

# Analysis Of Plastic Pellets Production Process To Reduce Waste Using Lean Six Sigma Method And FMEA

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**Abstract**—The rapid development of the industry has increased plastic production to meet market demand, which has led to a rise in plastic waste volume. One way to reduce plastic waste is by processing it into plastic pellets. CV. XYZ is a company that produces plastic pellets from PP, PS, and PE waste in Gresik, East Java. In its production process, the company faces issues such as high lead times of 990 minutes and non-standard product quality, including defects like clumping, cutting failures, and broken plastic pellets. This study aims to reduce waste and minimize lead time by applying the lean six sigma method with a DMAIC and FMEA approach. Three dominant types of waste were identified: inventory, defects, and transportation. The implementation of improvement proposals successfully reduced lead time from 990 minutes to 780 minutes. The average sigma level was recorded at 3.14 with a DPMO of 50009, which falls into the good category for the average industry in Indonesia. Recommendations include demand forecasting, operator training, supplier selection, improving raw material quality, material handling, and utilizing conveyors in certain areas while minimizing non-value-added activities. Through the design of process activity mapping and big picture mapping, the efficiency of plastic pellet production can increase from 50.51% to 64.10%.

**Keywords**—Lean Six Sigma, Plastic Pellet, Waste, FMEA

## I. INTRODUCTION

In the current era of industrial revolution, effectiveness and efficiency in the production process have become very crucial aspects to be optimized by the company [1]. The utilization of resources must be carefully calculated so that it can run well and smoothly. In recent years, the amount of plastic waste in Indonesia has continued to increase along with the increasing population, industrial growth and high public consumption [2]. According to data from the National Waste Management Information System (SIPSN), Indonesia produced 13.08 million tons of plastic waste in 2023. If this condition is left without the right solution, it can cause environmental pollution and will be bad in the future. One way to be able to control the amount of plastic waste that is wasted is to process it into plastic pellets to be reused [3].

CV. XYZ located in Gresik, East Java, is a company specializing in the production of plastic pellets using plastic waste materials such as PS, PP, and PE. With a production capacity of up to 2 tons per day. However, it faces several challenges in its production process. These include transportation such as workers manually transporting plastic materials multiple times, inventory of raw materials and additives that risk material degradation and expiration, and motion manual movements like climbing and handing materials to others near the machine funnel. Additionally, there are waiting in packaging due to idle time waiting for silos to fill and machine setup during productive hours. Over-processing occurs when defective products are reworked through the extrusion machine, and manufacturing defects such as clumping, cutting failures, and broken pellets further hinder production. The company also struggles with a lead time of 990 minutes to meet its production targets. One method that is suitable for the problems that exist in the company to reduce waste, minimize defects, and shorten the lead time is Lean six sigma. Lean Six Sigma is a data-driven approach designed to enhance business processes,

increase shareholder on customer satisfaction, quality, cost reduction, time efficiency, and process speed. [4]. Lean six sigma is used because the concept of improvement is structured and has a continuous control process. So that it is right as a solution to reduce non-value-added activities and make continuous improvement both in terms of production processes and quality [5]. To reduce waste, it is necessary to identify and propose improvements that can be implemented. One approach used is Failure Mode Effect Analysis (FMEA), which aims to analyze risks, prevent failures, and manage major risks. FMEA reduces the frequency and impact of failures by assigning a Risk Priority Number (RPN) based on the severity, likelihood of occurrence, and detectability of the risk [6].

Previous research on waste elimination in the production process was conducted by Hafizh and Prabowo in 2023. This research examines the production process of mosquito coils, employing the Lean Six Sigma methodology through the DMAIC framework. Tools such as Value Stream Mapping and Process Activity Mapping (PAM) are utilized, with improvement recommendations provided using Failure Mode Effect Analysis (FMEA) [7]. Similarly, a 2023 study by Candra et al. focused on the production process of the RR K12 cover handle, also applying the DMAIC approach. Their research incorporated fishbone diagrams and fault tree analysis for problem identification, alongside proposing improvements through FMEA. Both studies highlight the application of Lean Six Sigma principles to enhance production processes and address inefficiencies [8]. Furthermore, Karuna et al in 2023 conducted research on the copper wire production process using lean six sigma with sipoc diagrams, value stream mapping, and improvement recommendations using 5w + 1h and FMEA [9]. This research focuses on identifying and minimizing waste in the plastic pellet production process at CV. XYZ, while proposing improvement strategies using the Failure Mode Effect Analysis (FMEA) method. The study aims to provide the company with significant benefits by reducing waste, enhancing production efficiency, and ensuring more optimal utilization of resources to prevent unnecessary waste.

## **II. LITERATURE REVIEW**

### **A. Lean**

Lean is a way of managing an organization that supports the principle of continuous improvement. Its focus is on getting rid of anything that is not seen as creating more value for customers, with the goal of increasing efficiency and effectiveness of operations [10]. Lean is used to improve the efficiency of the production process in order to increase customer value. In analysis, the production process is generally divided into three types of activities [11]. Value added (VA), which are activities that add value to products or services; non-value added (NVA), which are activities that do not add value; and necessary non-value added (NNVA), which are activities without added value but are still needed in the production process [12].

Lean waste, which was originally developed by Taiichi Ohno as the core of the Toyota production system, is categorized into 7 types. [13]. First is transportation, which is the activity of moving materials or semi-finished goods between workstations that do not add value to the product. Second is inventory, which is an excessive supply of materials that requires large storage space. The third is movement, which is unnecessary and non-value-added operator movements. Fourth, waiting, which is the time lag between processes that prevent operators from performing. Fifth, overproduction, which is producing more than needed or ahead of schedule, leads to stock buildup. Sixth, overprocessing, which is the use of non-optimal work methods or sequences, can increase the risk of product damage. Lastly, defects, which are products that do not meet specifications or are damaged, require rework [14].

## **B. Six Sigma**

Six Sigma is a method to eliminate defective products and waste so as to achieve customer desires. Six sigma can build a framework for production process improvement. Six sigma uses statistical tools in improving the process [15]. Six sigma performance is a statistical terminology on a process that produces less than 3.4 defects or errors per one million opportunities for defects. The highest Six sigma standard at a value of 3.4 defects is a response to increasing customer expectations and the complexity of products and processes in today's modern era. Six sigma has six levels where the higher the value, the better the quality of the company. Despite its "complicated" name, Six Sigma uses well-known quality control and improvement tools. By implementing Six sigma in the company, the company can understand the threats that exist and know new opportunities to be utilized for the company's growth so that the company can survive and thrive in the midst of competitive competition [16].

The Define stage involves describing all process activities in each production line through a current stream map, identifying the relationship between waste that occurs, and defining the number of Critical to Quality (CTQ) values to help measure the Defects Per Million Opportunities (DPMO) value [17]. In the Measure stage, the proportion of defective products is evaluated to determine if they are within acceptable limits. This stage aims to validate problems, analyze issues from existing data, and measure current performance through DPMO calculations based on CTQ values. The goal of Six Sigma is to achieve a process capability of 3.4 DPMO, signifying defects per one million opportunities. The Analyze stage focuses on identifying the root causes of problems, prioritizing solutions, and understanding the impact of process failures on customers. During the Improve stage, corrective actions are planned and implemented to enhance quality, often using tools like the Kaizen five checklist. The Control stage ensures that the implemented improvements are sustained through monitoring and supervision. [18].

## **C. Lean Six Sigma**

Lean Six Sigma is a widely adopted business improvement methodology utilized across various industrial sectors. It combines the principles of Lean and Six Sigma to enhance profitability by optimizing resources and improving customer satisfaction. Initially introduced as an evolution of Six Sigma in 2003, LSS has gained significant popularity and is now applied in numerous industries to enhance process capability, maximize value, and boost customer satisfaction. When implemented effectively, LSS can lead to reduced production costs, improved output quality, and positive impacts on the financial performance of an organization [19].

## **D. Big Picture Mapping**

The production system/process flow is described using big picture mapping, along with the value stream that gives a summary of the information and physical flow of the current system, pinpoints waste locations, and explains the lead time needed based on the specifics of each process that takes place [20]. Big picture mapping is a tool whose function is to describe the overall system and value stream that arises in the company. Big picture mapping maps the process at the highest level which covers the process broadly but with a low level of detail [21].

## **E. Failure Mode Effect Analysis (FMEA)**

FMEA is a risk assessment technique employed to identify, minimize, or eliminate risks across a company's design, production, and service processes. The main goal is to predict potential risks and implement preventive actions, thereby improving the company's competitiveness. Minimizing risks reduces failure costs while improving quality and reliability, ensuring products meet customer needs. By analyzing potential failures from the design phase, identifying causes and effects, and implementing

corrective actions, FMEA helps improve product quality, customer satisfaction, and work safety. Ultimately, it supports quality improvement, development, and increased competitiveness [22]. Another purpose of conducting FMEA analysis is to identify faults or failures that may negatively affect the operation of the system and minimize their impact, respond satisfactorily to customer requests, determine the impact and likelihood of weak aspects of the system to improve safety and reliability and make continuous system improvements [23].

### III. METHODOLOGY

In this research, the dependent variable used is the level of waste in the production process of plastic pellets. The independent variables in this research are seven waste, which are transportation, inventory, motion, waiting, overproduction, overprocessing, and defects.

The data used in this research was gathered from both primary and secondary sources, employing methods such as observation, interviews, literature reviews, and documentation. The collected data was then analyzed using the Six Sigma methodology, specifically following the Define, Measure, Analyze, Improve, and Control (DMAIC). Below are the stages and tools applied in the research process :

1) *Define*

This stage is carried out to observe and define the existing conditions of the company. Describing with a process map of production which includes an information flow map and a physical flow map packaged in a big picture mapping tool.

2) *Measure*

In the measure stage, the production process is thoroughly mapped by analyzing collected data to differentiate between value-adding and non-value-adding activities. Key metrics are calculated, including PCE for production efficiency, DPMO for defect frequency per million opportunities, and Sigma Levels for assessing the process's ability to produce defect-free products. These metrics provide valuable insights into process performance and areas for improvement.

3) *Analyze*

This stage analyzes the mapped details to identify the dominant types of waste in the production process. It then examines the causes of waste and factors influencing production using Pareto and fishbone diagrams. Additionally, process capability is assessed to determine the process's ability before implementing further improvements.

4) *Improvement*

At this stage, researchers recommend improvements to address waste caused by production process failures using Failure Mode and Effects Analysis (FMEA). Additionally, improvement proposals are presented through future big picture mapping with reduced lead time.

### IV. RESULT AND DISCUSSION

#### A. Define

Physical flow is a flow of physical materials starting from the arrival of raw materials from suppliers to finished goods in the form of plastic pellets ready to be distributed to customers. The stages of the plastic seed production process can be seen as follows :

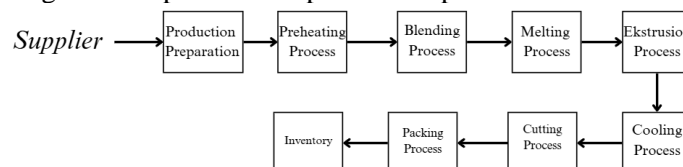


Figure 1 Plastic Pellets Production Flow

From Figure 1, it can be seen that the process begins with the receipt of materials from suppliers then, production prep, blending, melting, extrusion, cooling, cutting, and packing.

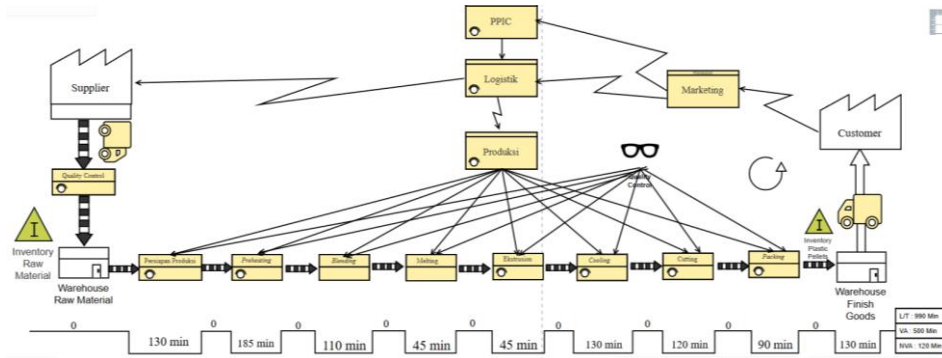


Figure 2 Big Picture Mapping Plastic Pellets Production Process

Figure 2 illustrates that the total lead time is 990 minutes, which consists of 500 minutes for value-added activities, 370 minutes for non-value-added but necessary activities, and 120 minutes for non-value-added activities.

Additionally, the questionnaire distributed within the company provided data on the common types of waste in the plastic pellet production process, with the waste weighting detailed in the table 1.

Table 1 Waste Identification

No	Type of Waste	Scor
1	Overproduction	2,3
2	Waiting	2,7
3	Transportation	3,3
4	Overprocessing	3,0
5	Inventory	3,7
6	Motion	2,5
7	Defect	3,5

The three highest-scoring wastes identified are inventory waste (3.7), defects waste (3.5), and transportation waste (3.3), as detailed in Table 1. Inventory waste arises from inefficient material management, driven by factors such as the lack of demand forecasting, imbalances in material flow, and the practice of ordering materials excessively to capitalize on discounts. Defects waste stems from production errors, poor raw material supplier selection, operator mistakes, and material quality degradation due to prolonged storage. Transportation waste occurs because materials are still moved manually during production, leading to inefficiencies in time and labor, as well as increased risks of delays and errors in the production process.

**B. Measure**

at this stage DPO and DPMO will be calculated. DPMO will be converted into sigma value, and PCE will be calculated to evaluate the overall efficiency of the plastic pellet production process.

Table 2 Plastic Pelet Data Production 12 Period

Period	Production Total (Kg)	Defects		
		Clumping	Cutting Fail	Broken
Dec-2023	47670	3337	2386	1430
Jan-2024	48660	3651	1947	1460
Feb-2024	45330	3174	2720	1361
Mar-2024	44730	2684	2684	1342
Apr-2024	46340	3246	1390	1854

May-2024	52260	3659	2352	2090
Jun-2024	53280	4262	1598	2131
Period	Production Total (Kg)	Defects		
		Clumping	Cutting Fail	Broken
Jul-2024	50460	3534	2018	2270
Aug-2024	45660	3197	1142	1826
Sep-2024	51660	3617	2066	1808
Nov-2024	52140	3652	2607	2086
Total	588380	41528	25170	21666

1) Calculation of DPO, DPMO, and Sigma Level

Furthermore, the calculation of DPO, DPMO, and sigma level values in the plastic pellet production process in each period is carried out to determine the chances of defects appearing on a million occasions. The calculation results can be concluded that the sigma value obtained shows that the company is good enough in handling the quality that arises during the production process. From the calculation, DPO, DPMO values, and sigma levels for 12 periods from December 2023 - November 2024 can be seen in the table 3.

Table 3 DPO, DPMO, and Sigma Level

Period	Production Total (Kg)	Defects Total (Kg)	CTQ	DPO	DPMO	Sigma Level
Dec-2023	47670	7153	3	0,050017	50017	3,14
Jan-2024	48660	7058	3	0,048349	48349	3,16
Feb-2024	45330	7255	3	0,053350	53350	3,11
Mar-2024	44730	6710	3	0,050004	50004	3,14
Apr-2024	46340	6490	3	0,046684	46684	3,18
May-2024	52260	8101	3	0,051671	51671	3,12
Jun-2024	53280	7991	3	0,049994	49994	3,14
Jul-2024	50460	7822	3	0,051671	51671	3,12
Aug-2024	45660	6165	3	0,045007	45007	3,19
Sep-2024	51660	7491	3	0,048335	48335	3,16
Nov-2024	52140	8345	3	0,053350	53350	3,11
Dec-2023	47670	7783	3	0,051690	51690	3,12
Average				0,050009	50009	3,14

Based on the table 3 of the above calculations and the sigma conversion table, CV. XYZ is at level 3.14 sigma or can be said to be at level 3 sigma with an average DPMO value of 50009 for every 1,000,000 productions made by CV. XYZ. Based on this explanation, it can be said that the company still does not meet the target, towards the Indonesian company standard. Therefore, improvements are needed by analyze the factors that cause defects to occur so that the company's sigma value can approach the standard value set by Six Sigma.

2) Calculation of Process Cycle Efficiency (PCE) Value

Table 4 Classification of Plastic Pellet Production Process Activities

No	Activity	Time (Minutes)	Activity Type		
			VA	NNVA	NVA
1	Raw material receiving	15		✓	
2	Raw material inspection	20		✓	
3	Raw material weighing	15		✓	
4	Manual recording of raw materials	20			✓
5	Entering data into the computer of raw materials that have been received.	10		✓	
6	Raw material storage	10		✓	
7	Arrangement of raw materials	20		✓	
8	Delivering materials to the machine area	20		✓	
9	Cleaning the machine area	20		✓	
10	Inspection of the machine area	15		✓	
11	Machine setup	110	✓		

12	Waiting for the machine to be ready	40			✓
13	Pouring PP plastic waste and coloring materials into the machine	60	✓		
No	Activity	Time (Minutes)	Activity Type		
			VA	NNVA	NVA
14	Inspection of material not bottlenecking in the machine funnel	5		✓	
15	Material mixing process	45	✓		
16	The process of melting plastic waste and coloring into a homogeneous melt	40	✓		
17	Inspection of the color of the melt	5		✓	
18	Extrusion process into plastic melt	30	✓		
19	Inspection of melt quality	15		✓	
20	Withdrawal of plastic melt to cooling bath	30	✓		
21	Cooling of plastic strands	30	✓		
22	Quality inspection of strands after cooling	10		✓	
23	Collection of lumpy defect strands	10		✓	
24	Sort defect products	15		✓	
25	Putting processable defect strands into the machine	30	✓		
26	Putting unprocessable defects into the defect special bin	10		✓	
27	Cutting plastic strands into plastic pellets pellets	35	✓		
28	Inspecting the results of cutting strands	15		✓	
29	Collecting defect strands into the defect bin	10		✓	
30	Inspection of plastic pellets	15		✓	
31	Collecting broken plastic pellets defects into the defect bin	15		✓	
32	Putting the good plastic pellets into the bin connected to the silo and blower.	30	✓		
33	Waiting for the silo to fill and preparing sacks	20		✓	
34	Filling the sacks	30	✓		
35	Stitching the sacks	30	✓		
36	Inspection of sacks	10		✓	
37	Lifting the sacks to the storage area	25		✓	
38	Arranging the sacks to the storage area	25		✓	
39	Recording production results manually	60			✓
40	Entering production data into computer by administration staff	20		✓	
Total		990	12	25	3

The process cycle efficiency (PCE) calculation is as follows:

$$PCE = \frac{\text{Value Added}}{\text{lead time}} \times 100\% = \frac{500}{990} \times 100 = 50,51\%$$

Based on the Process Cycle Efficiency (PCE) value of 50.31%, the plastic pellets production process is still inefficient, indicating the need for improvements in the production process.

### C. Analyze

At the analyze stage, an analysis will be carried out regarding the level of waste that occurs and the effect of negative impacts on the company. From this analysis, effective and efficient improvement proposals can be determined to eliminate existing waste.

#### 1) Identify Cause of Waste

In the plastic pellet production seven types of waste can be identified :

- a) Inventory waste occurs due to an imbalance between the materials being processed and those entering storage. Additionally, the company's tendency to order in larger quantities to take advantage of discounts leads to material accumulation. The absence of an inventory control system and proper monitoring of materials and products exacerbates the situation, resulting in excessive material buildup that occupies space without adding value.

- b) Defects occur when the production of plastic pellets does not meet the company's established specification standards. These defects stem from processes that deviate from the company's work standards, poor material quality composition, and errors in machine settings.
- c) Transportation waste occurs because the flow of materials from storage to the machines is still done manually and happens during each production cycle. This issue arises due to insufficient material handling systems and a suboptimal company layout.
- d) Overprocessing waste occurs when production failures lead to defective products. These defective products are reprocessed and reintroduced into the operating machines. This rework is considered wasteful because the products that should have been produced according to the amount of raw material are not achieved, requiring additional processing time.
- e) Waiting waste occurs because packaging operators wait for the silo to be filled before they can begin the packaging process. Additionally, operators also wait for the machine setup to be completed and ready for use.
- f) Motion waste occurs because operators engage in non-value-added activities during the plastic pellet production process. These activities are repetitive, such as manually placing materials into the machine hopper, recording data manually, and then transferring it to a computer.
- g) Overproduction waste is rare because the company does not experience overproduction or stockpile products for long periods. In fact, the company sometimes struggles to meet its daily production targets.

2) Pareto Diagram

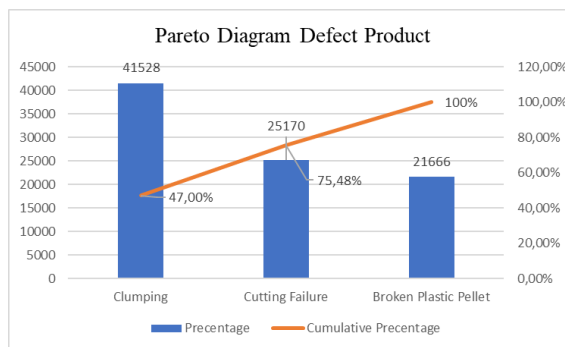
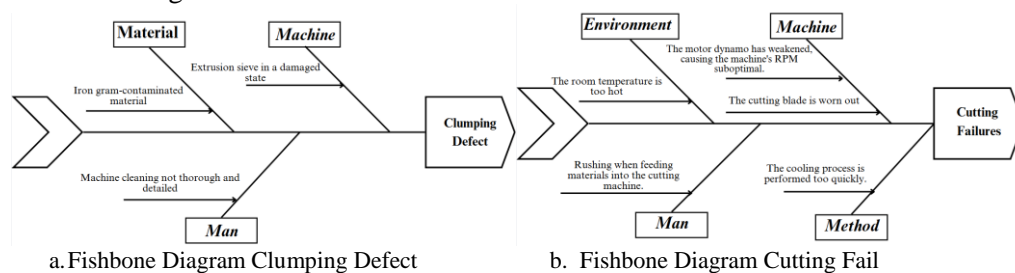
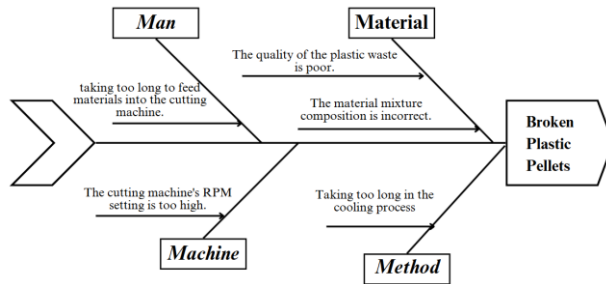


Figure 3 Pareto Diagram Defect Product

The Pareto diagram analyzes product defects, highlighting three main categories: clumping, cutting failure, and broken plastic pellets. Clumping has the highest frequency, with 41,528 cases (47% of total defects), followed by cutting failure with 25,170 cases. Together, these two categories account for 75.48% of total defects. Broken plastic pellets, with 21,666 cases, make up the remaining 24.52%. According to the Pareto Principle, most issues stem from clumping and cutting failures, making them the top priorities for improvement. Addressing these will significantly reduce overall defects, after which efforts can focus on broken plastic pellets to enhance product quality further.

3) Fishbone Diagram





c. Fishbone Diagram of Broken

Figure 4. Fishbone Diagram

The causal diagram in figure 4.a analysis of clumping defects identifies three factors: material, machine, and human. Material issues arise from mixing plastic waste with iron grams, which block extrusion filter holes, causing clumps. Machine-related causes include damaged extrusion filters, leading to uneven melts. Human factors involve operators neglecting detailed cleaning and periodic checks, disrupting the extrusion process.

The causal diagram in figure 4.b analysis of cutting failure defects identifies four factors: machine, environment, method, and human. Machine issues include worn blades that fail to cut pellets properly and a weakened dynamo reducing cutting speed. Environmental causes involve excessively high room temperatures. Method-related issues arise from a cooling process that is too fast, leaving plastic strands insufficiently hardened. Human factors involve operators misjudging the hardening time and inserting strands into the cutting machine prematurely.

The causal diagram in figure 4.c analysis of broken plastic pellet defects identifies four factors: material, human, method, and machine. Material issues stem from poor-quality plastic waste and improper mixture composition in the machine. Human factors include delays in inserting plastic strands into the cutting machine, causing breakage. Method-related causes involve extended cooling times, making strands too hard and brittle. Machine issues arise from improper settings, leading to overly fast cuts that cause the strands to break.

#### 4) Supply Chain Response Matrix

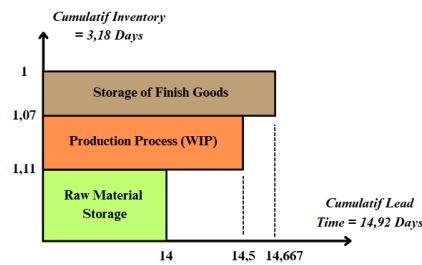


Figure 5. Supply Chain Response Matrix

In addition from figure 5 can be seen that the cumulative lead time value is 14.92 days. While the value of cumulative days of physical stock is 3.18 days. So the total supply chain response time in the plastic pellets production process is 18.1 days. Days physical stock is the average per day of the length of time the material is in the process. The greater the value of days physical stock, the longer the accumulation of inventory throughout the process. The largest days of physical stock occur in raw material storage. This is due to the imbalance between the amount of incoming material and the material that will be processed into plastic pellets. This imbalance occurs because, in the material procurement process, the company always overstocks in buying materials, causing raw materials to accumulate in storage for a long time.

**D. Improvement**

1) Failure Mode Effect Analysis (FMEA)

Table 5 Failure Mode Effect Analysis For Improvement Stages

Potential Failure Mode	Potential Effect of Failure	Severity	Potential Cause	Occurance	Current Control	Detection	RPN
Clumping Defect	lumpy plastic pellets have irregular shapes, poor texture, and the product cannot be cut.	8	Incomplete cleaning	8	Create cleaning checklist, periodic checks	8	512
			Extrusion sieve in a state of disrepair	7	Check the machine before starting production	5	280
			Iron gram contaminated material	6	Inspect before loading materials into the machine	5	240
Cutting Failures	The plastic strands are not completely cut and are still in the form of jagged strands, making them unsellable.	7	Low engine RPM due to lack of power	5	Monitor cutting machine power.	5	175
			Cutting blade is worn	8	Schedule maintenance and checks	6	336
			Too fast cooling process	5	Follow established SOPs.	5	175
			Room temperature is too hot	6	Address electrical voltage issues.	6	252
			In a hurry to insert into the cutting machine	5	Inspect strands before cutting.	6	210
Broken Plastic Pellets	Broken plastic pellets are smaller in size and have brittle properties that affect quality.	8	Poor quality of plastic waste	6	Tighten supplier selection process.	8	384
			Material mix composition is not right	7	Develop materials and dyes.	4	224
			Too long cooling process	5	Follow the SOP that has been set	5	200
			Cutting machine RPM is too fast	4	Control cutting machine mode.	4	128

Potential Failure Mode	Potential Effect of Failure	Severity	Potential Cause	Occurance	Current Control	Detection	RPN
			Too long in feeding into the cutting machine	5	Check texture and temperature of strands.	5	200

The RPN calculation results in Table 5 indicate that the three highest-ranking issues are clumping defects, cutting failure defects, and broken plastic pellets.. The highest RPN on clumping defects has a value of 512 with the cause of cleaning is not thorough and detailed and recommendations create a checklist of areas that must be cleaned and carried out periodically. The second highest RPN on the defect of broken plastic pellets has a value of 384 with the cause of poor quality raw materials and recommendations for improvement in the form of a strict selection of suppliers and providing feedback report cards to suppliers. The third highest RPN on the defect of failed cutting has a value of 336 with the cause of blade wear and improvement recommendations in the form of scheduling and maintenance of machine part changes.

2) Future Big Picture Mapping

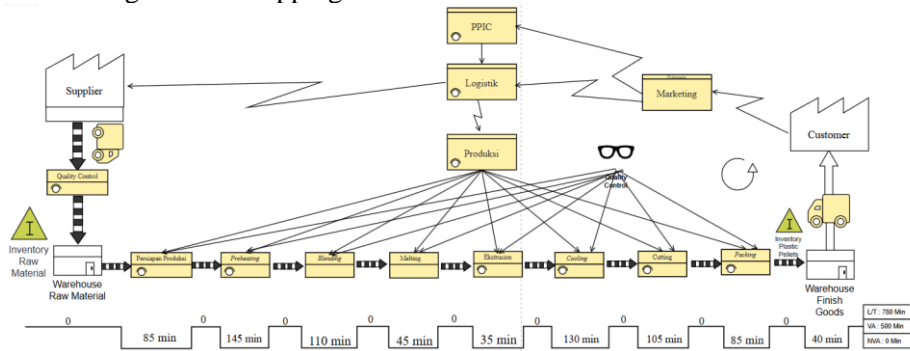


Figure 6. Proposals Big Picture Mapping

From the proposals big picture mapping, it can be seen that after processing the data using lean six sigma, the lead time for plastic pellet production has improved. It reduced from 990 minutes to 780 minutes, showing a decrease that can be calculated using the formula.:

$$\%Enhance = \frac{990 - 780}{990} \times 100\% = 21,2\%$$

Based on the efficiency percentage increase calculation, the result was 21.2%. The proposed Process Cycle Efficiency (PCE) value can then be determined using the following formula :

$$PCE = \frac{Value\ Added}{lead\ time} \times 100\% = \frac{500}{780} \times 100\% = 64,10\%$$

So the percentage value of efficiency in the plastic pellets production process has increased from 50.51% to 64.10%.

V. CONCLUSION

Based on the results and discussion chapter, the following conclusions can be drawn from this research. The results of waste identification show three dominant types of waste, namely waste in storage in the form of material accumulation which results in narrow space for movement, reduces the quality of raw materials, and has the potential to become deadstock. Defective waste in the form of products produced that do not meet

company standards and have an impact on the company's reputation and customer confidence in the company. Transportation waste is in the form of material movements that are carried out manually and repeatedly. Lead time, which initially amounted to 990 minutes, was successfully reduced to 780 minutes through a reduction in the form of delay activities of 120 minutes and a reduction in time on important but non-value-added activities of 90 minutes. Also obtained is a DPMO value of 50009 with a sigma level of 3.14.

Proposed improvements to reduce the level of waste were carried out through FMEA analysis, which resulted in recommendations for improvements to minimize waste and defects. For waste of inventory with the highest weight, it is recommended to do demand forecasting and evaluate the production process. For waste of defect, it is recommended to conduct training for operators, supplier selection, and maintain the quality of raw materials so that it does not decrease. For waste of transportation, it is recommended to provide material handling to operators and start using conveyors for certain parts. Furthermore, the highest RPN on clumping defects has a value of 512 with the cause of cleaning is not thorough and detailed and recommendations create a checklist of areas that must be cleaned and carried out periodically. The second highest RPN on the defect of broken plastic pellets has a value of 384 with the cause of poor quality raw materials and recommendations for improvement in the form of a strict selection of suppliers and providing feedback report cards to suppliers. The third highest RPN on the defect of failed cutting has a value of 336 with the cause of blade wear and improvement recommendations in the form of scheduling and maintenance of machine part changes.

## REFERENCES

- [1] R. Putra Pratama, A. Tri Wardana, and A. Hasibuan, "Implementasi Teknologi Terbaru dalam Manajemen Operasional Perusahaan Industri," *Kohesi J. Mulodisiplin Saintek*, vol. 2, no. 9, 2024.
- [2] A. D. Astuti, E. Frimawaty, and D. Dwiyitno, "Karakteristik Sampah Sungai dan Perilaku Masyarakat Pesisir Terhadap Sampah Plastik: Studi Kasus di Sungai Pengarengan, Kabupaten Cirebon," *J. Ilmu Lingkung.*, vol. 21, no. 1, pp. 76–85, 2023, doi: 10.14710/jil.21.1.76-85.
- [3] A. D. Astuti, J. Wahyudi, A. Ernawati, and S. Q. Aini, "Kajian Pendirian Usaha Biji Plastik di Kabupaten Pati, Jawa Tengah," *J. Litbang Media Inf. Penelitian, Pengemb. dan IPTEK*, vol. 16, no. 2, pp. 95–112, 2020, doi: 10.33658/jl.v16i2.204.
- [4] G. A. Setiamitra and A. Subroto, "Analysis of Lean Sigma - Dmaic Implementation With Enviromental Considerations in Oil & Gas Industry (Case Study: Onshore Field Abc Terminal Field Â€“ Pt Xyz)," *Mak. J. Manaj.*, vol. 9, no. 2, pp. 166–178, 2023, doi: 10.37403/mjm.v9i2.571.
- [5] A. Yohanes and F. A. Ekoanindiyo, "Analisis Perbaikan Untuk Mengurangi Defect Pada Produk Pelindung Tangan Dengan Pendekatan Lean Six Sigma," *J. Sains dan Teknol. J. Keilmuan dan Apl. Teknol. Ind.*, vol. 21, no. 2, p. 127, 2021, doi: 10.36275/stsp.v21i2.378.
- [6] E. D. A. Mawarni and A. Moesriati, "Kajian Kualitas Produksi Depot Air Minum Isi Ulang Kecamatan Genteng Kota Surabaya dengan Metode Failure Mode and Effect Analysis (FMEA)," *J. Tek. ITS*, vol. 10, no. 2, 2021, doi: 10.12962/j23373539.v10i2.64156.
- [7] M. A. Hafizh, R. Prabowo, and S. Artikel, "Implementasi Lean Six Sigma untuk Meminimasi Waste Proses Produksi Obat Nyamuk Bakar," *J. INTECH Tek. Ind. Univ. Serang Raya*, vol. 9, no. 1, pp. 1–12, 2023, [Online]. Available: <https://ejurnal.lppmunsera.org/index.php/INTECH/article/view/4583>
- [8] C. De Candra, L. L. Salomon, and M. A. Saryatmo, "Pengurangan Pemborosan

- Pada Proses Produksi Cover Handle Rr K1Z Dengan Metode Lean Six Sigma,” *J. Serina Sains, Tek. dan Kedokt.*, vol. 1, no. 1, pp. 159–168, 2023, doi: 10.24912/jsstk.v1i1.27151.
- [9] R. Karuna, H. J. Kristina, and I. W. Sukania, “PENINGKATAN KUALITAS DAN MINIMASI WASTE PADA PRODUKSI KAWAT TEMBAGA DENGAN METODE LEAN SIX SIGMA Rio Karuna 1) , Helena Juliana Kristina 2) , I Wayan Sukania 3),” vol. 2, no. 3, pp. 241–253, 2023.
- [10] A. Prabowo, Herry; Farida; Husnur, “Pengenalan Konsep Lean Untuk Meningkatkan Efisiensi Melalui Waste Elimination,” *J. Pengabd. Nas. Vol. 03, No.02, Tahun*, vol. 03, no. 02, pp. 1–23, 2023.
- [11] I. Baharudin, A. J. Purwanto, and M. Fauzi, “Analisis Pemborosan Menggunakan “9 Waste” Pada Proses Produksi Pt Abc,” *J. Ilm. Teknol. Infomasi Terap.*, vol. 8, no. 1, pp. 187–192, 2021, doi: 10.33197/jitter.vol8.iss1.2021.745.
- [12] G. Fattahillah, P. Merdeka, and D. Nurkertamanda, “Identifikasi 9 Waste Beserta Usulan Rekomendasi Perbaikan pada Proses Produksi Side Link dengan Pendekatan Lean Manufacturing pada Divisi Infrastruktur Perhubungan PT PINDAD (Persero),” *Ind. Eng. Online J.*, vol. 12, no. 3, 2020, [Online]. Available: <https://ejournal3.undip.ac.id/index.php/ieoj/article/view/40323>
- [13] A. Fole and J. Kulsaputro, “Implementation Of Lean Manufacturing To Reduce Waste In The Passion Fruit Syrup Production Process,” *J. Ind. Eng. Innov.*, vol. 01, no. 01, pp. 23–29, 2023.
- [14] I. Ramadhani, A. Rasyid, and S. Junus, “Identifikasi Dan Minimasi Waste Produksi Keripik Pisang Keju Menggunakan Metode Lean Manufacturing,” *RADIAL J. Perad. Sains, Rekayasa dan Teknol.*, vol. 11, no. 2, pp. 240–250, 2023, doi: 10.37971/radial.v11i2.398.
- [15] Pujo Mulyono and A. Y. Heryanto, “Analisis pengendalian mutu keju mozzarella menggunakan metode six sigma (studi kasus CV. ABC Malang),” *JENIUS J. Terap. Tek. Ind.*, vol. 4, no. 1, pp. 57–65, 2023, doi: 10.37373/jenius.v4i1.464.
- [16] D. Korintus Kurnianto and I. R. Hari Setyanto, “Usulan Perbaikan Kualitas Produk Menggunakan Metode Six Sigma di PT. ZYX,” *Semin. dan Konf. Nas. IDEC*, pp. 2579–6429, 2021.
- [17] E. W. Asih, L. Ode, R. Rain, A. Pohandry, T. Industri, and T. Industri, “Analisis Pengendalian Kualitas Produk Teh Hitam dengan Pendekatan Lean-Six Sigma Method di PT. Teh XY,” *J. Ind. Eng. Syst.*, vol. 2, no. 2, pp. 136–145, 2021.
- [18] Ibrahim, D. Arifin, and A. Khairunnisa, “Analisis Pengendalian Kualitas Menggunakan Metode Six Sigma Dengan Tahapan DMAIC Untuk Mengurangi Jumlah Cacat Pada Produk Vibrating Roller Compactor Di PT. Sakai Indonesia,” *J. Kalibr. - Karya Lintas Ilmu Bid. Rekayasa Arsitektur, Sipil, Ind.*, vol. 3, no. 1, pp. 18–36, 2020.
- [19] I. T. B. Widiwati, S. D. Liman, and F. Nurprihatin, “The implementation of Lean Six Sigma approach to minimize waste at a food manufacturing industry,” *J. Eng. Res.*, no. January, 2024, doi: 10.1016/j.jer.2024.01.022.
- [20] R. P. Naganingrum and L. Herdman, “Analisis Waiting Time dalam Proses Perakitan MV Switchgear dengan Lean Production,” *Performa Media Ilm. Tek. Ind.*, vol. 11, no. 1, pp. 37–44, 2012, [Online]. Available: <https://jurnal.uns.ac.id/performa/article/view/12632%0Ahttps://jurnal.uns.ac.id/performa/article/download/12632/10726>
- [21] N. Nelfiyanti, D. Saputra, and R. A. M. Puteri, “Penerapan Value Stream Mapping Tools dalam Meminimasi Pemborosan Proses Packing Part Disc di line Servis,” *JISI J. Integr. Sist. Ind.*, vol. 10, no. 1, p. 9, 2023, doi: 10.24853/jisi.10.1.9-18.
- [22] A. Anastasya and F. Yuamita, “Pengendalian Kualitas Pada Produksi Air Minum Dalam Kemasan Botol 330 ml Menggunakan Metode Failure Mode Effect Analysis (FMEA) di PDAM Tirta Sembada,” *J. Teknol. dan Manaj. Ind. Terap.*,

- vol. 1, no. I, pp. 15–21, 2022, doi: 10.55826/tmit.v1ii.4.
- [23] Z. Wu, W. Liu, and W. Nie, “Literature review and prospect of the development and application of FMEA in manufacturing industry,” *Int. J. Adv. Manuf. Technol.*, vol. 112, no. 5–6, pp. 1409–1436, 2021, doi: 10.1007/s00170-020-06425-0.