JOURNAL LA MULTIAPP

VOL. 06, ISSUE 06 (1496-1518), 2025
DOI: 10.37899/journallamultiapp.v6i6.2245

Waste Analysis in CPO Production using Lean Six Sigma

Yohanes Nababan[1], Rochmoeljati[1]

[1]Departement of Industrial Engineering Faculty of Engineering and Sains, University National Development "Veteran" East Java, Surabaya, East Java, Indonesia 60294

**Corresponding Author: Yohanes Nababan*
Email: yohanesnababan81@gmail.com

Article Info

Article history:
Received 21 May 2025
Received in revised form 21 June 2025
Accepted 25 December 2025

Keywords:
Lean Service
Root Cause Analysis
VALSAT
Waste Identification

Abstract

PT XYZ is a manufacturing company engaged in the production of Crude Palm Oil (CPO). In its production process, a significant amount of waste due to product defects is still found. This can be seen from the production parameters recorded from January to June 2024. Based on 137 samples taken over six months, 132 samples did not meet the company's established standards across four parameters. This study aims to determine the types of waste occurring in the CPO production process, assess the sigma level, provide waste reduction recommendations, and minimize non-value-added activities. The study uses the Lean Six Sigma method. It begins by identifying waste in the CPO production process, with the most dominant forms being defects, overproduction, and waiting. The sigma level of the CPO production process at PT XYZ was found to be 2.20, with a DPMO (Defects Per Million Opportunities) of 240,277.8, which falls into the "good" category based on the average performance of the palm oil industry in Indonesia. Further analysis was conducted to identify the root causes of defects using a fishbone diagram. Improvement proposals were developed using the Failure Mode and Effect Analysis (FMEA) tool. With the design of Process Activity Mapping (PAM) and Big Picture Mapping, the lead time was successfully reduced from 807.22 minutes to 728.88 minutes.

Introduction

In today's economic era, both service and manufacturing industries are experiencing rapid growth (Rodrik et al., 2025; Sagio et al., 2025; Ahmadi, 2024). Companies are required to sustain themselves and continuously improve the effectiveness and efficiency of their production processes in order to remain competitive in the market. In an increasingly intense and competitive business environment, the advancement of knowledge is expected to drive the emergence of new technologies and innovative, high-quality products that can compete on a global scale (Mahendra, 2023; Malek et al., 2024; Khatoon & Velidandi, 2025).

PT XYZ is a company focused on oil palm cultivation and the processing of plantation products into crude palm oil (CPO) and its derivatives. However, in the palm oil production process at PT XYZ, issues related to waste are still present, resulting in suboptimal production effectiveness and efficiency. The types of waste identified include failure to meet the established CPO quality standards, which affects the final product quality; excessive delay in processing fresh fruit bunches (FFB); stockpiling of FFB due to an oversupply at the storage area; and waiting time waste caused by the limited number of transport trolleys (lori) provided by the company. However, in the palm oil production process at PT XYZ, issues related to waste are still present, leading to suboptimal production effectiveness and efficiency. The types of waste identified include: waste of defects, waste of inappropriate processing, waste

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

of unnecessary inventory, waste of waiting, waste of overproduction, waste of transportation, and waste of motion.

The impact of this waste is not only felt internally by the company, but also extends to the customers. CPO products with declining quality due to high levels of free fatty acids (FFA), delayed deliveries caused by slow production processes, and inconsistency in product quality can reduce customer satisfaction and market trust. In the long term, this can affect the company's competitiveness, especially in the export market which demands strict quality standards (Carlin et al., 2001; Wang & Zhu, 2025; Alam et al., 2025).

Research on the CPO production process at PT Meganusa Inti Sawit is necessary to identify the most significant sources of waste using the Lean Six Sigma approach. This method aims to analyze the flow of activities within the production process, streamline production time, eliminate non-value-added activities, and implement continuous improvement to achieve defect-free results (Vierci-Codas et al., 2025; Fuad et al., 2025; Gomaa, 2025). It is expected that the application of the Lean Six Sigma method can help analyze waste in the production process and provide improvement recommendations to enhance the effectiveness and efficiency of the company (Henny et al., 2019; Adeodu et al., 2021; Thomas et al., 2008).

Lean Consept

Lean is a method aimed at improving processes by eliminating non-value-added activities and making workflows more effective and efficient, thereby creating faster and better performance (Dara et al., 2025; Taher et al., 2024; Olaolu & John, 2024). The goal of Lean is to enhance customer value across all work processes within a company in order to continuously increase customer satisfaction. Essentially, Lean can be applied to any type of company. Lean is defined as a business philosophy based on minimizing the use of resources (including time) in various company activities. It focuses on identifying and eliminating non-value-added activities in planning, production, or operations (including services) that are directly related to the customer (Wijaya, 2023; Pekarcikova et al., 2024; Ahmad et al., 2022).

Six Sigma

Six Sigma is a method for quality improvement aimed at achieving a target of 3.4 defects per million opportunities (Defects Per Million Opportunities – DPMO) for each product transaction (goods or services), or a vigorous effort toward perfection (zero defects). Six Sigma is a metric that can be interpreted as a process of measurement using statistical tools and techniques to reduce defects to more than 3.4 DPMO, or 99.99966% accuracy, with a focus on achieving customer satisfaction. Six Sigma is a disciplined approach based on five stages: Define, Measure, Analyze, Improve, and Control (DMAIC). It is uniquely driven by a strong understanding of customer needs, disciplined use of facts, data, and statistical analysis, and a careful focus on managing, improving, and institutionalizing business processes. Six Sigma is built upon several key concepts (Buer, 2002; Skalli et al., 2025; Gupta et al., 2024), including defects, variation, critical-to-quality (CTQ), process capability, and Design for Six Sigma (DFSS) (Gaspersz, 2005).

Lean Six Sigma

Lean-Sigma, which is a combination of Lean and Six Sigma, can be defined as a business philosophy and a systemic and systematic approach to identifying and eliminating waste or non-value-added activities through radical continuous improvement in order to achieve Six Sigma performance levels (Hossain et al., 2024; Safari et al., 2025; Badhotiya et al., 2024). This is accomplished by ensuring the flow of products (materials, work-in-process, outputs) and information using a pull system from both internal and external customers, in pursuit of excellence and perfection vnamely, a production rate of 3.4 defects per one million

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

opportunities or operations (3.4 DPMO – Defects Per Million Opportunities) (Gaspersz, 2007).

Value Stream Mapping

Value Stream Mapping is a visual method used to map the production flow of a product, including the movement of materials and information at each workstation (Abdulmalek & Rajgopal, 2007; Bugvia et al., 2021; Seth et al., 2017). Value Stream Mapping is used to map the value flow from the beginning to the end of the process, both for the current condition and a better future condition. One of the tools commonly used in Lean Six Sigma to map the entire flow of information and materials, as well as to identify waste, is Value Stream Mapping (VSM) (Syaher et al., 2024; Morato et al., 2024; Tian et al., 2025). VSM is an ideal tool to serve as the initial step in implementing process changes to achieve improved conditions.

Fishbone

The Fishbone Diagram is a visual analysis tool that helps identify various factors that may be the root causes of a problem (Sakdiyah et al., 2022; Coccia, 2018; Shinde et al., 2018). The shape of the diagram resembles a fishbone, with the main problem positioned at the "head" and the potential causes branching out as "bones" along the main line. This diagram is designed to break down complex problems into smaller parts, making it easier to identify the root cause of the issue (Sulianta & Widyatama, 2024; Manish, 2024; Gebreab et al., 2024).

Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a design and engineering analysis method used to assess the reliability of a system (Sunday et al., 2018; Subriadi & Najwa, 2020; Huang et al., 2020). It is a structured, systematic approach for identifying potential failure modes in a design or manufacturing process. FMEA then evaluates the impact of those failures on the system and takes the necessary steps to correct the problems. Thus, FMEA serves as a preventive tool aimed at addressing potential issues that may affect system reliability (Sanusi & Paramida, 2021; Ali et al., 2025; Samimi et al., 2025).

Methods

In this study, data collection to identify waste in the CPO production process was conducted using observation, interviews, and questionnaires for primary data. Secondary data were obtained from the company, such as production process flow data, production time, production volume, and defect counts. This stage involves identifying variables based on problems encountered during the study, referring to literature review and field observations. This process results in independent and dependent variables related to the research method used, as follows: the dependent variable in this thesis research is the level of waste in the Crude Palm Oil (CPO) production process at PT XYZ. The independent variables in this study are types of waste, including unnecessary inventory, overproduction, inappropriate process, defects, waiting, transportation, and excess motion.

The research stages followed the DMAIC approach (Define, Measure, Analyze, Improve, and Control); however, the Control stage was not implemented in this study and was left to the company. In the Define stage, identification was conducted on the flow diagram, waste identification, Critical to Quality (CTQ), value stream analysis tools (VALSAT), and process activity mapping (PAM). Next, in the Measure stage, data adequacy tests were performed, P control charts were created, sigma values were calculated, and current state value stream mapping was developed. In the Analyze stage, failure causes were analyzed using a fishbone diagram, 5 Whys analysis, and FMEA. Then, in the Improve stage, after identifying the causes of failure, improvements were made using FMEA analysis and proposed value stream mapping.

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

Results and Discussion

Define Stage

Physical Flow

The physical flow in the Crude Palm Oil (CPO) production process includes all stages of physical material movement, starting from the arrival of raw materials received from suppliers until becoming the final product in the form of crude palm oil (CPO). This final product is then ready to be delivered to customers or stored in storage facilities. The stages of the CPO production process can be seen in the following diagram.

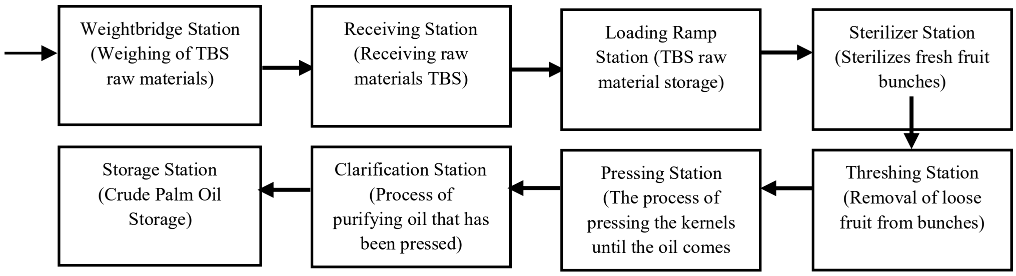

Figure 1. Physical Flow

Weighbridge:

Trucks transporting Fresh Fruit Bunches (FFB) are weighed twice first upon arrival (gross weight), and second after unloading (tare weight). The difference indicates the net weight of the FFB.

Receiving Station & Grading:

FFB is tipped into the grading area to be sorted based on the ripeness level of the fruit.

Loading Ramp (Temporary Storage):

Sorted FFB is temporarily stored while waiting for an empty cage trolley (lori) to transport it to the sterilization station.

Sterilizer (Boiling):

FFB is steamed using pressurized steam (3 bar, 130–140°C) for 85–90 minutes to deactivate enzymes and facilitate separation.

Threshing (Stripping):

The boiled FFB is separated into loose fruits and empty bunches using a rotating drum thresher.

Pressing (Oil Extraction):

The loose fruits are stirred and heated in a digester, then pressed to extract oil from the fruit pulp.

Clarification:

The extracted oil is purified to separate water, sludge, and impurities, producing high-quality crude palm oil (CPO).

Storage Tank:

CPO is stored in tanks with controlled temperature to maintain quality before being shipped to customers or central storage.

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

Waste identification

Waste in this research is based on 7 wastes, namely: waste of defects, waste of inappropriate processing, waste of unnecessary inventory, waste of waiting, waste of overproduction, waste of transportation, and waste of motion. This waste identification aims to identify what waste is dominant in CPO production. The waste identification process is carried out by filling out a questionnaire given by the company to the respondents targeted in the distribution of this questionnaire including five experts in the field of production, namely the Company Manager, Assistant Head, Laboratory Assistant, Grading Assistant, and Process Assistant. The results of filling out the questionnaire by experts in their fields are shown in Table 1, a recapitulation of the 7 waste questionnaire below.

Table 1. Summary of Waste Questionnaire Results

Waste	**Respondents**					**Average**	**Ranking**
	R1	R2	R3	R4	R5		
Overproduction	4	4	4	4	5	4	2
Waiting	4	4	3	5	4	3,6	3
Transport	2	3	3	3	4	2,6	6
Inappropriate processing	3	3	4	3	4	3,2	5
Unnecessary Inventory	3	4	3	4	3	3,4	4
Motion	2	2	3	3	3	1,8	7
Defects	4	4	5	5	4	4,4	1

Since the most dominant type of waste is defect, a fishbone analysis is conducted to identify the causes or root causes of this defect-related waste from the aspects of man, machine, environment, method, and material.

Qritical To Quality

Critical to quality is defined as input from customers. CTQ determination aims to identify characteristics that have the potential to be defective in the final product produced. Based on the results of the company in the production section and the head of the laboratory, there are 4 types of defects. Table 2 below is the quality characteristics for critical to quality (CTQ) of CPO products.

Tabel 2. CPO Quality Characteristics Data

Characteristics	Information (%)
Free Fat Acid (FFA)	< 3,00
Moisture	< 0,15
Dirt	< 0,03
DOBI	> 3,00

Process Activity

Tabel 3. Process Activity Production CPO

No	Process Description	Time (Second)	Time (Minute)	Activity Type
WEIGHTBRIDGE STATION				
1	Receipt of TBS Entering by Truck	28	0,47	NNVA
2	vehicle inspection and TBS	300	5	NNVA
3	The driver reported the SPB to the security guard	278	4,63	NVA
4	Trucks entering the weighbridge	180	3	NNVA
5	Performing the first weighing	300	5	NNVA

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

6	Vehicle Release to Fruit Receiving Station	300	5	NNVA
7	perform the second weighing	300	5	NNVA
RECEIVING STATION				
8	Discharge of raw materials to the grading area	1756	29,27	NNVA
9	sorting of raw materials according to fruit criteria	1856	30,93	VA
10	Recording the results of the physical examination of fruit	112	1,87	NNVA
11	Mandor grading mengambil SPB dari supir	116	1,93	NVA
12	Calculate fines or deductions for fruit that has been sent	256	4,27	NVA
13	SPB is returned to the driver	56	0,93	NVA
14	TBS is loaded into the loading ramp	926	15,43	NNVA
LOADING RAMP STATION				
15	Loading TBS into Lorries	924	15,4	NNVA
16	TBS on the surface of the Lori is leveled	910	15,17	NNVA
17	Transfer from filling rail to boiling rail	900	15	NNVA
18	Ensuring that the lorry series containing TBS is on standby in front of Rebusan	60	1	NVA
19	Retrieval of loose fruit that fell into the truck	600	10	NVA
STERILIZIER STATION				
20	Sterilizer Door Opening	28	0,47	NNVA
21	Moving the TBS filled lorry into the sterilizer	600	10	NNVA
22	Close the sterilizer door	28	0,47	NNVA
23	Pressure and temperature settings according to standards	120	2	NNVA
24	Turn on the steam supply to the sterilizer.	60	1	NNVA
25	Sterilization Process	5400	90	VA
26	Process Monitoring	210	3,5	NNVA
27	Steam engine shutdown	35	0,58	NNVA
28	Steam release	300	5	NNVA
29	Open the sterilizer door	28	0,47	NNVA
30	Removing the lorry from the sterilizer	630	10,5	NNVA
31	Clean the sterilizer from any remaining fruit or dirt.	600	10	NVA
32	Moving the lorry to the next station	600	10	NNVA
THRESHING STATION				
33	Receipt of TBS from Sterilizer	900	15	NNVA
34	Loading FFB from the truck into the thresher hopper	600	10	NNVA
35	Regulating the inflow of TBS	600	10	NVA
36	Turn on the machine to start the shelling process	300	5	NVA
37	Threshing Process	1500	25	VA
38	Monitoring the shelling process	250	4,17	NVA
39	Loose fruit is directed to the pressing station	610	10,17	NNVA

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

40	The bunches are fed to another conveyor to Re-Threshing	480	8	NNVA
41	The remaining Brondolan is sent to the pressing station	600	10	NNVA
42	Re-threshing process	900	15	NNVA
43	Empty bunches are sent to the empty bunch press machine	356	5,93	NNVA
PRESSING STATION				
44	Receiving loose fruit supplies from the threshing station	600	10	NNVA
45	Flowed to Fruit Elevator	300	5	NNVA
46	Flowed to Fruit Distributing Convenyor	300	5	NNVA
47	Distributed to Digester Machine	360	6	NNVA
48	Mashing and heating the fruit flesh	1200	20	VA
49	Flowed to the Press machine	120	2	NNVA
50	Fruit pulp pressing process	1200	20	VA
51	The process of flowing crude oil to the clarification station	300	5	NNVA
52	Wet fiber and nuts are sent to the kernel station	300	5	NNVA
CLARIFIKATION STATION				
53	Receipt of Crude Oil from Pressing Process	900	15	NNVA
54	Oil is drained from the oil gutter	300	5	NNVA
55	Flowed into the sand trap tank	600	10	NNVA
56	Sand trap process	1500	25	VA
57	oil is flowed from the header pipe over flow sand trap tank	600	10	NNVA
58	Oil Vibrating screen process (cutting oil)	300	5	VA
59	Clean oil is sent to the Crude Oil Tank	600	10	NNVA
60	Send oil using Continuous Settling Tank (CST)	600	10	NNVA
61	Clarification process	3600	60	VA
62	Sludge is discharged into the sludge tank	630	10,5	NNVA
63	Sludge separation with tricanter machine	1200	20	VA
64	*havy phase tricanter sent to rectangular tank*	900	15	NNVA
65	Minyak yang masih mengandung kadar air tinggi diproses ke *Vacuum Dryer*	1200	20	VA
66	*Oil that still contains high water content is processed into a Vacuum Dryer*	600	10	NNVA
67	Flowed to Oil Tank	900	15	NNVA
68	Oil Flow to Storage	600	20	NNVA
STORAGE STATION				
69	Clarified CPO Storage	600	10	NNVA
70	Storage Tank Monitoring and Control	620	10,33	NNVA
71	Tank temperature regulation and oil temperature maintenance	900	15	NNVA
72	Quality monitoring during storage	600	10	NNVA
73	Sounding Process	710	11,83	NVA

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

Measure Stage

Control Chart X And R

This research uses X and R variable control charts because the data obtained is a type of variable data. In this company, sampling is carried out five times a day. To determine the final parameters used, an average calculation is made from the samples that have been tested or calculated. X and R maps are used to control the proportion of defective products produced in a process. The process of making X and R maps is carried out through several stages, one of which is an example of calculating the number of FFA defects.

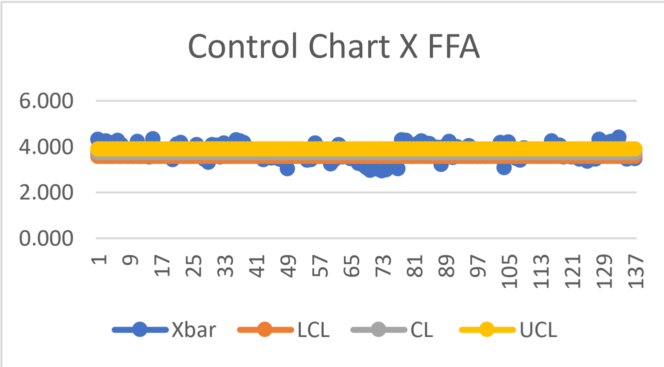

Figure 2. Control Chart X FFA

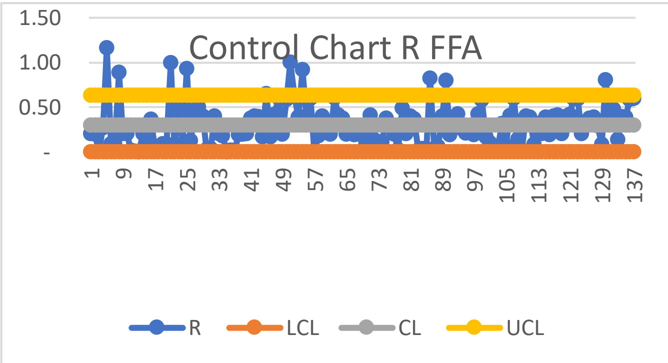

Figure 3. Control Chart R FFA

It can be seen that there are several periods with defect proportion values that are outside the upper control limit (UCL) and lower control limit (LCL) that have been determined from the results of data calculations. Therefore, it is necessary to implement an effective and implementable quality control system in order to reduce the level of defect proportion that occurs.

Sigma Value

Tabel 4. Recapitulation Sigma Value

Month	Production Sampel	Defect Sampel	CTQ	DPO	DPMO	Sigma Level
January	26	26	4	0,25	250.000	2,17
February	21	21	4	0,25	250.000	2,17
March	24	22	4	0,229	229.166,67	2,24
April	20	17	4	0,2	212.500	2,3
May	24	24	4	0,25	250.000	2,17
Juni	22	22	4	0,25	250.000	2,17

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

Average	137	132		0,238	240.277,8	2,20

From Table 4 above, the average DPMO value is 240,277.8 and the sigma value is 2.20. This shows that the level of sigma achievement of the CPO production process is included in the average of the Indonesian industry.

The four quality measurement parameters of CPO used in the analysis have not been clearly explained in terms of their origin. The company merely follows the guidelines set by the Indonesian National Standard (SNI) or export standards to examine the content of these four parameters in the CPO. Furthermore, an excessively long lead time also affects the quality of the CPO, particularly in relation to the parameter of saturated fatty acid content. The longer the production time, the higher the saturated fatty acid content becomes if the CPO is not processed immediately, often due to the presence of non-value-added activities in the production process.

Current State Value Stream Mapping

Value stream mapping (VSM) is a graph for current state value stream mapping in the CPO production process at PT XYZ. Figure 4 below is the VSM in the current condition or current state value stream mapping of CPO production.

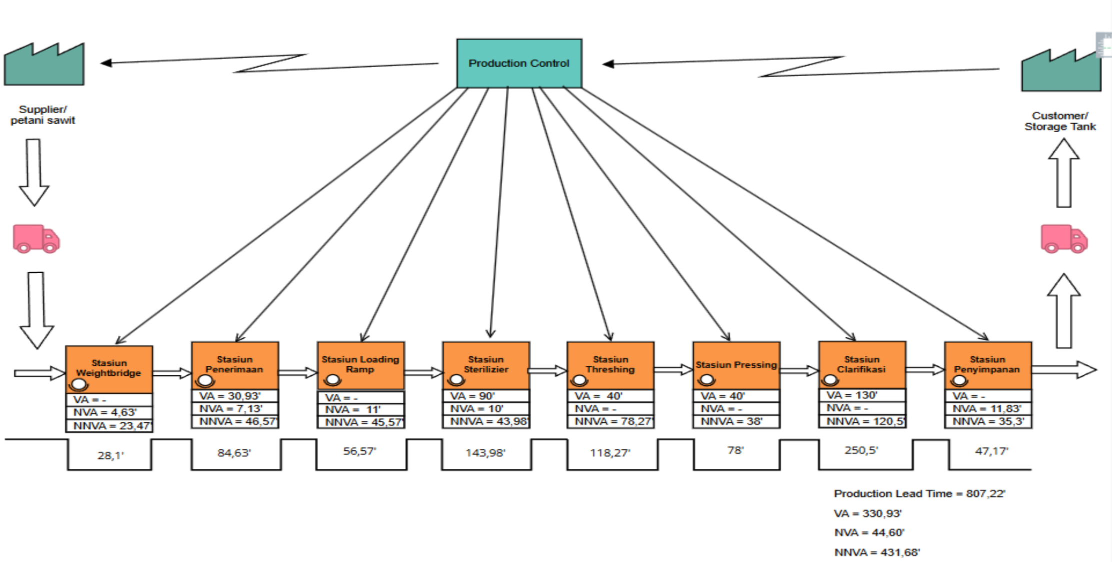

Figure 4. Current State Value Stream Mapping

$$\text{PCE} = \frac{Value\ Added}{Lead\ Time} \times 100\%$$

$$= \frac{330,93}{807,22} \times 100\%$$

$$= 40,997\%$$

Based on the Big Picture mapping, the total lead time for CPO production was 807.22 minutes, with a total time for value added of 330.93 minutes, time for necessary non-value added of 431.68 minutes, and time for non-value added of 44.60 minutes.

Analyze Stage

Value Stream Analysis Tools (VALSAT)

Tabel 5. Value Stream Analysis Tools (VALSAT)

Waste	Average	VALSAT						
		PAM	SCRM	PVF	QFM	DAM	DPA	PS
Overproduction	4	4	12	-	4	12	12	-

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

Waiting	3,6	32,4	32,4	3,6	-	10,8	10,8	-
Transportation	2,6	23,4	-	-	-	-	-	2,6
Inappropriate Processing	3,2	28,8	-	9,6	3,2	3,2	3,2	-
Unnecessary Inventory	3,4	10,2	30,6	10,2	-	10,2	10,2	3,4
Motion	1,8	16,2	1,8	-	-	-	-	-
Defects	4,4	4,4	-	-	39,6	-	-	-
Total		119,4	76,8	23,4	46,8	36,2	36,2	6

Based on the data in the table, the tool with the highest rating is Process Activity Mapping (PAM) with a value of 119.4, so PAM was chosen as the tool to be used in the calculation process.

Process Activity Mapping (PAM)

After determining the mapping tools using value stream analysis tools (VALSAT), the next step is to create the selected mapping tools, namely process activity mapping (PAM). This PAM is used to determine the flow of the dunnage production process and identify each activity that is categorized into the criteria of value added (VA), necessary non value added (NNVA), and non value added (NVA). Table 4 below is the process activity mapping (PAM) in this study.

Tabel 6. Process Activity Mapping

No.	Process Description	Activity Type					Distance (Meter)	Process Time (Menit)	Mechine/ equipment	labor (People)	Activity Type
		O	T	I	S	D					
WEIGHTBRIDGE STATION											
1	Receipt of TBS Entering by Truck	✓						0,47	Truck	1	NNVA
2	vehicle inspection and TBS			✓				5		1	NNVA
3	The driver reported the SPB to the security guard					✓		4,63		1	NVA
4	Trucks entering the weighbridge		✓				3	3		1	NVA
5	Performing the first weighing			✓				5	Weighbridge	1	NNVA
6	Vehicle Release to Fruit Receiving Station		✓				100	5		1	NNVA
7	perform the second weighing			✓				5	Weighbridge	1	NNVA
RECEIVING STATION											
8	Discharge of raw materials to the grading area	✓						29,27		10	NNVA
9	sorting of raw materials according to fruit criteria			✓				30,93		10	VA
10	Recording the results of the			✓				1,87		1	NNVA

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

	physical examination of fruit										
11	The grading foreman takes the SPB from the driver					✓		1,93		1	NVA
12	Calculate fines or deductions for fruit that has been sent			✓				4,27		1	NVA
13	SPB is returned to the driver		✓				1	0,93		1	NVA
14	TBS is loaded into the loading ramp				✓			15,43	wheel loader	1	NNVA
LOADING RAMP STATION											
15	Loading TBS into Lorries				✓			15,4	Lori	3	NNVA
16	TBS on the surface of the Lori is leveled	✓						15,17	Lori	3	NNVA
17	Transfer from filling rail to boiling rail		✓				12	15	Transfer cariage	1	NNVA
18	Ensuring that the lorry series containing TBS is on standby in front of Rebusan					✓		1		1	NVA
19	Retrieval of loose fruit that fell into the truck	✓						10		3	NVA
STERILIZIER STATION											
20	Sterilizer Door Opening	✓						0,47		1	NNVA
21	Moving the TBS filled lorry into the sterilizer		✓					10	Transfer cariage	1	NNVA
22	Close the sterilizer door	✓						0,47		1	NNVA
23	Pressure and temperature settings according to standards	✓						2		1	NNVA
24	Turn on the steam supply to the sterilizer.	✓						1		1	NNVA
25	Sterilization Process	✓						90	Sterilizer mechine	1	VA
26	Process Monitoring			✓				3,5		1	NNVA
27	Steam engine shutdown	✓						0,58	Sterilizer mechine	1	NNVA
28	Steam release	✓						5		1	NNVA
29	Open the sterilizer door	✓						0,47		1	NNVA
30	Removing the lorry from the sterilizer		✓				6	10,5	Lori	1	NNVA

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

31	Clean the sterilizer from any remaining fruit or dirt.	✓						10		1	NVA
32	Moving the lorry to the next station		✓				6	10	Lori	1	NNVA
THRESHING STATION											
33	Receipt of TBS from Sterilizer	✓						15	Lori	1	NNVA
34	Loading FFB from the truck into the thresher hopper		✓				1	10	hopper thresher	3	NNVA
35	Regulating the inflow of TBS	✓						10		1	NNVA
36	Turn on the machine to start the shelling process	✓						5	Mesin Threser	1	NNVA
37	Threshing Process	✓						25	Drum Thresher	1	VA
38	Monitoring the shelling process			✓				4,17		1	NNVA
39	Loose fruit is directed to the pressing station	✓						10,17	MPD conveyor	1	NNVA
40	The bunches are fed to another conveyor to Re-Threshing	✓						8	MPD conveyor	1	NNVA
41	The remaining Brondolan is sent to the pressing station	✓						10		1	NNVA
42	Re-threshing process	✓						15	Drum Thresher	1	VA
43	Empty bunches are sent to the empty bunch press machine	✓						5,93	Inclined Empty Bunch Conveyor	1	NNVA
PRESSING STATION											
44	Receiving loose fruit supplies from the threshing station	✓						10		1	NNVA
45	Flowed to Fruit Elevator	✓						5		1	NNVA
46	Flowed to Fruit Distributing Convenyor	✓						5	Fruit Distributing Convenyor	1	NNVA
47	Distributed to Digester Machine	✓						6		1	NNVA
48	Mashing and heating the fruit flesh	✓						20	Digester Mechine	1	VA
49	Flowed to the Press machine	✓						2	Chute Press	1	NNVA
50	Fruit pulp pressing process	✓						20	Press Mechine	1	VA

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

51	The process of flowing crude oil to the clarification station	✓						5		1	NNVA
52	Wet fiber and nuts are sent to the kernel station	✓						5	Cake Breaker Conveyor	1	NNVA
	CLARIFICATION STATION										
53	Receipt of Crude Oil from Pressing Process	✓						15		1	NNVA
54	Oil is drained from the oil gutter	✓						5	oil gutter	1	NNVA
55	Flowed into the sand trap tank	✓						10		1	NNVA
56	Sand trap process	✓						25	sand trap tank	1	VA
57	oil is flowed from the header pipe over flow sand trap tank	✓						10		1	NNVA
58	Oil Vibrating screen process (cutting oil)	✓						5	oil Vibrating screen	1	VA
59	Clean oil is sent to the Crude Oil Tank	✓						10		1	NNVA
60	Send oil using Continuous Settling Tank (CST)	✓						10		1	NNVA
61	Clarification process	✓						60	Vertical Continuous tank	1	VA
62	Sludge is discharged into the sludge tank	✓						10,5		1	NNVA
63	Sludge separation with tricanter machine	✓						20	mesin tricanter	1	VA
64	*havy phase tricanter sent to rectangular tank*	✓						15		1	NNVA
65	Minyak yang masih mengandung kadar air tinggi diproses ke *Vacuum Dryer*	✓						20	Vacuum Dryer	1	VA
66	*Oil that still contains high water content is processed into a Vacuum Dryer*	✓						10		1	NNVA
67	Flowed to Oil Tank	✓						15		1	NNVA
68	Oil Flow to Storage	✓						20		1	NNVA
	PENYIMPANAN STATION										

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

69	Clarified CPO Storage				✓			10		1	NNVA
70	Storage Tank Monitoring and Control			✓				10,33		3	NNVA
71	Tank temperature regulation and oil temperature maintenance	✓						15		3	NNVA
72	Quality monitoring during storage			✓				10		3	NNVA
73	Sounding Process	✓						11,83		3	NVA

From the process activity mapping (PAM) in Table 4 above, there are 49 operations, 8 transportation, 10 inspection, 3 storage, and 3 delays.

SPB Report to Security Guard (4.63 minutes/truck):

The SPB inspection process by the security guard takes time and causes queues. It is recommended that this process be conducted outside the gate so that trucks can proceed directly to the weighbridge.

Grading Supervisor Checks SPB:

The re-inspection by the supervisor is unnecessary, as it has already been checked by the security guard. This activity can be eliminated.

Penalty/Deduction Calculation (4.27 minutes):

This calculation is done in the grading area, causing congestion. It should be relocated outside the grading area to allow trucks to enter more quickly.

Returning SPB to Driver (56 seconds):

This activity adds to the waiting time. It is recommended that the SPB be returned after the truck exits the grading area.

Standby Lori Check at Sterilizer (1 minute):

Repeated checking is inefficient. The condition of the lori should be ensured from the beginning of the loading process.

Retrieving Fallen Loose Fruits (10 minutes):

This happens due to carelessness when transferring FFB to the lori. Workers should receive training to be more careful so this activity can be eliminated.

Sterilizer Cleaning (10 minutes):

Currently done after each sterilization cycle. It would be more effective if scheduled periodically to avoid delaying the next batch of FFB.

Fishbone Diagram

Fishbone diagram is one of the seven tools used to find the cause and effect of a problem by finding the root cause. The following is a fishbone diagram for each defect in this study.

Fishbone Diagram FFA Levels

The parameter of Free Facid Acid content must be less than 3%. Increasing FFA levels can cause a decrease in yield and reduce the quality of oil.

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

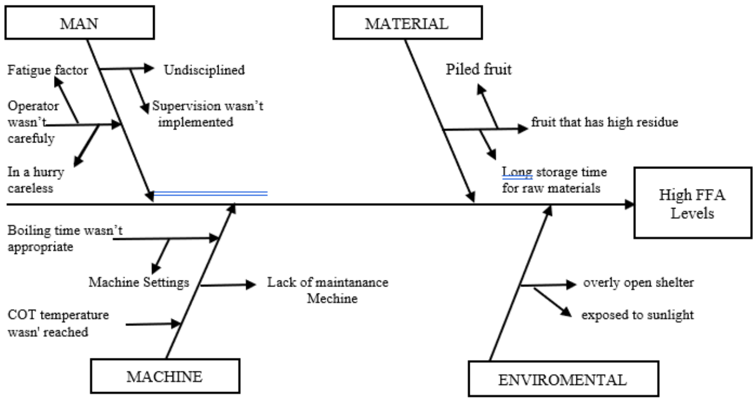

Figure 5. Fishbone Diagram FFA Levels

Fishbone Diagram Moisture Levels

The water content parameter must be less than 0.15%. High water content can cause the oil to have an unpleasant aroma or rancid odor and reduce the quality of palm kernel oil.

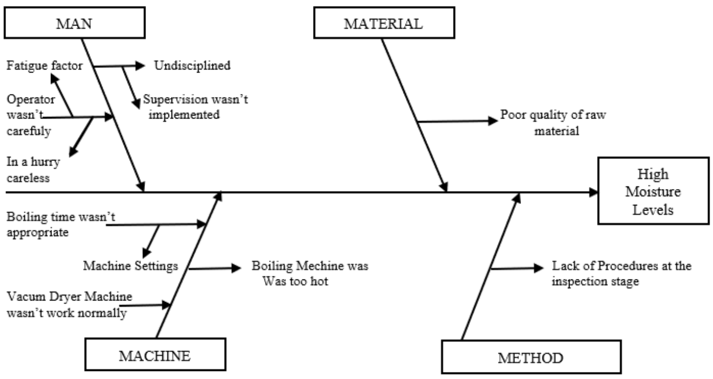

Figure 6. Fishbone Diagram Moisture Levels

Fishbone Diagram Dirt Levels

The impurity content parameter must be less than 0.03%. Better quality oil can be obtained by removing impurities. then the oil produced has met the standards as good quality oil and produces a color that meets the quality standards of CPO

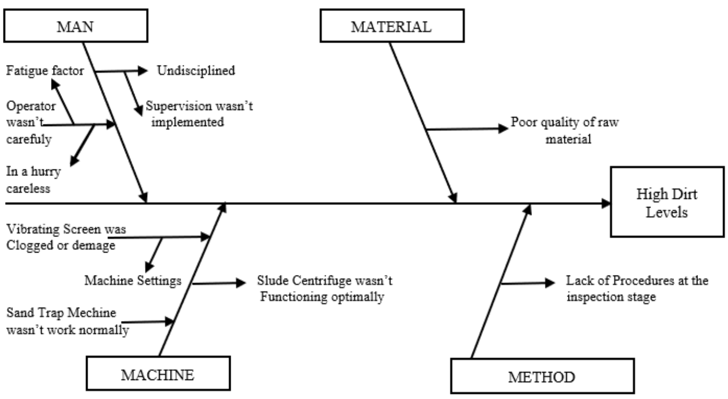

Figure 7. Fishbone Diagram Dirt Levels

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

Fishbone Diagram DOBI Levels

The DOBI level parameter must be more than 3%. The DOBI value reflects the level of carotenoid degradation in oil, which affects the ease of bleaching during the refining process. The higher the DOBI value, the better the quality of CPO because the oil is easier to bleach and produces a final product with a brighter color.

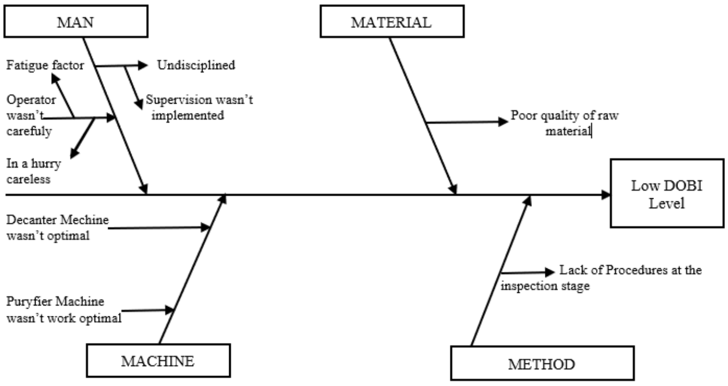

Figure 8. Fishbone Diagram DOBI Levels

Improvement Stage

Future Value Stream Mapping

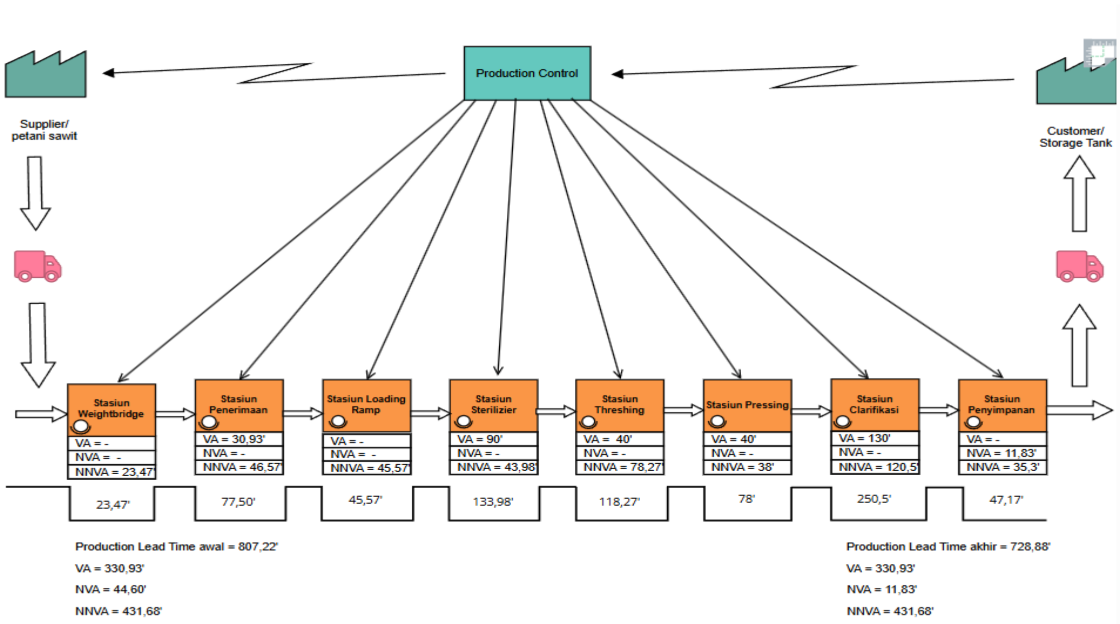

Figure 9. Future Value Stream Mapping

Failure Mode and Effect Analysis (FMEA)

This stage is implemented in the form of a proposal for improvement, considering the company's policy regarding its implementation. This study utilizes the Failure Mode and Effect Analysis (FMEA) tool, especially through cause-and-effect diagrams, to identify potential problem areas that are a priority for improvement and are used as a basis for preparing an improvement plan.

Tabel 7. Risk Priority Number (RPN) Calculation

Failure Mode	Effects of Failure	S	Causes of Failure	O	Detection Method	D	RPN

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

Saturated Fatty Acid Levels Vary	Causes low quality oil can damage human health	7	Operators are not careful when sorting fruit	6	Conduct intensive checks	7	294
			Inadequate quality of raw materials	7	Careful inspection of raw materials	7	343
			COT or CST temperature is not correct	4	Regular temperature checks	4	112
			Too long leaving of TBS	7	Want to load TBS into Loading ramp	5	175
Moisture content varies	Causes hydrolysis of the taste and rancid odor of the oil	6	Operators are not disciplined in carrying out procedures	6	Carry out supervision	5	180
			Inadequate quality of raw materials	5	Raw material inspection	7	210
			The sterilizer or vacuum dryer machine is not working optimally	5	Supervision of machine settings	4	120
			Water contamination with production equipment	3	Machine cleanliness check	5	90
			Processing temperature is unstable	5	Checking the temperature on the machine	7	210
Dirt content varies	Activates microbes and enzymes that react to produce free fatty acids and color changes in the oil.	6	The quality of raw materials is not appropriate	7	Perform maintenance on storage areas	4	168
			Sand Trap is not working optimally	6	Inspection of every part of the machine	4	144
			Oil purifier is not working optimally	6	Inspection of every part of the machine	4	114
DOBI Value's content varies	Shows high carotenoid content. The color of the oil becomes darker	6	Inadequate quality of raw materials	7	Raw material checking	5	210
			Too long leaving TBS contaminated with air and sunlight	6	Checking raw materials in grading	4	144
			The temperature during the sterilization process was not optimal	4	Check the temperature on the machine	4	96

From Table 7 above, the RPN value of the failure mode is obtained which is the cause of the defect in the dunnage. From the RPN value above, it can be seen that the highest RPN value is the Saturated Fatty Acid Content Varies, causing Low oil quality can damage human health with an RPN value of 343. This value is obtained from the following calculation:

RPN = Severtiy x Occurrence x Detection

RPN = 7 x 7 x7

RPN = 343

Findings of this research indicate that the inefficiencies in the CPO production line within PT XYZ still stand at high levels with the sigma level having 2.20. This performance indicator is an indicator of a process that is yet to reach an optimal state of performance, which has been largely discussed in the last five years in palm oil mills in Indonesia, whereby defect waste

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

and processing delays still prevail. To be taken in a slightly wider sense, the provided data do not just demonstrate the statistical deviation; it is the living contradiction of operational processes and the biology of palm fruit, which physically worsen unless treated effectively. This is consistent with the study of Sari et al. (2020) that has stated that a lengthy waiting time and pre-sterilisation exposure increase the activity of lipase and the amount of free fatty acid; therefore, the issue identified at PT XYZ needs to be perceived as a technical weakness as well as a biochemical susceptibility that requires urgent correction.

To this extent, the recognition of defect waste as the most important problem is very consistent with the current research on CPO quality. Latif and Mansur (2021) and Dewi et al. (2024) study underline that variations in qualities of raw materials have a deeper effect on the downstream oil properties compared to the mechanical control. The large risk priority number of the variation in saturated fatty acids in this paper adds more weight to the fact that quality assurance should occur on the first stage of supply and not necessarily at the mill. The view here changes perspective and puts emphasis on plants, grading systems, and supplier standardisation which, as Hidayat et al. (2022) point out, tend to either give a factory a head start or a headache on the first day. In the turn, the strategic implication of the findings on PT 30 XYZ is as follows: the company would be better off ensuring the reinforcement of the evaluation of raw fruits and enhanced filtering of their quality at the receiving gates than depending on the end-process corrections.

In the material issues, this research also reveals the role of the internal workflow in deteriorating quality. The Process Activity Mapping shows a very lengthy process that is full of non-value added activities, manual reporting and repetitions in validation points. Much of the palm oil business is plagued by these kinds of redundancies since operational systems are programmed to absorb human error, and ironically, they generate new degrees of delay (Jamaludin et al., 2025). The SPB double-checking system that has been identified herein is an example of how caution may become a bottleneck. According to previous research (Susanto et al., 2022), a perceived safety provided by frequent inspection does not contribute to the quality but only shifts issues deeper down the line. In this perspective, the recommendation to improve the process of this study that removal of redundant checks, fines calculation relocation and rescheduling of sterilising cleaning are positional changes towards the cultural redesign where trust, data-based validation, and clarity of roles replace layered control of manuals.

These remarks find a very close echo in the discourse of Lean Six Sigma providing that efficiency and quality cannot be separated. Lean minimises wastes in the physical flow, and Six Sigma stabilises results by monitoring results statistically (Habibullah & Hossain, 2021; Kumar et al., 2021; Gomaa, 2025). The integration that has been used in this study is thus based on sound conceptual basis. However, like most industrial case studies, the model applied in the given case comes to a halt at the Improve stage. Without a long-term Control mechanism, the improvements are likely to become worse over time with the work load or an employee changing hands. Johan et al. (2023) emphasize that the gains of Lean-Six Sigma are most susceptible not at the implementation stage, but after the implementation when the new practices become habitual and slowly transform the operations into previous rhythms. Thus, it is not the lack of Control phase but one of the aspects to be developed in the institution in future: PT XYZ should consider the monitoring dashboards, the regular audits, and the responsibility routine so that the performance is not staled.

More contemplation reveals more industrial implication. The related efficiency gains do not only result in the reduction of lead times but also in biochemical preservation, which suppresses the growth of free fatty acids, in addition to improving DOBI and the competitiveness in the market. This is especially relevant due to the fact that a global CPO trade has been becoming more interconnected with the quality and acceptance in the context

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

of European markets where the thresholds are quite high (Rahman et al., 2022). Studies concerning the minimisation of wastes in CPO milling prove that a coordinated workflow and managed exposure to storage can significantly increase the oil grade (Amin and Putri, 2023), which is fully aligned with the present research. At the same time, technological innovations, including IoT-based scheduling and traceability of raw materials, have demonstrated positive outcomes in order to shorten the queue times and standardize the maturity of the fruits at the input (Azizah et al., 2023; Tagarakis et al., 2021; Lamberty & Kreyenschmidt, 2022). Though automation is not yet incorporated in this research, the results provide a conceptual base to the implementation of digital tools in the future improvement patterns.

Conclusion

From the types of waste that occur in the Crude Palm Oil (CPO) production process, it can be seen that the most critical type of waste is the type of defect waste with an average weight value of 4.4. The initial production lead time was 807.22 minutes. Then after improvements were made by eliminating the seven non-value added activities or Non Value Added in the Crude Palm Oil production process, the production process time became more efficient with a reduction in lead time to 728.88 minutes so that the decrease in time before and after improvements was 78.34 minutes. Based on the Failure Mode and Effect Analysis (FMEA) analysis, the root causes of the problems and waste that occurred have been identified, and corrective action proposals have been prepared. The proposed improvement recommendations are intended to overcome waste in the form of defects in the four types of parameters that have been analyzed. For recommendations from the type of FFA content parameter with an RPM value of 343, it is to use suppliers with a good quality track record, then conduct routine audits and use a periodic sorting and supervision checklist.

References

Abdulmalek, F. A., & Rajgopal, J. (2007). Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. *International Journal of production economics*, *107*(1), 223-236. https://doi.org/10.1016/j.ijpe.2006.09.009

Adeodu, A., Kanakana-Katumba, M. G., & Rendani, M. (2021). Implementation of Lean Six Sigma for production process optimization in a paper production company. *Journal of Industrial Engineering and Management*, *14*(3), 661-680. https://doi.org/10.3926/jiem.3479

Ahmad, R., Amin, R. F. M., & Mustafa, S. A. (2022). Value stream mapping with lean thinking model for effective non-value added identification, evaluation and solution processes. *Operations Management Research*, *15*(3), 1490-1509. https://doi.org/10.1007/s12063-022-00265-9

Ahmadi, S. (2024). A comprehensive study on integration of big data and AI in financial industry and its effect on present and future opportunities. *International Journal of Current Science Research and Review*, *7*(01), 66-74.

Alam, M. N., Hasan, S. S., Masroor, I., Nabi, M. N. U., & Islam, M. R. (2025). Building Resilience Through Reputation Risk Management: A Study on Export-Oriented Shrimp Firms of Bangladesh. *Business Strategy & Development*, *8*(2), e70124. https://doi.org/10.1002/bsd2.70124

Ali, J. A., Khodakarami, L., Abdulqadir, S., Abdulrahman, H., & Mazar, G. (2025). Modified FMEA quality risk management technique for cross-country petroleum pipeline using GIS. *International Journal of Quality & Reliability Management*, *42*(6), 1672-1705. https://doi.org/10.1108/IJQRM-08-2023-0271

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

Badhotiya, G. K., Gurumurthy, A., Marawar, Y., & Soni, G. (2024). Lean manufacturing in the last decade: insights from published case studies. *Journal of Manufacturing Technology Management*, *35*(4), 766-798. https://doi.org/10.1108/JMTM-11-2021-0467

Bugvia, S. A., Hameeda, K., Jamila, M. F., Irfana, A., Murtazaa, S., Qaisera, M., & Bilala, M. (2021). Performance improvement through value stream mapping–A manufacturing case study. *Jurnal Kejuruteraan*, *33*(4), 1007-1018.

Carlin, W., Glyn, A., & Van Reenen, J. (2001). Export market performance of OECD countries: an empirical examination of the role of cost competitiveness. *The Economic Journal*, *111*(468), 128-162. https://doi.org/10.1111/1468-0297.00592

Coccia, M. (2018). The Fishbone diagram to identify, systematize and analyze the sources of general purpose Technologies. *Journal of social and administrative sciences*, *4*(4), 291-303.

Dara, H. M., Adamu, M., Ingle, P. V., Raut, A., & Ibrahim, Y. E. (2025). An MCDM Approach to Lean Tool Implementation for Minimizing Non-Value-Added Activities in the Precast Industry. *Infrastructures*, *10*(3), 55. https://doi.org/10.3390/infrastructures10030055

Fuad, A. M., Takia, N. A., Zafir, H. A., & Farrok, O. (2025). Enhancing operational efficiency through overall equipment efficiency optimization and Kaizen initiatives. *PLoS One*, *20*(5), e0320761. https://doi.org/10.1371/journal.pone.0320761

Gaspersz, Vincent. 2005. Sistem Manajemen Kinerja Terintegrasi Balanced Scorecard Dengan Six sigma Untuk Organisasi Bisnis dan Pemeritah. Jakarta: Gramedia Pustaka Utama.

Gebreab, S. A., Salah, K., Jayaraman, R., ur Rehman, M. H., & Ellaham, S. (2024, April). Llm-based framework for administrative task automation in healthcare. In *2024 12th International Symposium on Digital Forensics and Security (ISDFS)* (pp. 1-7). IEEE. https://doi.org/10.1109/ISDFS60797.2024.10527275

Gomaa, A. H. (2025). Optimizing Machining Process Performance Using Lean Six Sigma: A Case Study. *Transnational Supply Chain Research*, *1*(1), 54-83.

Gomaa, D. A. H. (2025). LSS 4.0: A Conceptual Framework for Integrating Lean Six Sigma and Industry 4.0 for Smart Manufacturing Excellence. *Indian Journal of Management and Language (IJML)*. https://doi.org/10.54105/ijml.H1810.05010425

Gupta, M., Digalwar, A., Gupta, A., & Goyal, A. (2024). Integrating Theory of Constraints, Lean and Six Sigma: a framework development and its application. *Production Planning & Control*, *35*(3), 238-261. https://doi.org/10.1080/09537287.2022.2071351

Habibullah, S. M., & Hossain, M. F. (2021). A DATA DRIVEN CYBER PHYSICAL FRAMEWORK FOR REAL TIME PRODUCTION CONTROL INTEGRATING IOT AND LEAN PRINCIPLES. *American Journal of Interdisciplinary Studies*, *2*(03), 35-70. https://doi.org/10.63125/20nhqs87

Henny, H., Andriana, I., Latifah, A. N., & Haryanto, H. (2019, November). The Application Lean Six Sigma Method Approach to Minimize Waste. In *IOP Conference Series: Materials Science and Engineering* (Vol. 662, No. 2, p. 022089). IOP Publishing. https://10.1088/1757-899X/662/2/022089

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

Hossain, A., Khan, M. R., Islam, M. T., & Islam, K. S. (2024). Analyzing the impact of combining lean six sigma methodologies with sustainability goals. *Journal of Science and Engineering Research*, *1*(01), 123-144.

Huang, J., You, J. X., Liu, H. C., & Song, M. S. (2020). Failure mode and effect analysis improvement: A systematic literature review and future research agenda. *Reliability Engineering & System Safety*, *199*, 106885. https://doi.org/10.1016/j.ress.2020.106885

Jamaludin, N. A., Zaki, H. O., & Foong, Y. P. (2025). From the Ground Up: Sustainable Palm Oil and Entrepreneurial Opportunities. In *The Palm Oil Export Market* (pp. 206-218). Routledge.

Khatoon, U. T., & Velidandi, A. (2025). An overview on the role of government initiatives in nanotechnology innovation for sustainable economic development and research progress. *Sustainability*, *17*(3), 1250. https://doi.org/10.3390/su17031250

Kumar, P., Bhadu, J., Singh, D., & Bhamu, J. (2021). Integration between lean, six sigma and industry 4.0 technologies. *International Journal of Six Sigma and Competitive Advantage*, *13*(1-3), 19-37. https://doi.org/10.1504/IJSSCA.2021.120224

Lamberty, A., & Kreyenschmidt, J. (2022). Ambient parameter monitoring in fresh fruit and vegetable supply chains using internet of things-enabled sensor and communication technology. *Foods*, *11*(12), 1777. https://doi.org/10.3390/foods11121777

Mahendra, A. P. (2023). Implementasi Metode Lean Six Sigma Guna Meminimalisir Waste Pada Proses Produksi Sarung Tenun Muzammil Sy. JUSTI (Jurnal Sistem Dan Teknik Industri), 3(4), 471. https://doi.org/10.30587/justicb.v3i4.6077

Malek, R., Yang, Q., & Dhelim, S. (2024). Toward sustainable global product development performance: Exploring the criticality of organizational factors and the moderating influence of global innovation culture. *Sustainability*, *16*(10), 3911. https://doi.org/10.3390/su16103911

Manish, S. (2024). An autonomous multi-agent llm framework for agile software development. *International Journal of Trend in Scientific Research and Development*, *8*(5), 892-898.

Morato, M. L. D. S., & Ferreira, K. A. (2024). Value stream mapping application for construction industry loss and waste reduction: a systematic literature review. *International Journal of Lean Six Sigma*, *15*(4), 817-837. https://doi.org/10.1108/IJLSS-06-2023-0100

Olaolu, E. O., & John, O. O. (2024). LEAN MANAGEMENT PRACTICES AND ORGANIZATIONAL PRODUCTIVITY. BAYERO JOURNAL OF SOCIAL SCIENCE AND ADMINISTRATION, 9(1), 92-112.

Pekarcikova, M., Trebuna, P., Kronova, J., & Kopec, J. (2024). Increasing the Efficiency of the Value-Chain for Non-Manufacturing Processes: Analytical Approach. *European Journal of Business and Management Research*, *9*(3), 91-100. https://doi.org/10.24018/ejbmr.2024.9.3.2352

Rodrik, D., & Stiglitz, J. E. (2025). A new growth strategy for developing nations. In *The New Global Economic Order* (pp. 89-107). Routledge.

Safari, A., Parast, M. M., & Al Ismail, V. B. (2025). Lean Six Sigma, ISO 9001, and organizational performance: An integrated approach. *Quality Management Journal*, *32*(3), 180-195. https://doi.org/10.1080/10686967.2025.2528597

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

Sagio, I., Pramesworo, I. S., & Ekasari, S. (2025). ARTIFICIAL INTELLIGENCE IN THE RETAIL SECTOR: MARKET AND BUSINESS MODEL TRANSFORMATION. INTERNATIONAL JOURNAL OF ECONOMIC LITERATURE, 3(4), 133-146.

Sakdiyah, S. H., Eltivia, N., & Afandi, A. (2022). Root cause analysis using fishbone diagram: company management decision making. *Journal of Applied Business, Taxation and Economics Research*, *1*(6), 566-576. https://doi.org/10.54408/jabter.v1i6.103

Samimi, A. (2025). Assessment of risks arising from neuropsychological crises in cardiac patients using FMEA. *Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research*, *1*(7), 196-203.

Sanusi, & Paramida, R. (2021). Industri Kreatif. Manajemen INDUSTRI KREATIF, 5(1), 125. https://doi.org/10.36352/jik.v4i2

Seth, D., Seth, N., & Dhariwal, P. (2017). Application of value stream mapping (VSM) for lean and cycle time reduction in complex production environments: a case study. *Production Planning & Control*, *28*(5), 398-419. https://doi.org/10.1080/09537287.2017.1300352

Shinde, D. D., Ahirrao, S., & Prasad, R. (2018). Fishbone diagram: application to identify the root causes of student–staff problems in technical education. *Wireless personal communications*, *100*(2), 653-664. https://doi.org/10.1007/s11277-018-5344-y

Skalli, D., Cherrafi, A., Charkaoui, A., Chiarini, A., Shokri, A., Antony, J., ... & Foster, M. (2025). Integrating Lean Six Sigma and Industry 4.0: developing a design science research-based LSS4. 0 framework for operational excellence. *Production Planning & Control*, *36*(8), 1060-1086. https://doi.org/10.1080/09537287.2024.2341698

Subriadi, A. P., & Najwa, N. F. (2020). The consistency analysis of failure mode and effect analysis (FMEA) in information technology risk assessment. *Heliyon*, *6*(1). https://doi.org/10.1016/j.heliyon.2020.e03161

Sulianta, F., & Widyatama, U. (2024). " Diagram Fishbone : Alat Analisis Penyebab Masalah untuk Pengembangan Bisnis Kafe dan Profesi Konsultan ". October.

Sunday, A., Enesi, S., Kehinde, O., Samuel, A., Ikechi, I., & Remilekun, E. (2018). Failure mode and effect analysis a tool for reliability evaluation. *European Journal of Engineering Research and Science*, *3*(4), 65-68.

Syaher, A. B., Mukti, M., Ramadhan, I., & Alfaritsy, A. Z. (2024). Pendekatan Lean Manufacturing Menggunakan Metode Value Stream Mapping (Vsm) Pada Umkm Samikem Sablon. Jurnal Ilmiah Penelitian Mahasiswa, 2(4), 423–432.

Syaher, A. B., Mukti, M., Ramadhan, I., & Alfaritsy, A. Z. (2024). Pendekatan Lean Manufacturing Menggunakan Metode Value Stream Mapping (Vsm) Pada Umkm Samikem Sablon. Jurnal Ilmiah Penelitian Mahasiswa, 2(4), 423–432.

Tagarakis, A. C., Benos, L., Kateris, D., Tsotsolas, N., & Bochtis, D. (2021). Bridging the gaps in traceability systems for fresh produce supply chains: overview and development of an integrated IoT-based system. Applied Sciences, 11(16), 7596. https://doi.org/10.3390/app11167596

Taher, M. A., & Bashar, M. A. (2024). The impact of lean manufacturing concepts on industrial processes' efficiency and waste reduction. International Journal of Progressive Research in Engineering Management and Science, 4(6), 338-349.

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0

Thomas, A., Barton, R., & Chuke-Okafor, C. (2008). Applying lean six sigma in a small engineering company–a model for change. *Journal of manufacturing technology management*, *20*(1), 113-129. https://doi.org/10.1108/17410380910925433

Tian, R., Kong, F., Zhang, S., Chen, T., Ding, K., & Yu, Z. (2025). SITI-value-added heat map: a structural analysis method for mapping and eliminating information waste of information flow. *International Journal of Lean Six Sigma*. https://doi.org/10.1108/IJLSS-11-2024-0242

Tiara, A., Jakaria, & Syafri. (2023). Analisis Determinan Ekspor Dan Daya Saing Produk Minyak Kelapa Sawit Indonesia Di Pasar Internasional. Jurnal Ekonomi Trisakti, 3(1), 999–1014. https://doi.org/10.25105/jet.v3i1.15583

Vierci-Codas, S., Insfran-Rivarola, A., Arevalos, A. P., Macias-Velasquez, S., Zepeda-Lugo, C., & Martínez-Mendoza, E. (2025). Improved performance in retail distribution process through a Lean Manufacturing approach: A case study. *Journal of Industrial Engineering and Management*, *18*(2), 342-372. https://doi.org/10.3926/jiem.8178

Wang, S., & Zhu, H. (2025). The adoption of international standards and export behavior of multi-product firms: A perspective based on differentiated competitive strategies. *Economic Analysis and Policy*, *86*, 351-362. https://doi.org/10.1016/j.eap.2025.03.034

Wijaya, H. (2023). Analisa Penerapan Konsep Lean Service Untuk Meningkatkan Kepuasan Konsumen Di Pt Honda Kjm (Cabang Ahmad Yani). Jurnal Rekayasa Sistem Industri, 8(2), 39–42. https://doi.org/10.33884/jrsi.v8i2.724

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2025, Journal La Multiapp, Under the license CC BY-SA 4.0