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Analysis of The Application of Lean Manufacturing with Methods Material Information Flow Chart (MIFC) and Fuzzy Failure Mode, Effects and Criticality Analysis (FMECA)

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ABSTRACT
PT XYZ is a company specializing in the manufacturing of agricultural equipment. Currently, the company is facing issues related to waste in its production processes, which are negatively affecting product quality. PT XYZ aims to address these problems in order to enhance both productivity and profitability. To resolve these challenges, the company has adopted a structured approach, beginning with the development of a Material Information Flow Chart (MIFC), followed by an analysis using Failure Mode, Effects, and Criticality Analysis (FMECA) based on fuzzy logic. The results of the MIFC analysis show a reduction in lead time from 0.45 days under current conditions to 0.35 days under the improved scenario. This improvement is attributed to the implementation of an ERP system and the introduction of visual monitoring tools. Meanwhile, the FMECA fuzzy analysis identified the primary causes of disruptions that should be prioritized for corrective action. These include non-compliance with standard operating procedures (SOPs), high levels of mental stress among workers, the use of materials that do not meet specifications, and unfavorable environmental conditions.

Keywords: FMECA, MIFC, Lean Manufacturing, Optimization.

I. Introduction

The rapid growth of various industrial sectors, including manufacturing, has intensified competition among companies, particularly those offering similar products. To maintain a competitive edge in this increasingly fierce market, companies must consistently enhance the overall quality of their products and services while ensuring compliance with relevant industry and environmental standards. Furthermore, rapid technological advancements have added complexity to companies' challenges in sustaining their competitiveness. These advancements underscore the importance of continuous improvement in product quality and production capacity. A company's success cannot be measured solely by outperforming competitors or achieving high sales volumes. Instead, it also depends on internal evaluations, including the efficiency of production processes, the quality of raw materials, cost control, resource management, and the effectiveness of production time. These internal factors are essential for sustainable growth and long-term success in a competitive market.

The lean concept is an efficiency approach designed to streamline processes and applies to manufacturing and service companies. Efficiency is achieved by minimizing activities that do not add value, commonly called waste. One widely used method for eliminating waste is the lean manufacturing approach. Lean manufacturing emphasizes continuous process improvement to reduce waste within a company, ultimately minimizing production lead time and enhancing overall operational efficiency (Setiawan & Rahman, 2021). MIFC (Material Information Flow Chart) is a method or tool to map the flow of materials, processes, and information in product manufacturing. By implementing MIFC, companies can identify waste within the production process and analyze its root causes. MIFC provides a comprehensive overview of the production line, enabling companies to implement holistic improvements to enhance overall production efficiency and quality (Ihsan et al., 2023). FMECA (Failure Mode, Effects, and Criticality Analysis) is a method that combines two types of analysis: FMEA (Failure Mode and Effects Analysis) and CA (Criticality Analysis). The FMEA method evaluates risks arising from potential problems by systematically identifying, analyzing, and mitigating their impact. Meanwhile, fuzzy logic-based criticality assessment enables experts to evaluate risks associated with specific failure modes more intuitively, using linguistic values to describe risk factors instead of relying on precise numerical values (Iadanza et al., 2021).

This study aims to optimize the production process by minimizing waste, reducing lead time, and addressing the root causes of issues affecting worker performance and product quality. Additionally, the study seeks to provide actionable recommendations for improvements to effectively overcome the challenges faced by the company.

II. Literature Review and Hypothesis Development

2.1 Lean Manufacturing

Lean Manufacturing is a systematic approach aimed at reducing or eliminating waste in the production process while increasing the added value of products or services. This approach focuses on delivering optimal customer value by minimizing the use of resources, including time, energy, and materials, across all company activities. As a business philosophy, Lean Manufacturing emphasizes identifying and eliminating non-value-adding activities to ensure efficiency and effectiveness. This approach is applicable across various sectors, including production design in manufacturing, operational activities in the service industry, and supply chain management, which directly impacts customer satisfaction (Parwati et al., 2023). Lean Manufacturing examines how the production floor interacts with other organizational components to identify and remove activities that do not contribute to value creation. Any activity that fails to add value to transforming inputs into outputs along the value chain is classified as waste. Two primary ways to implement Lean Manufacturing are identifying and eliminating waste that directly affects the production process. Second, accelerating the production process saves time and improves efficiency (Shidqi et al., 2024).

2.2 Material Information Flow Chart (MIFC)

The Material Information Flow Chart (MIFC) is a crucial method for mapping the flow of materials, processes, and information within a production process. By using MIFC, companies can identify various forms of waste and analyze their root causes. This method comprehensively visualizes the production line, enabling targeted improvements to enhance efficiency and product quality. MIFC is an essential operations management tool, helping organizations optimize their production processes for higher productivity. MIFC uses symbols and arrows to represent the movement of materials and information, including the sequence of operations, storage areas, transportation routes, and data flow. This visual representation allows teams to understand current production conditions better, pinpoint improvement areas, and design more effective

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future operational states. Although there are differences in terminology between Value Stream Mapping (VSM), commonly used in Western industries, and MIFC, which is more prevalent in Japan, these differences are primarily terminological. Both approaches share the same core objective: to provide a clear overview of the flow of materials and information within the production process and to optimize these flows for greater efficiency and effectiveness (Ihsan et al., 2023).

2.3 Failure Mode, Effects and Criticality Analysis (FMECA) Fuzzy

FMECA is a method that combines two types of analysis: FMEA (Failure Mode Effect Analysis) and Criticality Analysis. The FMEA method evaluates risks arising from potential failures, applying a specific approach to assess issues' severity, frequency, and detection. One common approach in FMEA is the calculation of the Risk Priority Number (RPN), which helps prioritize risks based on their severity, frequency of occurrence, and the ability to detect the problem (Rahman, 2021). Significant efforts have been made to address the limitations of this method and enhance the FMECA approach, one of which is Zadeh's introduction of fuzzy logic and fuzzy set theory. Fuzzy logic offers a valuable tool for handling ambiguous or vague information, which can be easily translated into linguistic variables for risk analysis in a fuzzy rule-based system. The fuzzy logic-based criticality assessment allows experts to more naturally evaluate the risks associated with a particular failure mode, using linguistic values to describe risk factors rather than relying on exact numerical values. Before explaining the Fuzzy FMECA rule-based system, it is essential to recognize that FMEA/FMECA standards recommend specific criteria for determining the levels of Severity, Occurrence, and Detectability (Iadanza et al., 2021).

2.4 Waste Classification

Waste is any loss resulting from activities that incur costs but do not add benefits or value to the product from the consumer's perspective. It also includes the loss of materials, time, and costs due to work that does not contribute value to the product (Setiono et al., 2024). Waste encompasses all activities in the work process that do not provide added value. In lean manufacturing, waste is classified into seven categories: Excessive production, Defective products, Excessive raw material stock, Transportation, Movement, Waiting Activities, and Excessive processes.

III. Research Method

PT XYZ, a company engaged in the manufacturing sector that produces agricultural equipment, is facing issues related to waste in its production process, which has impacted product quality. PT XYZ seeks practical solutions to address these problems and enhance the company's productivity and profitability. The approach to solving these issues involves several stages, starting with using the Material Information Flow Chart (MIFC), followed by analysis using Failure Mode, Effects, and Criticality Analysis (FMECA).

IV. Results and Discussion

4.1 Material Information Flow Chart (MIFC)

The current MIFC represents the flow of materials and information in the present state. From the mapping above, it can be observed that the current lead time is 0.45 days. Based on these current conditions, improvement suggestions include implementing an ERP system and adding visual monitoring tools to the production area as part of a 4.0 solution.

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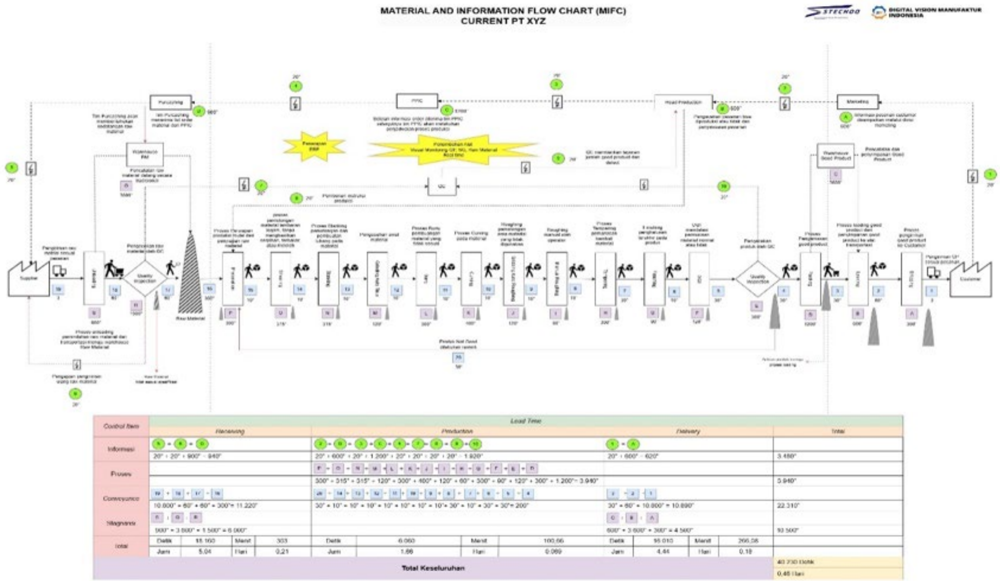

Figure 1. MIFC Current

The condition after these improvements are implemented can be seen in the future material information flow chart (MIFC) shown below:.

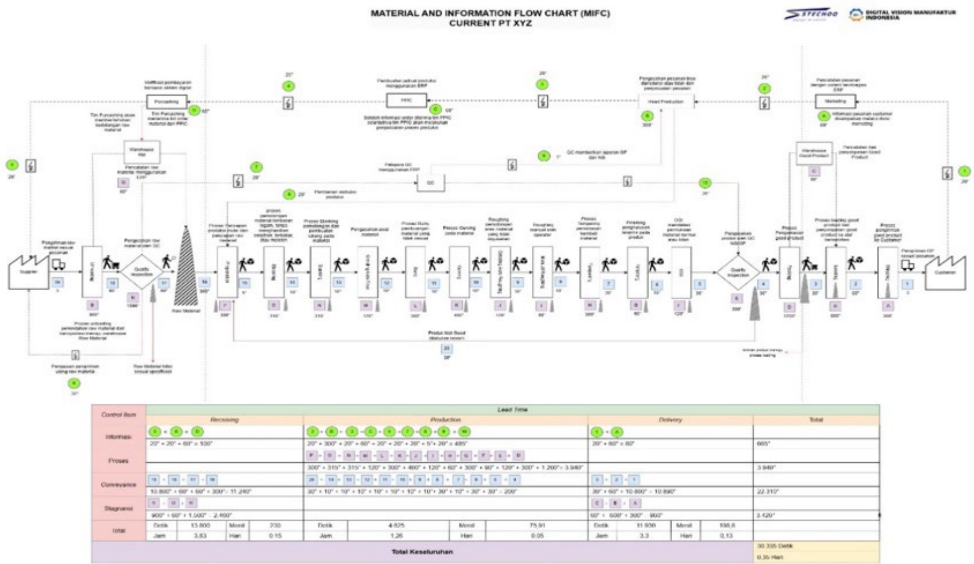

Figure 2. MIFC Future

The future MIFC represents the future state's flow of materials and information. In this scenario, the ERP system has been implemented, and visual monitoring tools have been added to minimize time waste, resulting in a reduced lead time of 0.35 days.

4.2 Fuzzy FMECA

a. Failure Modes and Potential

The first stage of analysis using FMECA is identifying the failure modes that are causing issues in the company. Based on the information gathered, the following failure modes have been identified:

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Table 1. Failure Mode

Failure Mode
High mental pressure at work, so that work is not optimal
Workers have less rest time.
The material does not meet specifications.
Workers do not comply with SOP.
Environmental conditions are not suitable, so work is not carried out optimally.

b. Calculation of Risk Priority Number for each Failure Mode

Table 2. Risk Priority Number (RPN) Calculation

No	Failure Mode	Potential Effects of Failure	S	Potential Causes of Failure	O	Current Control Process	D	RPN
1	High mental pressure at work, so that work is not optimal	Product results at the process stage do not meet specifications	6	Workers are not focused due to high stress	6	Monitoring the mental condition and well-being of workers	8	288
2	Workers have less rest time.	Decreased productivity, work fatigue, defective products due to worker error	4	Tight work schedule, lack of rest time arrangements	3	Scheduling sufficient rest time	3	36
3	The material does not meet specifications	Production results do not meet quality standards	8	Materials that do not meet quality standards	8	Material quality check upon arrival	4	256
4	Workers do not comply with SOP	Procedure error, inconsistent product results	9	Workers do not follow operational procedures	9	Direct training and supervision	4	324
5	Environmental conditions are not suitable, so work is not carried out optimally	Quality of work decreases, and Products are contaminated	8	Dust, humidity, or ambient temperature is not controlled	8	Environmental maintenance and cleanliness supervision	4	256

Using the known RPN values, a Pareto diagram can be created to depict the influence of the causes of failure in terms of percentage. Pareto diagrams identify the most dominant factors or significant influences on the problem.

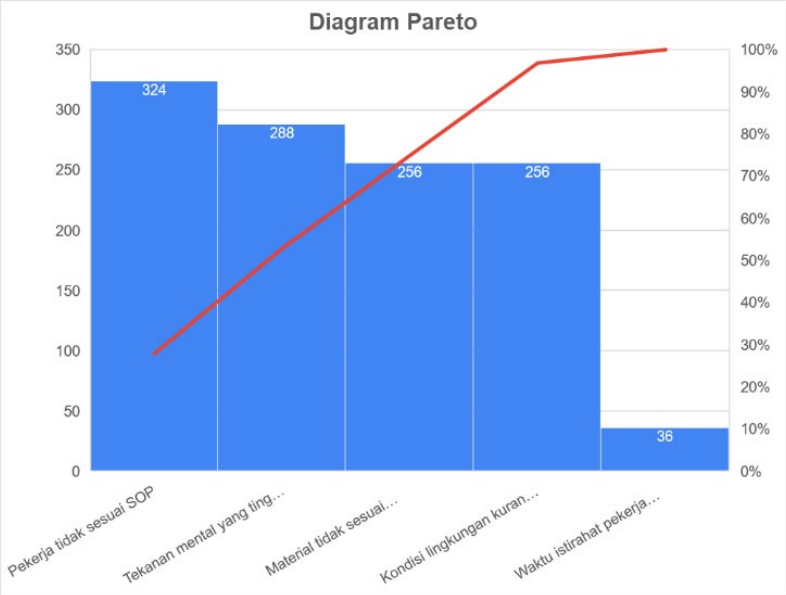

Figure 3. Pareto Diagram Causes of Failure

Based on the Pareto principle, which states that 80% of the effects are caused by 20% of the causes, the primary focus of improvement should be directed at issues such as workers' non-compliance with SOPs and high mental stress, as these two factors contribute to the majority of the problems.

c. Criticality Level of Each Failure Mode

FMECA is a simple and effective method for identifying and evaluating potential failures that can impact the performance of a process or product. The parameters used to determine the priority for critical analysis are as follows:

Table 3. Criticality Parameters

Criticality Level	RPN value	Risk
Minor	0–30	Acceptable
Medium	31–60	Tolerable
High	61-180	Unacceptable
Very high	181-252	Unacceptable
Critical	>252	Unacceptable

Table 4. Critical Level of Each Failure Mode

Indicator	RPN	Criticality level
Workers do not comply with SOP	324	Unacceptable
High mental pressure at work, so that work is not optimal	288	Unacceptable
Materials do not comply with specifications.	256	Unacceptable
Environmental conditions are less than ideal, so work is not done optimally.	256	Unacceptable
Workers' rest time is lacking.	36	Tolerable

The RPN and criticality value calculations indicate that the prioritized causes for handling and prevention disruptions are non-compliance of workers with SOPs, high mental pressure at work, materials that do not meet specifications, and unfavorable environmental conditions.

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Table 5. Fuzzy Number

Fuzzy Number								
S			O			D		
5	6	7	5	6	7	7	8	9
3	4	5	2	3	4	2	3	4
7	8	9	7	8	9	3	4	5
8	9	10	8	9	10	3	4	5
7	8	9	7	8	9	3	4	5

Table 6. FRPN value

Indicator	FRPN			Df	Criticality Level
High mental pressure at work, so that work is not optimal	210	210	504	308	Unacceptable
Workers' rest time is lacking	60	24	24	36	Acceptable
Materials do not meet specifications	504	504	60	356	Unacceptable
Workers do not meet SOP	720	720	60	500	Unacceptable
Environmental conditions are less than ideal, so that work is not carried out optimally	504	504	60	356	Unacceptable

Based on the results of the FRPN and criticality value calculations, the prioritized causes of disruptions for handling and prevention are non-compliance of workers with SOPs, high mental stress at work, materials that do not meet specifications, and unfavorable environmental conditions.

V. Conclusion

Based on the MIFC analysis, lead time was successfully reduced from 0.45 days under current conditions to 0.35 days in future conditions. This improvement was primarily driven by implementing ERP systems and visual monitoring tools, which enable real-time tracking of good products, defective products, raw materials, and other critical production factors. The MIFC method was applied to effectively analyze and map the production process conditions. The results of the Fuzzy FMECA analysis identified key causes of disruptions that require prioritized attention. These include workers' non-compliance with SOPs, high mental pressure in the workplace, materials failing to meet specifications, and suboptimal environmental conditions. To address these issues, PT XYZ should adopt advanced technologies to reduce lead time further and minimize production waste. Additionally, the company should focus on worker training to ensure SOP compliance, monitoring workers' mental health and well-being, conducting regular quality checks on raw materials, and maintaining a safe and conducive work environment. These steps are essential for achieving sustainable efficiency and improving overall production performance.

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