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Waste Analysis in The Production Process Urea Fertilizer Using The Lean Six Sigma Method and Recommendations for Improving Failure Mode Effect Analysis (FMEA) at PT. Damai Sejahtera

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Abstract. Agriculture plays an important role in the Indonesian economy, fertilizer is an important element in the development of the agricultural sector, especially urea fertilizer. PT. Damai Sejahtera, as one of the largest fertilizer producers in Indonesia, experienced waste in the urea fertilizer production process. In this study, lean six sigma was utilized. Using a lean approach, a reduction in non-value-added activities formed by the nine types of waste of 1360 to 1276 or 6.17% was achieved. However, using six sigma, it was found that the production process was not satisfactory as it resulted in many product defects with 36,331 DPMO and a sigma level of 3.32. Improvement suggestions to increase the sigma value were obtained through FMEA. Through this research, Process Cycle Efficiency was obtained from 74.85% to 80.35%.

Keywords: urea fertilizer production, waste reduction, lean six sigma, FMEA,

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1. Introduction

Indonesia is renowned as an agrarian country due to its abundant natural resources and biodiversity. Agriculture plays a central role in supporting the national economy. The success of agriculture depends not only on the efforts of farmers but also on other factors, including the selection of appropriate fertilizers. Fertilizers are crucial in agricultural development. The success of the process can be seen from the number of defective products produced. The more defective products there are, the indication of an inefficient process that requires improvement.

PT. Damai Sejahtera is one of the largest and most comprehensive fertilizer producers in Indonesia. However, there are inefficiencies in the production process of urea fertilizer at PT. Damai Sejahtera, leading to wastage. During the production period from January 2023 to February 2024, the lead time reached 1,360 minutes or approximately 22.67 hours. Another issue is the wastage in the form of product defects. The amount of defective products during the same production period was 12.6% of the total production of 50,110.5 tons. Various issues at PT. Damai Sejahtera involve activities that are inefficient or lack value-added elements in various aspects. These activities represent wastage that needs to be eliminated, requiring improvement to minimize the occurring problems along the production floor.

According to Fajar (2023), one strategy to address these issues is through the Lean Six Sigma method [1]. Lean Six Sigma combines the lean philosophy to identify and eliminate waste and non-value-added activities with continuous improvement, along with the Six Sigma technique [2][3], to reduce defects in both products and services [4][5]. The DMAIC method (Design, Measure, Analyze, Improve, Control) [6][7][8] is utilized in Lean Six Sigma to eliminate wastage, defects, and identify root causes. This leads to improved process efficiency and zero defects [6]. Furthermore, according to Nisa (2023), Failure Mode Effect and Analysis (FMEA) is a technique that helps identify failure causes in systems, products, or processes during the production cycle, along with their impacts and criticality levels. The use of FMEA can enhance the reliability of components or systems within a company [9]. Therefore, this research was conducted to eliminate wastes, make the process more efficient with a lean six sigma approach, and provide improvement suggestions to reduce the number of defective products produced using FMEA at PT. Damai Sejahtera.

2. Methods

This research uses qualitative and quantitative methods. Quantitative methods are research procedures that produce descriptive data in the form of written or everyday language and observable behavior [10][11]. Qualitative research is the study of understanding phenomena faced by the object of study, such as behavior, perception, motivation and behavior [12][13]. The respondents were a team of experts who understand the production process at PT. Damai Sejahtera a total of 10 people. The research framework can be seen in the following flowchart image:

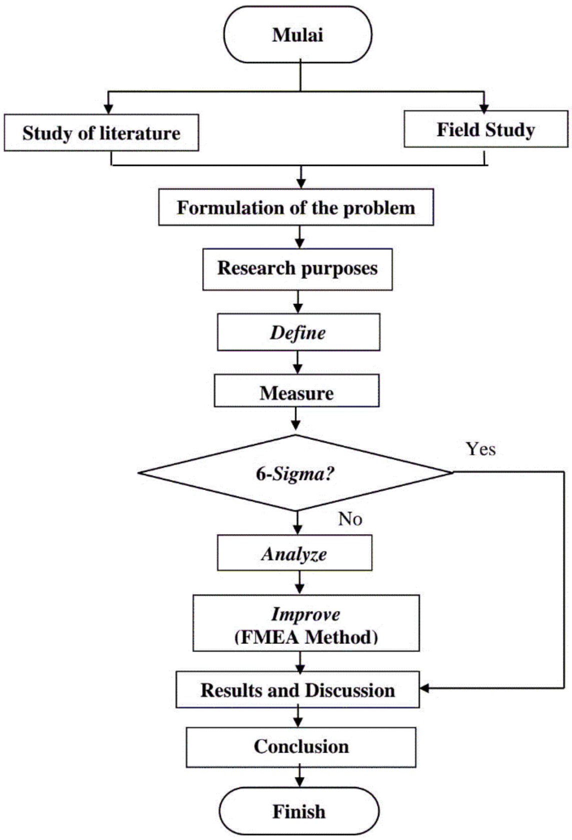

Figure 1. Flowchart

The Define stage aims to define the entire product or service production process, and identify potential defects or failures [14]. Measure, namely selecting problems that have been researched in the process

[15]. In this measure phase, Valsat was used. Analysis is the stage of identifying factors that cause defects or failures that occur [18]. The next step was improve. FMEA (Failure Mode and Effect Analysis) was used. FMEA is an improvement strategy used in the identification, risk assessment, and prioritization of risks that must be addressed.

3. Results and Discussion

3.1. Define

In describing the urea fertilizer production process at PT. Damai Sejahtera, a tool is needed, namely big picture mapping. Big picture mapping of the beginning of the urea fertilizer production process at PT. Damai Sejahtera can be seen in the following picture.

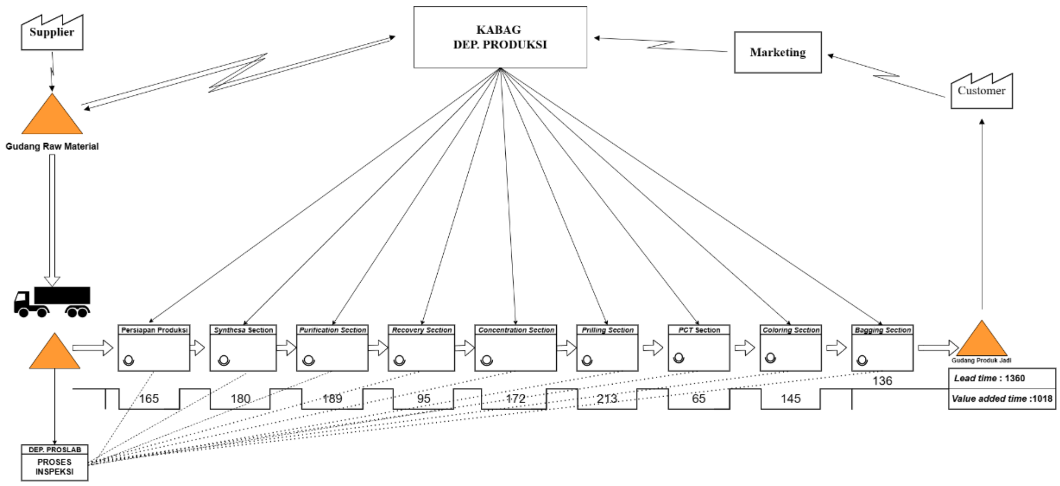

Figure 2. Big Picture Mapping Beginning

Then the work continues to the Measure stage by carrying out VALSAT analysis, the activity mapping process, and calculating the sigma value. Based on the big picture mapping above, it can be seen that there are still many non-value-added activities that make the production process lead time lengthy.

3.2. Measure

The following are the measure phase steps that have been conducted.

3.3. Value Stream Analysis Tools (VALSAT)

Value Stream Analysis Tools (VALSAT) is a tool that is useful for choosing a detailed process flow mapping method for value streams that focuses on value adding processes and non-value adding processes which are used as a guide in identifying waste in the implementation of lean manufacturing [16][17].

Table 1. Mapping Tools

		Mapping Tools						
Wastes	**Weight**	**PAM**	**SCRM**	**PVF**	**QFM**	**DAM**	**DPA**	**PS**
Over Production	2,2	2,2	6,6		2,2	6,6	6,6	
Waiting	2,8	25,2	25,2	2,8		8,4	8,4	
Transportation	2	18						2
Excess Process	2,4	21,6		7,2	2,4		2,4	
Inventory	2,1	6,3	18,9	6,3		18,9	6,3	2,1
Motion	2,5	22,5	2,5					
Defect	3	3			27			
Environtmental Health, and Safety	2,9	26,1			2,9	8,7		
Non-Utilizing Employee	2,3	6,9			20,7			

Total Weight	**131,8**	**53,2**	**16,3**	**55,2**	**42,6**	**23,7**	**4,1**

Based on the calculation results, the weighting was obtained based on the largest score with the first ranking to the smallest with the ninth ranking. So that the weighting results can be obtained in the order of the most relevant tools to use according to the following Table 2:

Table 2. VALSAT Determination Rating Tool

No	VALSAT	Weight	Rank
1	*Process Activity Mapping*	131,8	1
2	Suppy Chain Response Matrix	55,2	2
3	Product Variety Funnel	53,2	3
4	Quality Filter Mapping	42,6	4
5	Demand Amplificatin Mapping	23,7	5
6	Decision Point Analysis	16,3	6
7	Physical Structure	4,1	7

Based on the table, the largest ranking is obtained in determining the ranking, so the tool that will be used in the calculation is Process Activity Mapping (PAM).

Table 3. DPO, DPMO and Sigma Level Values for Urea Fertilizer for January 2023-February 2024

Month	Production Quantity (Ton)	Defects Quantity (Ton)	CTQ	DPO	DPMO	Level Sigma
Januari 2023	1.438,0	241,0	4	0,041898	41.898	3,23
Februari 2023	2.431,5	352,5	4	0,036243	36.243	3,29
Maret 2023	2.603,5	551,4	4	0,052948	52.948	3,12
April 2023	3.220,0	518,0	4	0,040217	40.217	3,25
Mei 2023	4.145,5	458,1	4	0,027626	27.626	3,42
Juni 2023	3.425,0	613,7	4	0,044796	44.796	3,2
Juli 2023	4.332,5	412,4	4	0,023797	23.797	3,48
Agustus 2023	6.431,0	570,6	4	0,022182	22.182	3,51
September 2023	3.368,0	426,5	4	0,031658	31.658	3,36
Oktober 2023	5.052,5	503,0	4	0,024889	24.889	3,46
November 2023	5.214,5	658,9	4	0,031590	31.590	3,36
Desember 2023	4.625,0	423,1	4	0,022870	22.870	3,5
Januari 2024	1.495,0	416,5	4	0,069649	69.649	2,98
Februari 2024	2.328,5	356,5	4	0,038276	38.276	3,27

Based on the table above, the average DPMO value and average sigma value for January 2023-February 2024 can be seen as follows:

$$\text{average DPMO value} = \frac{\text{Total DPMO for Januari 2023} - \text{Februari 2024}}{14} \quad (1)$$

$$= \frac{508639}{14} = 36331$$

$$\text{average sigma value} = \frac{\text{Total sigma for Januari 2023} - \text{Februari 2024}}{14}$$

$$= \frac{46{,}43}{14} = 3{,}32$$

Based on the results above, it shows that based on the six sigma conversion table, PT So it can be said that the company still has not met its target, namely towards world class company standards or six sigma. Therefore, improvements need to be made by analyzing the factors that cause defects so that the company's sigma value can approach the six sigma value.

3.4. Analyze

Analysis is the stage of identifying factors that cause defects or failures that occur [18].

a) Defects
This waste occurs because the results of urea fertilizer production do not comply with the quality specifications determined by company standards and SNI. This is caused by production processes that do not comply with standards, use of raw materials that are less than optimal, and a lack of perfection in the production process.
b) Environmental Health and Safety
This waste occurs because employees are less aware of the completeness of PPE and the ladders in the plant are less ergonomic and rusty, causing work accidents and delays in the work process.
c) Waiting
This waste occurs because the waiting time for raw material procurement is relatively long, apart from that, recording activities are still carried out manually, which causes time inefficiency.
4. Motion
This waste occurs because there are many non-value-added activities that are not needed in the production process. Next, the fertilizer stapling process is carried out twice, namely manually and by machine, which is not efficient.
5. Excess Process
This waste occurs because there is excess product that must be reprocessed, where the product that must be reprocessed is a defective product that is still viable.
6. Non-Utilizing Employees
This waste occurs because employees need training and training according to their field of work.
7. Overproduction
This waste occurs due to excess product in the production process that does not comply with production standards. This can result in a buildup of unsold stock and ultimately result in wastage of resources such as raw materials, energy and labor.
8. Inventory
This waste occurs due to product buildup because consumers are late in taking orders for urea fertilizer products.
9. Transportation
This waste occurs because during the fertilizer transfer process there is a lack of forklifts resulting in process delays

3.5. Pareto Diagram

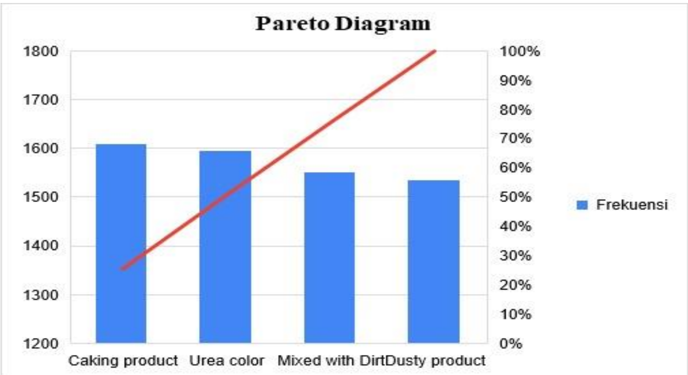

Figure 3. Diagram Pareto

From the Pareto diagram it can be seen that the highest order of defect types is product caking defects at 25.59%, urea color defects at 25.34%, Dirt Mixed defects at 24.66% and product dusty defects at 24.41%.

3.6. Fishbone Diagram

Fishbone analysis is an effective method to use in analyzing existing data to identify problems, by analyzing the causes of problems that occur to find out various sources [19].

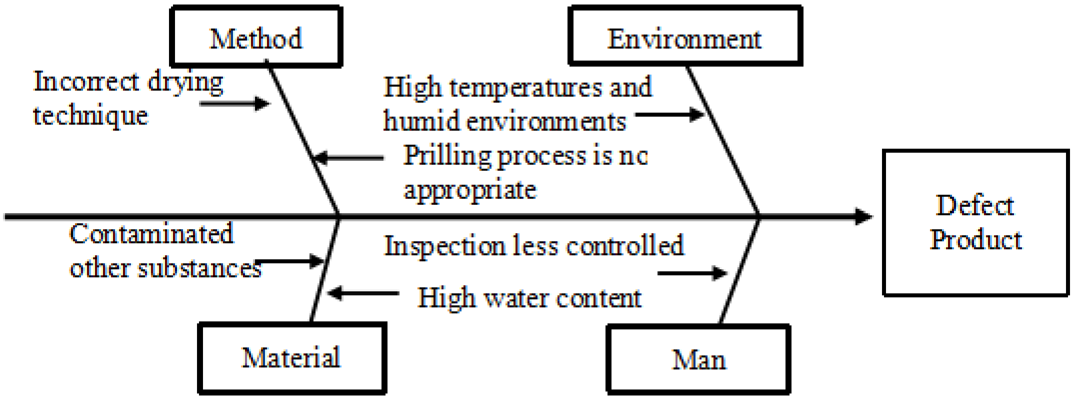

Figure 4. *Fishbone Diagram*

3.7. Improve

Failure Mode Effect and Analysis (FMEA)

The main purpose of using FMEA is to identify potential failure modes within the system unit [20].

Table 4. *Failure Mode Effect and Analysis*

Potential Failure Mode	*Potential Effect of Failure*	*Potential Cause*	*Current Control*
Mixed with Dirt	Urea mixed with dirt is where the urea is wet, moldy and lumpy so it is not worth selling.	Dirty machines and lack of control	Create a cleaning schedule for the machine
		Torn fertilizer sacks	Routine inspection of sacks
		Moist fertilizer storage area	Check the fertilizer storage area
Dusty Products	Granules that do not comply with the provisions (fine urea), so consumers do not want to receive them.	The spray process is too long	Controlling the process time accordingly
		The operator is not careful in operating the machine	Conduct training to operators
		The machine lacks maintenance	Carry out routine machine maintenance
Caking Products	Urea crystallizes so consumers do not want to accept it and must be reprocessed.	The screener capacity is forced to sift the fertilizer granules	Determine the right and appropriate amount of capacity
		The amount (rate) of cold air entering the cooler is not optimal	Controlling the temperature in the storage room that is too high
		Ice forms on the plate on the outer wall of the heat exchanger tube	Strict inspection so that ice does not form on the plate
Urea Color	A faded color reduces the aesthetic value, consumers think that urea fertilizer with a faded color has poor content	The coloring agent contains sludge	Routinely clean the dye spray filter to avoid deadlocks
		Wrong product sampling point	Provide operator training to determine the right sampling point
		Centrifugal pump error	Carry out routine pump maintenance

Based on the calculation of the RPN (Risk Priority Number) value, the cause of process failure can be identified which results in defective products. The causes of defects (potential causes) are then sorted from highest to lowest and then recommendations for improvement for each cause are given.

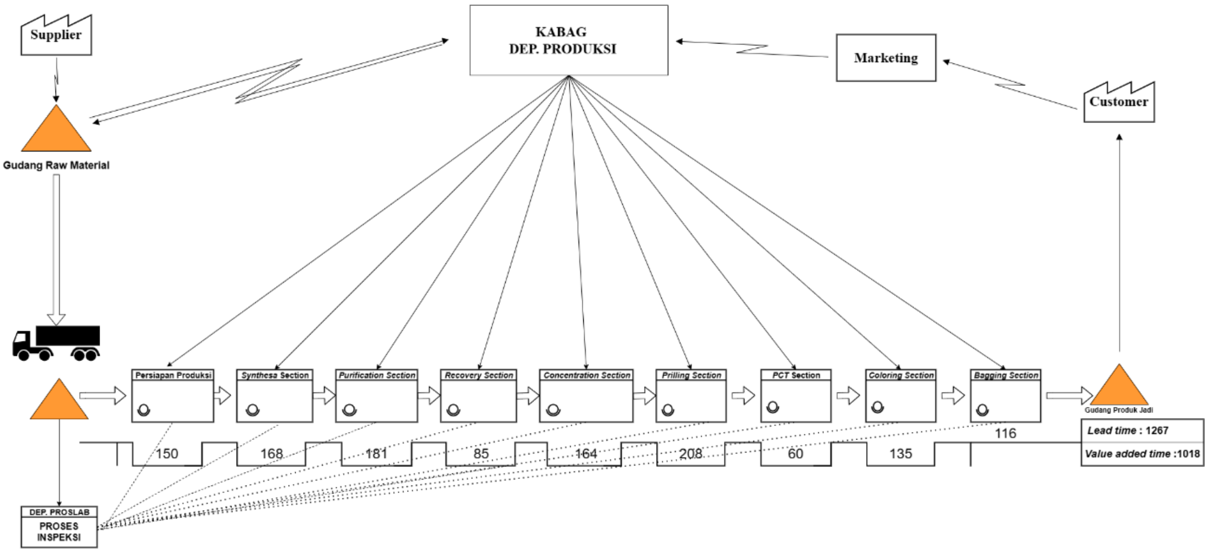

Figure 5. Big Picture Mapping Recommendation

From the Big Picture Mapping Recommendation image can be seen after processing the data using the lean six sigma approach, the lead time value for urea fertilizer production is obtained which is faster than before. The lead time for urea fertilizer production was initially identified as 1360 minutes, then identified again as 1267 minutes. So the value for the percentage increase in Process Cycle Efficiency (PCE) proposed is 80.35%, which means that the urea fertilizer production process has increased. The results support the research conducted by [6] that lean six sigma makes the process more efficient and increases its sigma level.

3.8. Control

The control stage functions to monitor the improvement of waste in the urea fertilizer production process which takes place continuously and for quite a long time. In this research, the control stage cannot be implemented because the decision on this research proposal is left to the company, so control efforts cannot be carried out.

4. Conclusion

The results of reducing lead time for non-value-added waste in the urea fertilizer production process, which was originally 1360 minutes can be reduced to 1267 minutes or 6.17% through reducing non value added activity thereby reducing the cycle time in the urea fertilizer production process. The DPMO value obtained was 36331 with a sigma level of 3.32. Proposed improvements to reduce defects through the help of Failure Mode and Effect Analysis (FMEA), obtained the highest Risk Priority Number (RPN) defect value of 448, namely urea mixed with dirt which causes the fertilizer storage area to be damp, recommended improvements to carry out checks in fertilizer storage area. Apart from that, the second highest Risk Priority Number (RPN) value is 336, namely urea mixed with dirt which causes dirty machines and lack of control. The recommendation is to create a cleaning schedule for the machine. Meanwhile, for the third highest Risk Priority Number (RPN) value of 288, namely dusty urea products which cause the spray process to take too long. By implementing the improvement proposals generated by FMEA, the company can increase its process sigma level, resulting in more uniform production processes with a smaller DPMO value.

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