FFB onto trucks	Tojok	√	-	1	2.37	-	Loading FFB that does not meet standards back onto the truck for return. (VA)
	Move appropriate FFB to loading ram	Loader	√	10	1	4.28	2	Move FFB to temporary storage at the loading ramp. (NNVA)
3	Loading FFB into lorries	-	√	-	2	1.45	0,5	Loading lorries with FFB on the loading ramp. (VA)
				√	-	0.44		Activities other than those that are supposed to be carried out. (NVA)
	Move the lorries to the Sterilization Station	Wire rope sling and Capstand	√	34	2	11.34	-	Move the lorries to the sterilization station using wire rope slings, which are rotated by the capstan and moved by the transfer carriage. (NNVA)
4	Loading lorries into the pressure sterilization vessel	Capstand	√	-	2	13.68	-	Loading lorries into the pressure sterilization vessel using wire rope slings and capstans. (NNVA)
	Sterilization of FFB	Pressure Sterilization Vessel	√	-	2	115	-	Carrying out the FFB sterilization process using steam with a 3-peak system. (VA)
				√	-	14.61	-	Additional time is caused by leaks in the pressure sterilization vessel. (NVA)
	Total		5	1	4	-	4	286,91
	VA							200.14
	NNVA							36.55
	NVA							50,22

Measurement of Process Cycle Efficiency

$$PCE = \frac{200,14}{286,91} \times 100\% = 69.8\%$$

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Measurement of losses at sortation stations

At the sorting station, an average of 2 kg of raw materials (FFB) is lost when moving the FFB to the loading station. If there are 20 trucks in one day, then the amount of FFB lost at the sorting station is 40 kg/day. If the price of FFB is Rp. 2,500/kg, then:

Cost due to the loss of FFB per day = 40 kg x Rp. 2,500/kg = Rp. 100,000

Measurement of losses at loading ramp stations

At the loading ramp station, losses occur when loading FFB into lorries. The average loss is 0.5 kg/lorry. There are 9 lorries for one sterilization process, and there are 7 processes a day, so the amount of FFB loss at the ram loading station is 31.5 kg/day. For this reason, losses and disadvantages at this station are:

Cost due to the loss of FFB per day = 31.5 kg x Rp. 2,500/kg
= Rp. 78,750

So, the total of FFB losses per day = losses at the sorting station + losses at the ram loading station.

= 40 kg - 31.5 kg
= 71.5 kg

Total costs due to FFB losses per day = losses at the sorting station + losses at the ram loading station
= Rp. 100,000 + Rp. 78,750
= Rp. 178,750

Analyze:

Based on the results of time measurements for each activity in the activity mapping process, it is known that for value-added activities (VA), it is 200.14 minutes; for non-value-added activities (NVA), it is 50.22 minutes; and for activities that are necessary but non-value-added (NNVA), it is 29.30 minutes. Furthermore, non-value-added activities must be eliminated or reduced to increase process cycle efficiency.

Some waste, which is a non-value-added activity, is found at the weighing station for

FFB weighing activities and is waiting for FFB unloading. Waste at the ram loading station occurs during lorries filling activities. Waste at the sterilizer station occurs due to leaks in the pressure sterilization vessel, so additional time is needed for the sterilization process. For activities carried out by humans, the existing time is converted into standard time by considering rating factors and allowances. For other activities, it will be resolved by finding the cause of the problem and the possibility of eliminating or reducing it. The rating factors and allowances that will be used to calculate the standard time for each activity can be seen in Table 2 below.

Table 2. Rating Faktor dan Allowance

Activities	Rating Factor	Allowance
Weighing raw materials (FFB)	0.24	13.0
Unloading FFB from the truck	3.32	59.0
Loading inappropriate FFB onto trucks	0.32	74.0
Move appropriate FFB to loading ram	0.26	14.5
Loading FFB into lorries	0.26	15.0
Move the lorries to the Sterilization Station	0.34	45.0
Move the lorries into the pressure sterilization vessel	0.38	50.0

Improve

To determine the improvement that has occurred, it is done by comparing the activity time before and after the improvement. Activity time after improvement is determined by changing the existing activity time to standard time by considering adjustments and allowances. After that, standard time can be used to control worker activities. To compare the two times, they are entered into the future activity mapping table, as shown in Table 3 below.

Table 3. Future Process Activity Mapping

No	Station	Activity	Tools	Before		After		Information for Improvement
				Times (minute)	Losses (kg)	Times (minute)	Losses (kg)	
1	Weighing	Weighing raw materials (FFB)	Avery	1.39	-	1.19	-	Convert activity time to standard time.
			-	0.63	-	0	-	Time activities should be eliminated because they don't add value.
		Queue to unload FFB at the weighing station	Truck	34.54	-	0	-	Time activities should be eliminated because they don't add value.
		Bringing FFB to sorting station	Truck	7.25	-	7.25	-	Bringing FFB to sorting station
2	Sorting	Unloading FFB from the truck	Tojok	79.93	-	86.42	-	Convert activity time to standard time.
		Loading inappropriate FFB onto trucks	Tojok	2.37	-	2.80	-	Convert activity time to standard time.
		Move appropriate FFB to loading ram	Loader	4.28	2	3.63	0,05	Convert activity time to standard time, and losses are reduced by improving work methods.
3	Loading Ramp	Loading FFB into lorries	-	1.45	0,5	1.23	0	Convert activity time to standard time, and losses are eliminated by improving work methods.
			-	0.44		0		Time activities should be eliminated because they don't add value.
		Move the lorries to the Sterilization Station	Wire rope sling and Capstand	11.34	-	10.85	-	Convert activity time to standard time.
4	Sterilization	Loading lorries into the pressure sterilization vessel	Capstand	13.68	-	12.72	-	Convert activity time to standard time.
		Sterilization of FFB	Pressure Sterilization Vessel	115.00	-	115.00	-	Convert activity time to standard time.
				14.61	-	0	-	The additional time caused by vessel leaks can be eliminated by repairing the pressure sterilization vessel.
Total				286.91		241.10		
VA				200.14		206,65		
NNVA				36.55		34,45		
NVA				50,22		0		

$$\text{Process Cycle Efficiency} = \frac{206.65}{241.10} \times 100\% = 85.7\%$$

By comparing the data in Table 3, we obtain:

- Increased process cycle efficiency by 16%, namely from 69.8% to 85.7%.

- FFB losses for loading FFB into lorries activities can be eliminated; however, for moving appropriate FFB to loading ram activities, they can only be reduced to 0.05 kg or 1 kg/day. This is due to the condition of the location of the FFB that will be moved.

- Losses due to the loss of FFB per day = 1 kg
x Rp. 2,500
= Rp. 2,500
Decrease in daily FFB loss.

$$= 71,5 \text{ kg} - 1 \text{ kg}$$
$$= 70,5 \text{ kg}$$

- Decrease in losses due to FFB loss per day.
= loss before evaluation - loss after
evaluation
= Rp. 178,750 - Rp. 2,500
= Rp. 176,750

Control

Standard time can be used to control activities for the time after improvements in the improve stage, just like it is in the future process activity mapping table. Future process activity mapping can be used to identify and oversee each

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