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Enhancing quality in plastic manufacturing: Six sigma application to polybox containers

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ABSTRACT

Historical production data from November 2021 to February 2022 revealed that polybox plastic containers suffered from a 2.84% defect rate, exceeding the company's 2% threshold. This study applies the Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) methodology to enhance product quality. The Define phase utilized SIPOC and Critical to Quality (CTQ) diagrams to outline quality characteristics. In the Measure phase, P and U Control Charts established a baseline performance with a Defect Per Million Opportunities (DPMO) of 8,420 and a sigma level of 3.89. The Analyze phase employed Fishbone diagrams and Failure Mode and Effects Analysis (FMEA) to isolate root causes. High Risk Priority Numbers (RPN) highlighted worker carelessness (294), welding inaccuracies (252), and manual handling issues (210). Consequently, the Improve phase implemented new Standard Operating Procedures (SOPs), welding guidelines, and hand-truck trolleys. Post-implementation monitoring during the Control phase showed immediate improvements: the DPMO dropped to 6,305, and the sigma level increased to 3.99. These findings confirm the efficacy of Six Sigma interventions in reducing manufacturing defects and aligning production with quality standards.

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1. INTRODUCTION

Quality is a critical standard that companies must uphold through consistent quality control to ensure products meet high standards, enhance customer satisfaction, boost market sales, build a reputable brand image, and gain trust and acceptance in both domestic and international markets [1]–[5]. By prioritizing quality, companies can foster long-term customer loyalty and differentiate themselves in competitive markets, further solidifying their position as reliable industry leaders, especially in a plastic manufacturing company. Plastic manufacturing has a great concern for quality control due to the conformity, performance, competitiveness, and profitability of plastic materials. It has led to the adoption of modern investigation techniques (noncontact nondestructive measurements: laser spectroscopy, NMR, etc).

A polybox basket is a plastic product used as a storage medium for automotive spare parts before being assembled for the final production process. These spare parts usually are car rear lights, car headlights, and other types of spare parts, based on the customer's order. The use of a polybox basket as a medium for storing spare parts is to make the spare parts safer and facilitate the ease of the assembly process at the end of the automotive production process. By these functions, polybox baskets, as shown in Figure 1, are designed to be equipped with a preboard or hollow plastic cardboard cover coated with plastic material on the outside and a sponge inside.

Figure 1. Polybox basket product

The polybox basket is produced on customer order. As a consequence, each customer's complaint becomes a main concern for the company, especially in product defect cases. The polybox basket's producer set the maximum defect standard of 2%. But the achievement is often beyond the standard, as can be seen in Table 1. It shows historical data regarding production numbers and the number of defects in polybox products from November 2021 to February 2022. The historical data shows not only the number of product defects beyond the standard, but also that there is a trend that product defects tend to increase over time. This is a serious problem for the company to maintain the quality of the product.

Table 1. Historical data on production and product defects for November 2021 – February 2022

Month	Amount of Production/*Polybox*	Amount of Defects	Percentage of Defects	Average Percentage of Defects
November	9.500	227	2,38%	
December	10.080	283	2,8%	
January	11.337	365	3,21%	2,84%
February	10.542	317	3%	
Total	41.459	1192		

This study mainly aims to improve the quality of polybox products. It includes some specific goals according to the Six Sigma concept, like identifying the types of defects that occur in polybox products; identifying the DPMO (Defect Per Million Opportunities) value and sigma level for polybox products; analyzing the causes of dominant defects in polybox products; providing suggestions for improvements to improve the quality of polybox products; and determining the DPMO value and sigma level after implementing the proposed improvements to the polybox product.

2. METHODS

The methods used in this study follow a structured sequence that begins with identifying the core problem, followed by collecting and processing the required data, and applying Six Sigma principles to analyze system performance. A set of analytical tools, techniques, and supporting software is employed to ensure accuracy and consistency throughout the research. The detailed procedures for each stage are presented in the subsections that follow.

2.1. Preliminary Research and Problem Identification

This stage involves conducting literature studies, identifying existing problems, and determining research objectives. This research was organized through direct observation and interviews to understand the production flow and gather information about the problems occurring in this company.

2.2. Data Collection

There are secondary and primary data that have been collected. Secondary data consists of historical data on polybox product defects and company profiles. Meanwhile, primary data consists of data on polybox product production volumes, defects, and product defects.

2.3. Data Processing and Application of Six Sigma

This research processed the data using the Six Sigma method with the Define – Measure – Analyze – Improve – Control (DMAIC) phases, P control chart, U control chart, DPMO, sigma level, Pareto diagram, Fishbone diagram, and Failure Mode and Effects Analysis (FMEA) [6]. Six Sigma is a method for controlling and improving a product to maintain quality and maximize and achieve planned targets [7], [8]. The goal of Six Sigma is to improve the quality and performance of the production process, eliminating factors that cause defects to occur. Six Sigma uses the DMAIC approach, namely Define, Measure, Analyze, Improve, and Control [9], [10].

1. The Defining phase [11], [12] is to identify the factors that cause problems with polybox products so that they affect quality. At this stage, the tools used is the Suppliers Inputs Processes Outputs Customers (SIPOC) and Critical to Quality (CTQ) diagrams.
2. The Measuring phase [13], [14] is the data measurement stage by collecting all the data needed to calculate. After obtaining the data, it is calculated and analyzed using P control charts, U control charts, Defect Per Opportunities (DPO) calculations, DPMO calculations, and sigma values.

   The P control chart is calculated as follows [15]:

$$CL = \bar{p} = \frac{total\ defects}{total\ inspection} \tag{1}$$

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} \tag{2}$$

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} \tag{3}$$

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} \tag{4}$$

   The calculation for the U control chart is as follows [15]:

$$CL = \bar{u} = \frac{total\ of\ product\ defect}{total\ of\ inspection} \tag{5}$$

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} \tag{6}$$

$$UCL = \bar{u} + 3\sqrt{\frac{\bar{u}}{ni}} \tag{7}$$

$$LCL = \bar{u} - 3\sqrt{\frac{\bar{u}}{ni}} \tag{8}$$

Next, the DPMO and sigma level calculations [16], [17] are as follows :

- *Defect Per Units* (DPU)

$$DPU = \frac{Number\ of\ Defects}{Total\ of\ Production} \tag{9}$$

- Defect Per Opportunities (DPO)

$$DPO = \frac{Number\ of\ Defects}{Total\ of\ Production\ x\ Opportunity} \tag{10}$$

- Defect per million opportunities

$$DPMO = DPO\ x\ 1.000.000 \tag{11}$$

- Sigma level

$$Sigma\ Level = \left(NORMSINV\left(\frac{1.000.000 - DPMO}{1.000.000}\right)\right) + 1,5 \tag{12}$$

3. The analysis phase [18], [19] is analyzing and finding the root causes of problems in the production process. This stage identifies root causes in the polybox production process to support targeted improvements. The tools used at this analysis stage are Pareto diagrams, Ishikawa or fishbone diagrams, and FMEA.
4. The improvement phase [4], [5] is the stage of proposed improvements to repair and improve the quality of polybox products so that they can reduce defects that occur during the production process. Improvement proposals are carried out aimed at improving product quality so that they can overcome previous problems.
5. The control phase [20], [21] is the final stage in the DMAIC approach. The control phase aims to measure the proposed improvements that have been planned and implemented in the company. The proposed improvements made at the improvement stage follow the plan and can improve production quality. The control stage ensures that the implementation that has been made is running well, and then a comparison is made between the data processing that has not yet been improved and that which has been proposed for improvement.

2.4. Tools and Techniques Used

There are some tools and techniques used in applying Six Sigma, such as SIPOC and CTQ diagrams [22], P and U control charts [23], Pareto and Ishikawa diagrams [24], and FMEA [25], [26]. Table 2 summarizes each tool and technique used in each phase:

Table 2. Summary of tools used in DMAIC phase

DMAIC Phase	Tools Used	Purpose
Define	SIPOC, CTQ	Identify key quality factors and stakeholders
Measure	P-chart, U-chart, DPMO	Quantify defect levels and variability
Analyze	Pareto Diagram, Fishbone, FMEA	Diagnose root causes and prioritize improvement areas
Improve	Proposed Improvements	Eliminate key causes of defects
Control	Post-implementation Analysis	Ensure sustainability of improvements

2.5. Software Used

This research used Minitab Software to process data, especially in the process of P control chart, U control chart, and Pareto diagram. Minitab was chosen for generating control charts and conducting Pareto analysis due to its specialized tools for statistical process control, which enabled efficient data visualization, outlier detection, and prioritization of defects in our dataset.

3. RESULTS

Observation and collection of data on production date, quantity, number of defects, type, and number of product defects that did not pass inspection. There are 4 types of failures, namely letter defects (1), chips (2), black spots (3), and imperfect connections (4). Table 3 shows the type and amount of defects.

Table 3. Type and amount of defects

No	Date	Sampling	Amount of Defects	Types of Defects				Number of Defects
				(1)	(2)	(3)	(4)	
1	01/03	300	9	0	6	2	2	10
2	02/03	325	11	0	5	2	4	11
3	03/03	313	5	0	3	0	2	5
4	04/03	332	13	2	6	1	5	14
5	05/03	308	7	0	3	2	3	8
6	07/03	327	12	0	6	1	6	13
7	08/03	350	15	2	8	2	4	16
8	09/03	346	14	1	6	2	5	14
9	10/03	321	11	0	6	1	4	11
10	11/03	315	5	0	3	0	2	5
11	12/03	328	13	1	6	0	6	13
12	14/03	342	11	0	7	0	4	11
13	15/03	316	6	0	3	1	2	6
14	16/03	321	8	1	4	0	3	8
15	17/03	330	12	1	7	1	3	12
16	18/03	326	10	0	4	1	5	10
17	19/03	329	9	0	6	0	3	9
18	21/03	338	13	0	6	1	6	13
19	22/03	343	15	0	8	2	5	15
20	23/03	351	17	2	8	0	7	17
Total		6561	216	10	111	19	81	221

3.1. Defining Phase

The defined stage is the process identification phase and the quality characteristics of the polybox products. This stage uses the SIPOC and CTQ diagram tools. The SIPOC diagram illustrates the main process activities and customers involved in each process from Supplier, Input, Process, Output, to Customer. It helps to clarify the root causes of defects by identifying the production process from raw materials to polybox products [27]. Table 4 shows the production process from raw material as input to the polybox product as the end output of the process, which is illustrated in the SIPOC diagram.

Table 4. SIPOC diagram

Supplier	Input	Process	Output	Customer
Alfa Gemilang Makmur, Kreasi Dasa Tama, Pratama Eka Bigco, Victory Indah Prima	Plastic Bos Raw Material, Plastic Impraboard, Plastic, Sponge	*Incoming Material*	Raw Material Plastic Box, Impraboard, Plastic, Sponge	Raw Material Warehouse

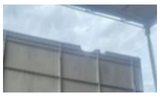
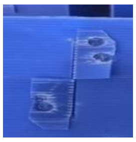
Supplier	Input	Process	Output	Customer
Raw Material Warehouse	Plastic Box	Take Plastic Box	Plastic Box	Emboss Machine
Emboss Machine	Plastic Box	Company's Name Embossing	The company's name on Plastic Box	Workbench
Workbench	Impraboard	Take Impraboard	Impraboard	Workbench
Workbench	Impraboard	Cut the Impraboard as Cover	Impraboard as Cover	Workbench
Workbench	Impraboard	Take Impraboard	Impraboard	Pond Impraboard Machine
Pond Impraboard Machine	Impraboard	Cut Impraboard according to the pattern	Impraboard according to the pattern	Welding Machine
Welding Machine	Impraboard sesuai pola	Connect the impraboard	Connected Impraboard	Workbench
Workbench	Sponge	Take the Sponge	Sponge	Workbench
Workbench	Sponge	Cut the Sponge as a Cover	Sponge as Cover	Workbench
Workbench	Sponge	Cut the Sponge as an Inner Layer	Sponge as Inner Layer	Pond Sponge Machine
Pond Sponge Machine	Sponge	Cut the Sponge according to the pattern	Sponge according to the pattern	Workbench
Workbench	The Impraboard has been connected & the Sponge according to the pattern	Assembly Sponge and Impraboard	Impraborad with an inner Sponge	Sewing Machine
Sewing Machine	Plastic	Plastic Collection	Plastic	Cutting Machine
Cutting Machine	Plastik	Cut the plastic according to the pattern	Plastic according to the pattern	Pattern Machine
Pattern Machine	Cut the plastic according to the pattern	Smooth the edges of the plastic	Smooth plastic	Sewing Machine
Sewing Machine	Impraboard dengan Sponge didalam dan plastik sudah rapih	Sew	Stitched Plastic	Workbench
Workbench	Impraboard dengan box plastik	Assembly	Polybox	Inspection Station

Supplier	Input	Process	Output	Customer
Inspection Station	Polybox	Inspection	Polybox lolos inspeksi	End Product Warehouse
End-Product Warehouse	Polybox passed inspection	Delivery	Polybox	Customer

CTQ indicates the characteristics of a process or product that meet specifications to obtain a standard [17], [27]. Table 5 describes the quality characteristics of polybox products that comply with established standards. It is a tool used to describe the quality characteristics of polybox products that comply with established standards [28], [29]. Table 5 is the CTQ of polybox products. The quality standards desired by customers for polybox products are:

1. The company name embossing process has no name or letter errors.
2. Overall the polybox product complies with the standards set by the company, namely that there are no lumpy parts in the polybox product.
3. There are no stains or black marks on polybox products.
4. The connection between smartboards during the welding process is neatly installed, tight, and strong.

Table 5. CTQ of polybox product

No	Types of Failures	Pictures	Types of Defects	Description
1	Letter Defect		Attribute	Errors in the embossing process, where there is a mismatch between the name or letters and the customer's wishes
2	Chips		Attribute	There are imperfect parts in polybox products
3	Black Spots		Attribute	There are black stains or spots on the polybox product.
4	Imperfect Connection		Attribute	Errors in the welding process connecting impraboards resulted in the sides of the impraboard not sticking properly and not being neat.

3.2. Measurements Phase

This measure stage aims to calculate the performance of the polybox production process, where process performance measurement begins with data collection. This measurement stage uses the P Control chart, U Control chart tools, DPMO (Defect per Million Opportunity) calculations, and sigma values [15], [16]. Table 6 contains the calculation of the P-control chart used to assess the proportion of defects based on observation data.

Table 6. Calculation of P-control chart

Data	Number of Production Samples	Number of Defective Products	Proportion of Defective Products	CL	UCL	LCL
1	300	9	0.030	0.034	0.065	0.002
2	325	11	0.034	0.034	0.064	0.003
3	313	5	0.016	0.034	0.065	0.003

Data	Number of Production Samples	Number of Defective Products	Proportion of Defective Products	CL	UCL	LCL
4	332	13	0.039	0.034	0.064	0.003
5	308	7	0.023	0.034	0.065	0.002
6	327	12	0.037	0.034	0.064	0.003
7	350	15	0.043	0.034	0.063	0.004
8	346	14	0.040	0.034	0.063	0.004
9	321	11	0.034	0.034	0.064	0.003
10	315	5	0.016	0.034	0.065	0.003
11	328	13	0.040	0.034	0.064	0.003
12	342	11	0.032	0.034	0.063	0.004
13	316	6	0.019	0.034	0.065	0.003
14	321	8	0.025	0.034	0.064	0.003
15	330	12	0.036	0.034	0.064	0.003
16	326	10	0.031	0.034	0.064	0.003
17	329	9	0.027	0.034	0.064	0.003
18	338	13	0.038	0.034	0.064	0.004
19	343	15	0.044	0.034	0.063	0.004
20	351	17	0.048	0.034	0.063	0.004
Total	6561	216				

The following are the calculation for the P control chart based on formulas (1), (2), and(3) :

$$CL = \bar{p} = \frac{216}{6561} = 0.329$$

$$UCL = 0{,}329 + 3\sqrt{\frac{0{,}329\ (1 - 0{,}329)}{300}} = 0.0638$$

$$LCL = 0{,}0329 - 3\sqrt{\frac{0{,}329\ (1 - 0{,}329)}{300}} = 0.002$$

Based on plotting data (Figure 2) using Minitab, it indicates that the defective product is still within control limits, and nothing has exceeded control limits. Therefore, it can be concluded that the production process is still stable.

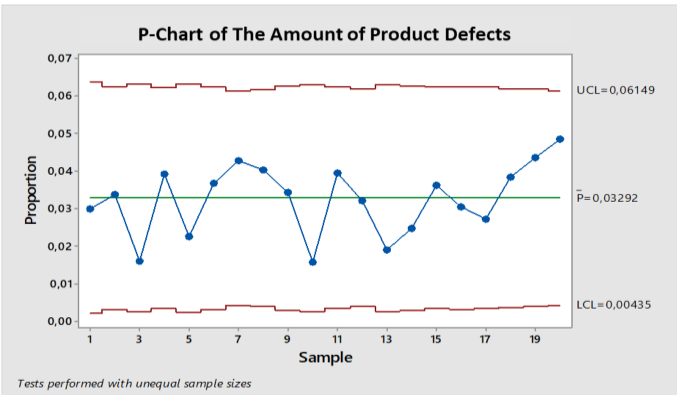


Figure 2. Data Plot of P-Control Chart

Table 7 contains the calculation of the U-control chart used to to measure defects occurring in a polybox product unit.

Table 7. Calculation of U-control chart

Data	Number of Production Samples	Number of Defective Products	Proportion of Defective Products	CL	UCL	LCL
1	300	9	10	0.034	0.065	0.002
2	325	11	11	0.034	0.064	0.003
3	313	5	6	0.034	0.065	0.003
4	332	13	13	0.034	0.064	0.003
5	308	7	8	0.034	0.065	0.002
6	327	12	13	0.034	0.064	0.003
7	350	15	16	0.034	0.063	0.004
8	346	14	14	0.034	0.063	0.004
9	321	11	11	0.034	0.064	0.003
10	315	5	5	0.034	0.065	0.003
11	328	13	13	0.034	0.064	0.003
12	342	11	11	0.034	0.063	0.004
13	316	6	6	0.034	0.065	0.003
14	321	8	8	0.034	0.064	0.003
15	330	12	12	0.034	0.064	0.003
16	326	10	10	0.034	0.064	0.003
17	329	9	9	0.034	0.064	0.003
18	338	13	13	0.034	0.064	0.004
19	343	15	15	0.034	0.063	0.004
20	351	17	17	0.034	0.063	0.004
Total	6561	216	221			

The following are the calculation for the U control chart based on formulas (4), (5), and (6):

$$CL = \bar{u} = \frac{221}{6561} = 0.03368$$

$$UCL = 0{,}03368 + 3\sqrt{\frac{0{,}03368}{300}} = 0.06547$$

$$LCL = 0{,}03368 - 3\sqrt{\frac{0{,}03368}{300}} = 0.0019$$

Based on plotting data (Figure 3), the data is still within control. Although the result of the P-Control Chart and U-Control Chart shows that the data is within control, improvement still needs to be proposed to achieve the company's standard of defective products.

Next, the DPMO and sigma level calculations based on formulas (9), (10), (11) and (12):

a. *Defect Per Units* (DPU)

$$DPU = \frac{221}{6561} = 0.03368$$

b. *Defect Per Opportunities* (DPO)

$$DPO = \frac{221}{6561\ x\ 4} = 0.00842097$$

c. *Defect per million opportunities*

$$DPMO = 0.00842\ x\ 1.000.000 = 8420.97$$

d. Sigma level

$$Sigma\ Level = \left(NORMSINV\left(\frac{1.000.000 - 8420}{1.000.000}\right)\right) + 1{,}5 = 3.89014$$

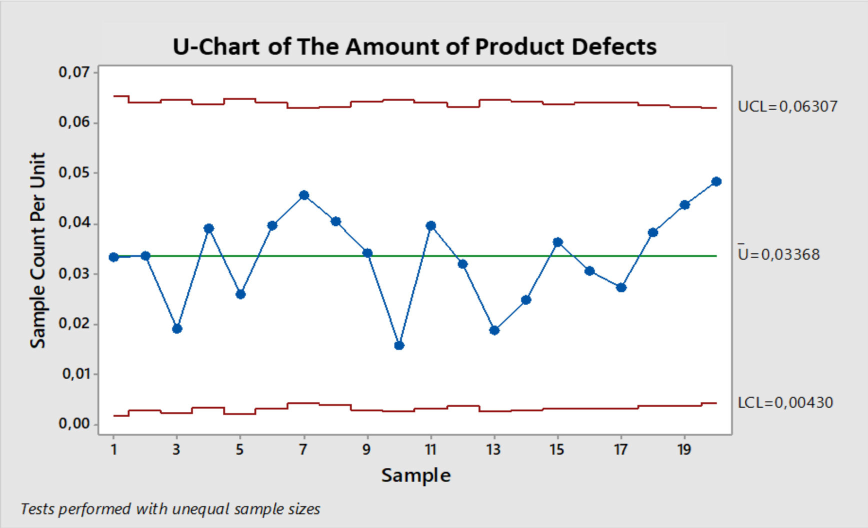


Figure 3. Data Plot of U-Control Chart

3.3. Analysis Stages

The cause or root cause problem of the polybox product is identified at the analysis stage. It used the Pareto diagram to identify the most dominant or highest defects of the polybox product [19]. To identify the cause of the problem or defect, a fishbone or Ishikawa diagram is used. FMEA is used to analyze the causes of problems that occur during the production process.

3.3.1. Pareto Chart

After identifying polybox products with CTQ, four defects were found in the polybox product production process. There are four types of defects: letter defects, chips, black spots, and imperfect connections. The Pareto diagrams help identify the most frequently occurring problems. Figure 4 shows the results of the Pareto diagram, where the most frequent defects in polybox products are chips, with a percentage of 50.2%, and imperfect connections, with a percentage of 36.7%.

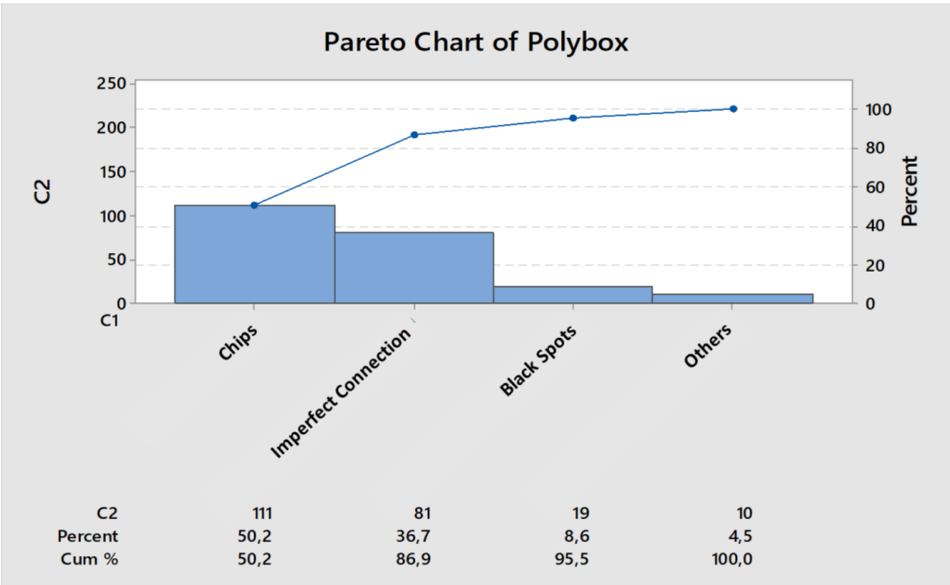


Figure 4. Pareto Diagram

According to the results shown in Figure 4, following the Pareto principle, the root causes of chip defects and imperfect connections—the major contributors to polybox defects—will be investigated using a Fishbone Diagram.

3.3.2. Fishbone Diagram

The Fishbone diagram is used to identify the causes of defects in polybox products. The diagram is based on the Pareto diagram, where the dominant defects are lumpy and imperfect connections. The following is a fishbone diagram for lumpy defects and imperfect connections.

1. Fishbone Diagram for Types of Chip Defects. In the Ishikawa diagram below (Figure 5), the cause of broken polybox products is caused by 3 factors, namely man, method, and material. The human factor is caused by workers not being careful. The method factor is caused by the arrangement of polybox products stacked too high, and the transfer of polybox products is still done manually. The material factor is because sorting raw materials from suppliers was carried out less carefully and the raw materials from suppliers were not good.

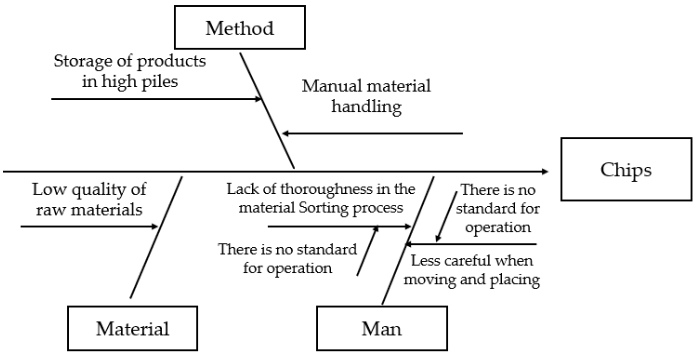


Figure 5. Fishbone diagram of chips

2. Fishbone Diagram for Types of Imperfect Connection Defects. The Fishbone diagram (Figure 6) identifies the causes of imperfect connection defects due to three factors: man, machine, and environment. The human factor is caused by the lack of a standard in the operation, so the workers are too hasty and lack thoroughness in the welding process. The machine factor is caused by the lack of maintenance, so the welding machine was not functioning properly. Environmental factors are caused by the low quality of lamps. Hence, the production floor is less bright during welding or when using the welding machine.

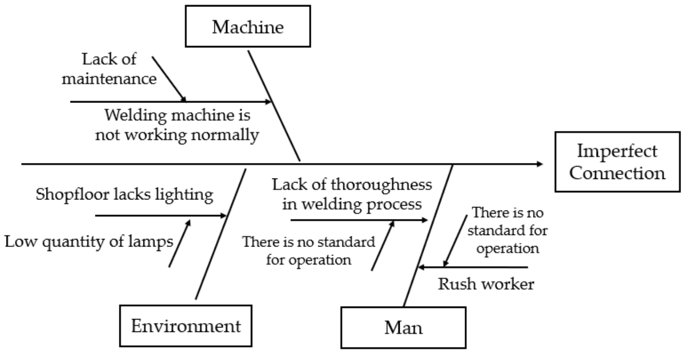


Figure 6. Fishbone diagram of imperfect connection

3. FMEA. After knowing the cause of the defect by using a fishbone diagram, the FMEA method is used for detecting potential failures and errors in the production process [30], [31]. The process of identifying and analyzing FMEA failure risks uses the results of the Risk Priority Number (RPN) assessment. The RPN value is obtained from calculating three criteria, namely Severity (S), Occurrence (O), and Detection (D). The values for S, O, and D are determined based on the results of interviews with Mr. Bahtiar Eko Atmojo, the representative of the company's stakeholders. The RPN value can be obtained by multiplying these three criteria [14], [32]. The RPN value determines the repair priority value. Table 8 summarizes the process of identifying and analyzing FMEA based on S, O, and D criteria and calculating the RPN value.

Table 8. Failure mode and effect analysis

Process	Types of Failure	Effects Arising from Failure	S	Causes of Process Failure	O	Controls that have been carried out	D	RPN
Transferring and Placing	Chips	Lowering the level of product quality so that it is not accepted by customers	7	Employees are less careful	7	Supervision of workers every week	6	294
Transferring				Transferring polybox products is still done manually	6	Not yet	5	210
Storage				The process of sorting raw materials from suppliers is less thorough; Raw materials from suppliers are not good	5	Supervise the checking of raw materials by the supervisor	3	105
				The resulting arrangement of polybox products is stacked too high	3	The preparation of production results is supervised by the supervisor	4	84
Welding	Imperfect Connection		6	Workers are less careful in doing the welding process	7	Supervise and give instructions to employees	6	252
				The welding machine is not working properly; Welding machines lack maintenance	5	Carry out maintenance on the welding machine regularly	5	150
				Workers are in a hurry	3	Carry out supervision and provide training	3	54
				The production floor lacks lighting	4	Addition of lights to the production process	3	72

Based on the FMEA table analysis (Table 8), there are three causes of failure that have a high total RPN value. In the lumpy failure type, the cause of failure is that the worker is not careful enough; it has an RPN value of 294, and the transfer of polybox products is still done manually; it has an RPN value of 210. In the failure type, the connection is not perfect (less attached and not neat), and the cause of failure is that the worker is not careful enough. in carrying out the welding process, it has an RPN value of 252.

3.4. Improvement Phase

The improvement phase [17] is the fourth stage in DMAIC, in the form of drafting improvement proposals to resolve problems identified in the analysis stage. The design of proposed improvements is carried out to minimize the causes of defects and improve product quality. This draft improvement proposal will be submitted to or given to the company so that it can be implemented from the improvement proposals that have been made. The proposed improvements are expected to reduce defects and improve the quality of polybox products. Table 9 below shows the improvement recommendations based on the previous problem analysis.

Table 9. Improvement recommendation

Problems	Causes	Improvement Recommendation
Chips	Employees are less careful	Create standard operating procedures and posters regarding handling polybox products
	Transferring polybox products is still done manually	Using material handling tools, namely a hand truck trolley
Imperfect Connection	Workers are less careful in the welding process	Create standard operating procedures and posters regarding the welding process

3.4.1.Proposed Improvements for Careless Workers

Based on the analysis carried out in the previous stage, the cause of chipped defects is due to workers not being careful when handling polybox products. In the analysis using the FMEA method, the causes of problems in workers who were not careful had an RPN result of 294. The workers in moving and placing the product were not careful, which could cause defects in the product and reduce product quality. Standard Operating Procedures (Figure 7) and posters (Figure 8) are expected to provide direction to workers so that they can be more careful and not slam products when placing them on the floor. The posters are pasted in several corners of the production floor so that workers pay more attention to placing products without slamming them.

Dai Sabisu DSI PT DAI SABISU INDONESIA	No Dokumen	: 01
STANDARD OPERATING PROCEDURE	Tahun	: 2022
JL. Citarik Raya No. 1, Kp. Kobak Bitung RT. 03 RW. 01, Desa Serta Jaya, Cikarang Timur	Bulan	: Mei
Polybox Handling	Tanggal	:

Objective	:	Provide guidelines to workers regarding handling polybox products
Tools and Materials	:	Polybox
Scope	:	Workers
Procedure	:	

1.Take the polybox product by holding both sides of the product tightly with both hands
2. Bring a maximum of 2 polyboxes of product so that the product does not fall when being moved
3. Place polybox products slowly and do not slam them in the finished goods warehouse
4. Product placement is carried out carefully so that the product remains safe in the finished goods warehouse
5. Polyboxes may only be arranged in a maximum of 10 polyboxes in the finished goods warehouse
6. The production floor must be clean and there is no rubbish or waste left over from production
7. Workers must check each polybox carefully

Made by	Known by
Nadia Nabila Priyanti	Bahtiar Eko Atmojo

Figure 7. Standard operating procedure for polybox handling

Figure 8. Poster for the implementation of polybox handling SOP

3.4.2. Proposed Improvements for Moving Polybox Products are Still Done Manually

The analysis results using the FMEA method show that the cause of chipped defects is that moving polybox products is still done manually, with an RPN of 210. In this company, polybox products are moved manually because no material handling tools can make it easier for workers to move products. Polybox safely reduces the occurrence of polybox products falling when moved to another place. This proposed improvement uses material handling tools, namely a hand truck trolley. This trolley hand truck can help workers move polybox products to make work easier, more efficient, and faster. This handtruck trolley is 1240 mm x 790 mm x 1000 mm because this size is sufficient for a production floor that is not too large. The size of the polybox itself is 640 mm x 430 mm x 260 mm. This HandTruck Trolley (Figure 9) can carry 8 polybox products. Hand Truck Trolley is used to move polybox products from the production floor to the quality control area, where prior checks are carried out on the polybox products. Furthermore, this hand truck trolley is used to move polybox products from the quality control area to the finished goods warehouse, so using a hand truck trolley can reduce defects that occur when moving the polybox products.

Figure 9. Hand Truck Trolley (Source: Prestar https://www.prestar.jp/)

3.4.2. Recommendations for Improvements for Workers who are Less Careful in Carrying Out the Welding Process

The FMEA shows that the cause of imperfect connection defects is that the workers were not careful in carrying out the welding process, with an RPN value of 252. The defects that occurred were a lack of adhesion to the impraboard and not being neat in the welding process. Proposed improvements are made to reduce imperfect connection defects in welding by creating standard operating procedures (Figure 10) and posters (Figure 11). Having standard operating procedures and posters can help connect the impraboards so that defects do not occur and improve quality.

Dai Sabisu DSI PT DAI SABISU INDONESIA		No Dokumen	: 01
STANDARD OPERATING PROCEDURE		Tahun	: 2022
JL. Citarik Raya No. 1, Kp. Kobak Bitung RT. 03 RW. 01, Desa Serta Jaya, Cikarang Timur		Bulan	: Mei
Welding Process		Tanggal	:
Objective: To provide guidance to workers regarding the welding process			
Tools and Materials	:	Cut impraboard	
	:	Welding Machine	
Scope	:	Workers	
Procedure	:		
1. Prepare impraboard that has been cut with an impraboard pond machine			
2. Turn on the red on button on the side of the welding machine			
3. If the button is lit, then set the weld time			
4. Set the weld time to 0.400s			
5. Set the hold time to 0.600s			
6. If the settings are correct, then press the test button			
7. Wait until the screen on the welding machine says ready			
8. If the welding machine is ready, then next place the impraboard you want to connect in the welding machine			
9. The impraboard you want to connect is placed right in the middle			
10. Next step on the welding machine pedal which is below			
11. Leave it for 6 seconds during the welding process			
12. If the impraboard is connected, you can release the welding machine pedal			
13. Turn off the machine when the welding process is complete			
14. Collect the impraboard that has been connected in one place			
Made by		Known by	
Nadia Nabila Priyanti		Bahtiar Eko Atmojo	

Figure 10. SOP for welding process

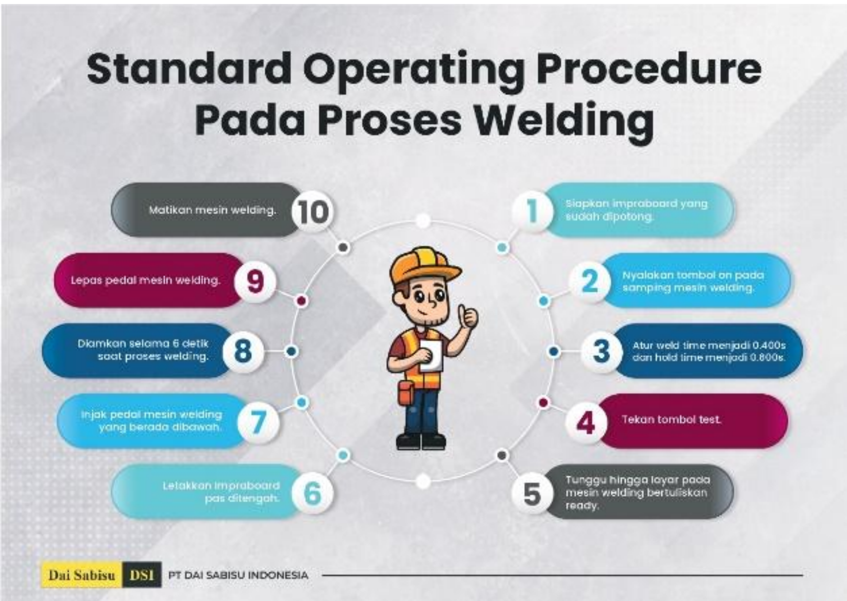


Figure 11. Poster implementation of welding process SOP

3.5. Control Stages

The proposed improvements were implemented at Plastic Manufacturing Company at this stage. Based on three proposed improvements, the company agreed to implement two proposals: the proposed improvements for careless workers and the recommendations for less careful workers in the welding process. The proposed improvements in the problem of polybox product moving activity, which was done manually, were not accepted due to budget constraints. The two proposed improvements were implemented in five days because of the time limitation from the company. Table 10 shows the implementation schedule.

Table 10. Implementation schedule of proposed improvements

Date	Activity
11th July 2022	Explained and confirmed the proposed improvements implementation activity
12th – 16 July 2022	The implementation of the proposed improvements
18th July 2022	Collecting the results data of the proposed improvements implementation
19th July 2022	Calculating and analyzing the result of proposed improvements implementation

4. DISCUSSION

After implementing the proposed improvements for five days, polybox products were observed by inspecting them. Table 11 shows the attribute defect data after implementation.

Table 11. The attribute defect data after implementation

No	Date	Amount of Production	Amount of Defective	Types of Defects (1)	(2)	(3)	(4)	Number of Product Defects
1	12/07	305	5	1	2	0	3	6
2	13/07	319	7	0	3	1	4	8
3	14/07	315	6	0	3	0	4	7
4	15/07	325	11	1	4	1	5	11
5	16/07	322	8	0	4	0	4	8
Total		1586	37	2	16	2	20	40

This study used a two-proportion test to analyze and determine the difference between the two defect proportion data before and after implementation, and whether it can reduce defects in polybox products. The test uses a 95% confidence level with a real level of 0.05. p1 is the proportion of defects before implementation, and p2 is the proportion after implementation. The following is the calculation of the test between two proportions:

1. H_0: $p_1 = p_2$
2. H_1: $p_1 > p_2$
3. Confidence Interval ($\alpha = 0.05$)
4. Critical Area : $Z > Z\alpha$, where $Z > 1.645$
5. Calculations:
   - $\hat{p}_1 = \frac{x1}{n1} = \frac{216}{6561} = 0{,}0329$
   - $\hat{p}2 = \frac{x2}{n2} = \frac{37}{1586} = 0{,}0233$
   - $\hat{p} = \frac{x1 + x2}{n1 + n2} = \frac{216+37}{6561+1586} = \frac{253}{8147} = 0.0310$
   - $\hat{q} = 1 - 0{,}0309 = 0{,}9689$
   - $Z = \frac{p1 - p2}{\sqrt{\hat{p}.\hat{q}\{(\frac{1}{n1})+(\frac{1}{n2})\}}} = \frac{0{,}0329 - 0{,}0233}{\sqrt{(0{,}0310).(0{,}9689)\{(\frac{1}{6561})+(\frac{1}{1586})\}}} = 1.97$

- The decision is to reject Ho because Z > Zα, the proportion of defects before implementation is greater than after implementation.

4.1. P Control Chart (After Implementation)

After obtaining defect data by making observations, perform calculations using the P control map to control the proportion of defects. After calculating CL, UCL, and LCL with a p control map, then plotting the data in Figure 12.

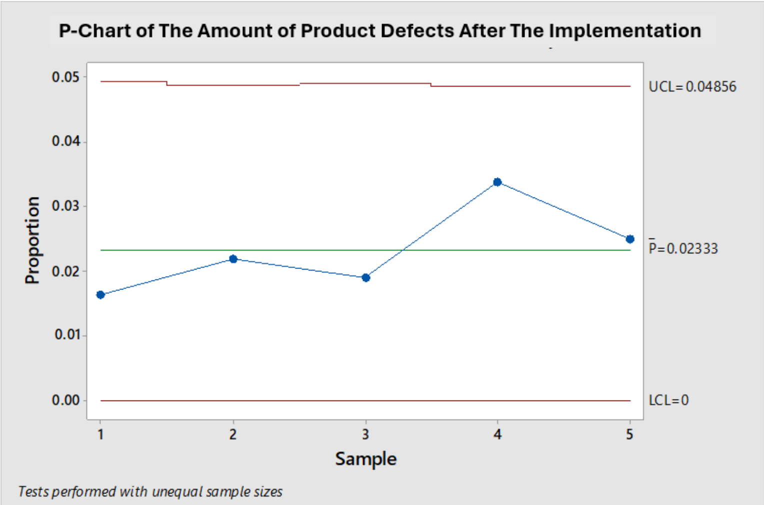


Figure 12. Data Plot of P-Control Chart After the Implementation

Judging from the data, plotting the defective product data is still within the control limits, and nothing crosses the control limits, so the production process is still stable.

4.2. U Control Chart (After the Implementation)

Furthermore, the calculation of the U control map after implementation is used to determine whether the defect data is still within the control limits or outside the control limits, as shown in Figure 13.

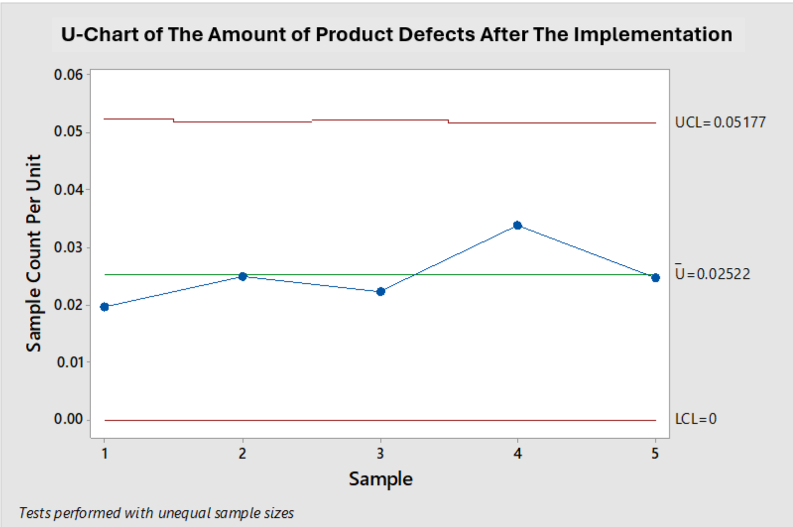


Figure 13. Data plot of P-control chart after the implementation

Based on the results of the data plotting, it can be seen that all data is still within the control limits and there is no out-of-control data. There is no out-of-control data, so the production process is still within the control limits and is stable.

4.3. DPMO and Sigma Value After Implementation

The next calculation is DPMO and Sigma Value after Implementation. After doing the calculation, the DPMO results after implementation will be compared with the DPMO results before implementation. The following is the calculation of DPMO:

1. Defect Per Units (DPU)
$$DPU = \frac{40}{1586} = 0{,}0252$$
2. Defect Per Opportunities (DPO)
$$DPO = \frac{40}{1586\ x\ 4} = 0{,}0063$$
3. Defect Per Million Opportunities
$$DPMO = 0{,}0063\ x\ 1.000.000 = 6305$$
4. Level of Sigma
$$Level\ of\ Sigma = \left(NORMSINV \left(\frac{1.000.000 - 6305}{1.000.000} \right) \right) + 1{,}5 = 3{,}99$$

After the implementation of the proposed improvements, calculate the sigma level to get the results of the sigma level after implementation. Table 12 compares the results of the sigma level before and after implementation.

Table 12. Level of Sigma Comparison Before and After The Implementation

DPMO	Before	After
Data Attribute	3.89	3.99

5. CONCLUSION

This study aimed to enhance the quality of polybox plastic containers at Plastic Manufacturing Company, addressing an average defect rate of 2.84% based on production data from November 2021 to February 2022. Analysis revealed dominant defects, including chipping and imperfect connections (e.g., misalignment and poor adhesion), with a baseline DPMO of 8,420 and a sigma level of 3.89, primarily caused by operator carelessness, manual product transfer, imprecise welding, and the absence of standardized operating procedures (SOPs) and material handling tools. Targeted interventions were implemented, including the development of SOPs, instructional posters for proper handling and welding, and the introduction of hand truck trolleys to improve material transport. These measures significantly improved process performance, reducing the DPMO to 6,305 and increasing the sigma level to 3.99, demonstrating the effectiveness of Six Sigma methodology in driving structured quality improvements and enhancing product quality.

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