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Lean Six Sigma Integration with VALSAT and FMEA Methods for Waste Identification in PT. X

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ABSTRACT

This study identifies and reduces waste in the cooking oil production process at PT X by integrating Lean Six Sigma with Value Stream Analysis Tools (VALSAT) and Failure Mode and Effects Analysis (FMEA). VALSAT is used to classify value-added and non-value-added activities, while FMEA prioritizes waste based on Risk Priority Number (RPN). The results show that defects are the most dominant waste (RPN 294), followed by waiting and inventory. Process mapping reveals a total lead time of 370 minutes, in which 60 minutes are non-value added. Improvement recommendations include scheduling preventive maintenance, aligning raw material orders with actual demand, optimizing operator coordination, applying FIFO in inventory handling, and increasing transportation efficiency. This integrative approach provides a structured method for identifying critical waste sources and supports operational efficiency improvement in food-processing industries.

Keywords: *FMEA; Lean Six Sigma; Manufacturing; VALSAT; Waste*

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ABSTRAK

Lean Manufacturing menekankan efisiensi aliran, penghapusan pemborosan, dan perbaikan berkelanjutan. Six Sigma melengkapi Lean dengan menghadirkan ketelitian analitis melalui siklus DMAIC. Lean Six Sigma banyak diterapkan untuk peningkatan produktivitas dan pengurangan pemborosan di berbagai industri. VALSAT menyediakan alat untuk memvisualisasikan aliran nilai dan mengklasifikasikan aktivitas menjadi Bernilai Tambah (VA) dan Tidak Bernilai Tambah (NVA). Sementara itu, FMEA menilai potensi kegagalan dan memprioritaskan tindakan korektif menggunakan nilai RPN yang berasal dari tingkat keparahan, frekuensi kejadian, dan deteksi. Studi sebelumnya (Dewi et al., Situmeanga et al., Rosarina et al.) menunjukkan bahwa integrasi pemetaan dan analisis risiko secara efektif mengidentifikasi jenis pemborosan dominan seperti cacat, waktu tunggu, dan inefisiensi transportasi. Namun, penerapannya dalam lingkungan proses kontinu masih terbatas, sehingga diperlukan kerangka kerja yang lebih komprehensif.

Keywords: *FMEA; Lean Six Sigma; Manufactur; Pemborosan; VALSAT*

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INTRODUCTION

The rapid development of the industrial sector requires companies to innovate and enhance product and service quality to remain competitive and maintain customer loyalty [1]. Manufacturing companies must optimize their production performance to achieve operational excellence [2]. Efficiency improvements can be realized by reducing non-value-added activities that contribute to waste throughout the manufacturing process [3], [4]. These efforts are expected to increase overall production efficiency [5]. Effective planning and control of production operations also demand sufficient capacity to meet scheduled output consistently [6].

A systematic approach is essential for addressing various forms of waste while ensuring process sustainability. Lean provides a management framework that focuses on eliminating non-value-added activities and improving value creation for customers [7], [8]. Companies must consistently apply the QCDS concept to maintain product quality, ensure cost competitiveness, achieve timely delivery, and provide satisfactory service [9]. Many industries emphasize quality and sustainable performance, making Lean Six Sigma increasingly relevant as an integrated process management framework proven to improve productivity and operational outcomes [10], [11].

PT X experiences several challenges in its production process, including delays caused by machine breakdowns, inconsistent raw material inventory levels, and defects that fail to meet quality standards. These issues disrupt production continuity and negatively affect the company's image among business partners, suppliers, and customers [12]. A decline in corporate reputation can hinder the restoration of customer trust [13]. An analytical approach that accurately captures the underlying issues is thus essential.

This study adopts two main analytical methods, VALSAT and FMEA. VALSAT serves as a tool for mapping value streams and distinguishing between value-added and non-value-added activities, while FMEA evaluates potential failures in production processes and assigns risk priority values based on severity, occurrence, and detection [14][15] [16] [17]. Previous studies demonstrate that process-based mapping can reduce non-value-added activities and shorten processing time [18]. Other studies highlight that waste identification can be addressed through improvements in inspection activities, maintenance scheduling, standard operating procedures, and setup time reduction [19].

This research focuses on reducing waste in the cooking oil production process at PT X by integrating Lean Six Sigma with VALSAT and FMEA. This combined approach offers a structured analysis of waste by linking value stream mapping with risk-based prioritization, providing a comprehensive foundation for formulating sustainable improvement strategies in continuous production environments.

LITERATURE REVIEW

Lean Manufacturing focuses on improving process flow by eliminating non-value-added activities, while Six Sigma enhances analytical precision through the DMAIC cycle, making their integration an effective framework for productivity improvement and waste reduction across industries [7][8][11]. VALSAT provides structured tools for mapping value streams and distinguishing between value-added and non-value-added activities, whereas FMEA supports risk assessment by prioritizing potential failure modes through RPN scoring [14][15][16][17]. The complementary nature of these methods enables a more comprehensive evaluation of process inefficiencies.

Previous studies demonstrate the effectiveness of combining process mapping and risk analysis in identifying dominant waste categories such as defects, waiting, and transportation inefficiencies [18][19][20]. Research in continuous processing environments remains limited, indicating the need for a more integrated framework to address waste and risk simultaneously in such industries.

METHOD

The selection of VALSAT and FMEA in this study is grounded in their complementary capabilities for identifying and evaluating waste within production processes. VALSAT supports detailed value stream mapping by distinguishing Value Added and Non Value Added activities and quantifying the time allocated to each stage. The method is effective for detecting waste related to waiting, overprocessing, and concealed inventory. FMEA is applied to evaluate potential failures by assessing severity, occurrence, and detection, producing RPN values that guide the prioritization of improvement actions. The integration of VALSAT and FMEA was preferred over individual Lean based tools such as VSM or DMAIC because it offers a more comprehensive and risk oriented analytical framework for examining production performance. The procedural stages of this study are illustrated in the research process flow diagram.

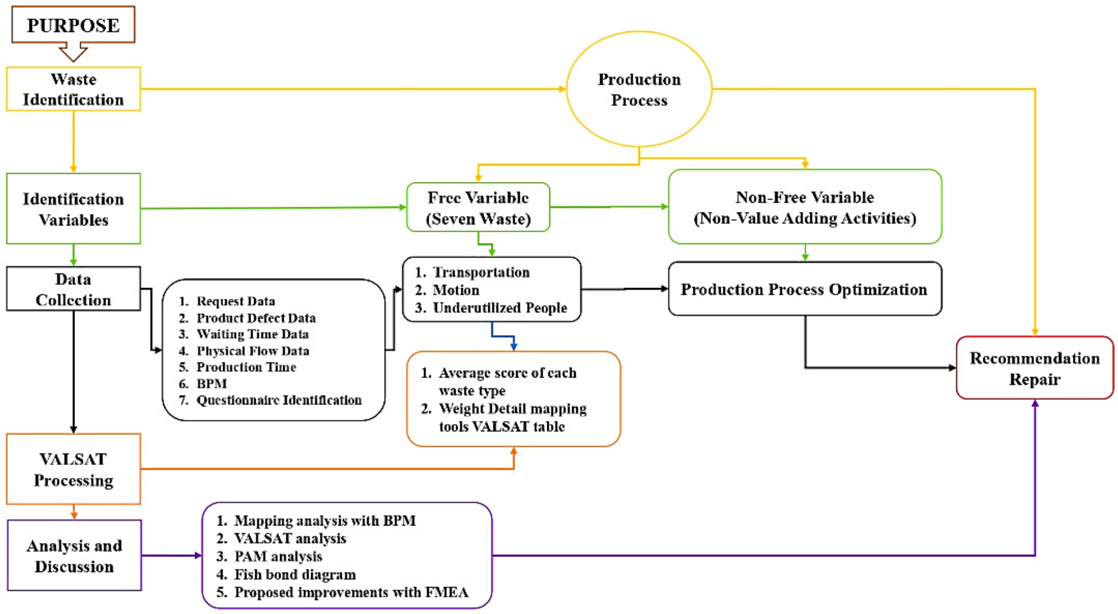

Figure 1. Research Process Flow

RESULTS AND DISCUSSION

Result

Table 1 presents the 2023 production profile of PT X. The company produced an average of 600 tons of cooking oil monthly, fulfilling 240 tons of domestic demand and 343 tons of overseas requests. The defect rate reached 2.8 percent, indicating that part of the olein failed to meet the maximum FFA limit of 0.3 percent set by national standards.

Table 1. Average Production and Demand Data for 2023

Average production in 2023			**2023 average FFA content>0.3%**		**Average time for 2023**		
Production (tonnes)	Total domestic demand (ton)	Number of overseas requests (tons)	The number of defective production	Percentage of defective production (%)	Production process time plan (minutes)	Average actual production time (time)	Average production lead time (minutes)
600	240	343	2	2,8	600	240	343

The production system relies on Crude Palm Oil, supported by phosphoric acid and bleaching earth. PT X operates approximately seventy two cycles each month with a raw material requirement of thirty tons per day. Each liter of Crude Palm Oil produces olein along with by-products such as PFAD, stearin, and moisture content. Elevated free fatty acid levels require reprocessing, which contributes to longer cycle times and reduces operational efficiency.

Inventory evaluation shows that PT X requires seven hundred twenty tons of Crude Palm Oil monthly, while supply reaches seven hundred eighty tons. This surplus indicates inefficiency in raw material planning even though available storage capacity is sufficient. Finished goods storage accommodates six hundred fifty tons, while monthly olein output reaches approximately six hundred four point eight tons, leaving unused capacity. Indicators of transportation waste, motion waste, and underutilized personnel are summarized in Table 2.

Table 2. Identified Waste Indicators

Waste Type	Indicators
Transportation waste	Transport volume not maximized; transported goods below optimal load; deliveries not reaching capacity
Motion waste	Required tools far from the work area; storage not organized; panel locations far from operator positions
Underutilized people	Operators not using full skills; lack of initiative; minor issues escalated to maintenance; cross-department operator placement causing inefficiency

As shown in Table 2, transportation, motion, and underutilized employees appear as recurring issues that potentially increase overall lead time.

A classification of activities into value-added and non-value-added categories is presented in Table 3. The results show that activities contributing no value amount to sixty minutes, consisting of inspection, waiting, and unnecessary movement of materials. Value-added activities constitute three hundred ten minutes, which cover degumming, bleaching, filtration, deodorizing, fractionation, and packing.

Table 3. Classification of Activities and Required Time

Category	Included Activities (simplified)	Time (min)
NVA	CPO stacking, CPO transfer, PA & BE transfer, warehouse filling, product movement, GBJ buildup	60
VA	Material weighing, preparation, CPO processing, degumming, bleaching, filtration, deodorizing, fractionation, packing	310
Total Lead Time = **370 minutes** (VA 310 + NVA 60)		

Table 3 indicates that non-value-adding activities, although smaller in duration than value-adding activities, still contribute to avoidable delays in the production process.

A structured questionnaire supported waste identification. Defects received the highest weight, followed by waiting and excess inventory. Table 4 summarizes the prioritization.

Table 4. Waste Prioritization Results

Waste Type	Weight	Rank
Defects	3.3	1
Waiting	2.3	2
Excess inventory	2.2	3
Transportation	2.0	4
Overproduction	1.8	5
Underutilized people	1.5	6
Unnecessary motion	1.3	7

The distribution in Table 4 reinforces the need to minimize non-value-adding activities to optimize total processing time.

The VALSAT method was applied to determine the most appropriate analytical tools. Waste weights were used to calculate tool relevance. Process Activity Mapping achieved the highest score, indicating suitability for representing current production conditions.

Table 5. VALSAT Weighting Summary

Waste Type	Weight
Defects	3.3
Waiting	2.3
Inventory	2.2
Transportation	2.0
Overproduction	1.8
Underutilized people	1.5
Motion	1.3

Table 5 confirms defects as the most critical form of waste based on respondent assessments, followed by waiting and excess inventory.

Table 6. VALSAT Tool Ranking

VALSAT Tool	Score	Rank
Process Activity Mapping (PAM)	75.3	1
Supply Chain Response Matrix	46.3	2
Product Variety Funnel	31.2	3
Quality Filter Mapping	20.1	4
Demand Amplification Mapping	15.0	5
Decision Point Analysis	10.1	6
Physical Structure	4.1	7

The scoring in Table 6 highlights the dominance of Process Activity Mapping, making it the most suitable tool for analyzing existing process flows.

The simplified PAM results are presented in Table 7. Operations dominate the cycle time at more than eighty percent indicating that production efficiency impro

Table 7. Summary of PAM Activity Classification

Activity Type	Time (min)	Percentage
Operation (VA)	305	82.4%
Transportation	25	6.8%
Inspection	5	1.4%
Storage	10	2.7%
Delay	25	6.8%
Total	**370**	**100%**

Table 7 clearly ranks Process Activity Mapping as the leading analytical tool, supporting its use in subsequent process evaluations.

Discussion

Failure Mode and Effects Analysis was applied to determine improvement priorities. Defects reached the highest RPN value, followed by waiting and excess inventory. Table 8 summarizes the results.

Table 8. Failure Mode and Effects Analysis Results

No	Waste Type	S	O	D	RPN	Potential Root Cause	Improvement Plan
a	Defects	7	6	7	294	Product quality does not meet standards; material buildup in GBJ causes degradation; unscheduled maintenance reduces machine performance.	Order raw materials according to production needs, ensure production follows demand, and perform scheduled preventive maintenance.
b	Waiting	6	5	5	150	Poor field communication; machine speed reduction due to delayed repair response.	Improve communication among field operators and conduct periodic machine inspections to prevent unexpected failures.
c	Unnecessary Inventories	6	5	6	180	Raw material orders exceed actual production needs, causing product buildup and quality decline.	Adjust raw material procurement to actual demand and implement FIFO/LIFO inventory policies.
d	Excessive Transportation	4	5	4	80	Inefficient material movement, incomplete loading volume, and long transport distance.	Provide regular operator training to optimize equipment capacity and streamline transport routes.
e	Overproduction	5	5	4	100	Production exceeds actual orders due to rigid scheduling and late communication from PPIC.	Synchronize production schedules with real-time order data and enhance coordination with PPIC.
f	Underutilized People	5	4	6	120	Operators do not fully utilize their skills; inadequate task understanding, inefficient manpower allocation.	Assign tasks based on operator competencies and conduct periodic skill training.
g	Unnecessary Motions	4	4	4	64	Tools/materials are not stored properly, causing operators to search or move unnecessarily.	Standardize storage locations and ensure tools are returned to designated areas.

Defects had the highest RPN value, confirming their position as the most influential source of waste. This finding is consistent with previous studies that identified inadequate quality control as a major contributor to inefficiency in food processing. Waiting ranked second, differing from studies that linked delays primarily to machine scheduling issues. The identification of non value adding activities through VALSAT supports previous recommendations that reducing unnecessary activities can significantly shorten lead time. The combined use of time based and risk based analysis in this study provides a comprehensive approach to determining priority areas for improvement in the production system of PT X.

CONCLUSION

This study identified and evaluated sources of waste in the cooking oil production process at PT X using an integrated Lean Six Sigma approach supported by VALSAT and FMEA. The findings indicate that defects represent the most critical form of waste, followed by waiting and unnecessary inventory. The combination of activity mapping and risk-based assessment enabled a clear prioritization of improvement actions, which include enhancing raw material control, strengthening coordination among operators, adjusting inventory policies, optimizing transportation practices, and aligning production schedules with actual demand. These improvements provide a practical framework for increasing efficiency and reducing losses in similar food processing operations.

This study is limited by its focus on a single production line and the use of questionnaire-based weighting, which may introduce subjective bias. Future research may expand the analysis to multiple production units, incorporate real-time data monitoring, and compare alternative Lean tools to validate the robustness of the proposed improvements.

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