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Proposed Improvements To Improve Helmet Quality Using Six Sigma And FMEA Approaches

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Abstract— This study was conducted to identify defects that occur in the helmet production process at PT Sidoarjo Helmet. The research method used is Six Sigma with DMAIC (Define, Measure, Analyze, Improve, Control) approach combined with FMEA (Failure Mode and Effect Analysis) analysis. This research was conducted during the period January-December 2024 with a total inspection of 44,249 units and a total defect of 4,670 units. The purpose of this study is to identify the types of defects that occur most frequently, calculate DPMO values and sigma levels to determine the capability of the production process, and provide improvement proposals based on the priority of the failures found. Based on the calculation results, the DPMO value of 433,860 is obtained, which shows that the defect rate is still relatively high, with a sigma level of only 1.67. The results of the FMEA analysis show that bubbly paint has the highest RPN (Risk Priority Number) value, making it the main focus of improvement efforts. Suggested corrective actions include improving operator training, strengthening work procedures, and controlling the quality of raw materials and production processes. At the control stage, the company is advised to implement regular quality control using control maps and internal audit systems. This research is expected not only to reduce the product defect rate, but also to improve the process efficiency and competitiveness of the company in the national helmet market.

Keywords— Six Sigma, FMEA, Defect, Helmet, Quality

I. INTRODUCTION

The helmet manufacturing industry has an important role in supporting rider safety, especially in Indonesia, which is one of the countries with the largest number of motorcycle users in the world. Quoting data from the National Police's Traffic Corps [1], the total vehicle population in Indonesia reached 164,117,244 units and motorcycle users were 137,350,299 units. With the number of motorcycle users reaching more than 137 million units or around 83.6% of the total vehicles in Indonesia, the need for helmets as head protection equipment is increasing..

PT Sidoarjo Helmet, a bogo helmet manufacturer located in Sungon, Sidoarjo, East Java, is facing serious problems related to product quality. The high defect rate led to customer dissatisfaction, as evidenced by low ratings and complaints on e-commerce sites such as Shopee and TikTok, particularly regarding materials and comfort aspects. This issue impacts brand reputation, decreases customer loyalty, and risks reducing long-term sales.

Based on these problems, this study aims to assess and identify the main causes of high defect rates in the helmet production process at PT Sidoarjo Helmet using the Six Sigma approach with the DMAIC method and FMEA (Failure Mode and Effect Analysis) tools. Through this approach, the research aims to reduce the defect rate, increase the company's sigma level, and produce concrete improvement recommendations in the production process. This research also aims to improve the overall quality of the product to meet the expectations and needs of consumers, as well as improve the company's image on e-commerce platforms through increased customer satisfaction.

II. RELATED WORKS

A. Manufacturing

Manufacturing comes from the Latin manusfactus, which means "made by hand", and is generally defined as the process of turning raw materials into products. This process includes design, material selection, and production stages [2]. In a modern context, manufacturing involves various processes, machines, and operations organized to produce products [3]. According to [4], manufacturing includes design, planning, production, quality assurance, management, and marketing, and plays an important role in sustainable development because it provides goods for people's needs.

B. Process Production

According to [5] production comes from the word production which means making or producing goods from various materials, while management includes the functions of planning, organizing, directing, recruiting, and supervising. So, production management focuses on managing production activities so that the product is as planned. [6] states that the production process is an activity of combining various production factors to create useful goods or services. The main goal is to produce products and add value by utilizing labor, machinery, raw materials, and funds. Types of production processes are classified by form (chemical, shape change, assembly, etc.), flow (continuous or discontinuous), and process priority [7].

C. Product Defect

According to [8], defective products are goods or services that have deficiencies so that the quality is not perfect. [9] states that defective products do not meet the specifications and quality standards that have been set. Defective products have an impact on increasing quality costs, decreasing the company's image, and decreasing customer satisfaction, because inspection and rework are required. Prevention can be done by improving the inspection of raw materials and safeguarding the production process from the beginning. Unorganized machines can hinder workflow, force manual systems, and increase the risk of defects. Defective products greatly affect the quality and profit of the company, as they cannot be sold at standard prices. Therefore, it requires proper understanding and accounting treatment, as well as serious attention so as not to disrupt the smooth and efficient production [10].

D. Six Sigma

Six Sigma is a quality improvement method that is an innovation in quality management [11]. Sigma, a symbol of standard deviation, measures the variation of a process. The higher the sigma value, the lower the tolerance for defects, so process capability increases and product quality improves [12]. Six Sigma emphasizes the close relationship between product defects, reliability, cost, cycle time, inventory, and production schedules. This method focuses on customers by using the DMAIC (Define, Measure, Analyze, Improve, Control) statistical approach to achieve operational excellence [13].

E. Failure Mode and Effects Analysis (FMEA)

Failure Mode and Effects Analysis (FMEA) is a structured method used to identify, analyze, and prevent various potential failure modes in a product or process. Failure modes include design defects, out-of-specification conditions, or changes that interfere with product function. Through FMEA, potential failures are evaluated and prioritized using the Risk Priority Number (RPN), which is the product of Severity, Occurrence, and Detection [14].

III. METHOD

This research uses interviews and observation methods to collect data. The data obtained was then analyzed using the Six Sigma approach (DMAI stage) to measure the defect rate and determine the activities that have the highest risk. The main causes of defects were identified using the Failure Mode and Effects Analysis (FMEA) method. Based on the results of the analysis, improvement proposals were made to increase the efficiency of the production process and reduce the number of defective products. This method was chosen so that problems in the helmet production process can be analyzed thoroughly, both from a quantitative and qualitative perspective.

Tabel 1.The Historical Company Data January - December 2024

Month	Total Product Inspection (Unit)	Total Product Defect (Unit)
January	2383	440
February	3531	491
March	3661	354
April	3710	500
May	3794	344
June	4015	325
July	3870	360
August	3950	342
September	3805	390
October	3925	371
November	3760	398
Desember	3845	355
∑ Total	44249	4670
		10,6%

IV. RESULT AND DISCUSSION

A. Research Data Collection

One of the products produced by PT Sidoarjo Helmet is bogo helmet. The data that will be used in this study is data for 12 months from table 1, and it is known that there are 4 kinds of product defects, the first is bubbly paint, size not according to specifications, loose rubber list and protective foam.

B. Define Phase

The data processing steps taken are based on the DMAIC cycle (Define, Measure, Analyze, Improve, Control). The DMAIC stage is a process for continuous improvement towards Six Sigma targets. but in this study did not carry out the control stage of the research only until the improve stage [15].

Define is the phase where the problem is defined, customer requirements are determined and the team is formed. Not many statistics are used in this phase. The statistical tool commonly used in this phase is the Pareto diagram [16].

Tabel 2.Defect Data from January to December 2024

Month	Defect Product				Number of Defect Products
	Painting (Bubbly Paint)	molding (Size not according to specifications)	Accessories (List of loose rubber)	Protective foam	
January	144	120	98	78	440
February	203	86	135	67	491
March	182	73	52	47	354
April	179	130	98	93	500
May	137	95	68	44	344
June	151	67	54	53	325
July	130	92	80	58	360
August	128	84	76	54	342
September	145	101	88	56	390
October	138	94	86	53	371
November	152	102	85	59	398
December	133	88	80	54	355
∑ Total	1822	1132	1000	716	4670

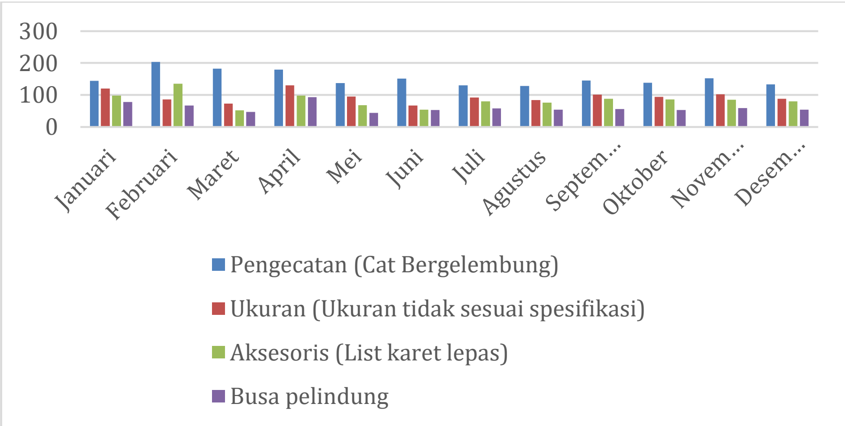

Figure 1. Histogram of the number of defect types of bogo helmets

From the histogram 1 above, it can be seen that the number of defects that occurred in January - December 2024 has increased and sometimes decreased or can be called fluctuating.

C. Measure Phase

The Measure stage reflects the current state of the current system through data that has been collected through observations and determining the goals to be achieved. This is very important because it is a reference for the project [8].

Table 3.Defect data from the largest month

Month	Defect (unit)	Defect Percentage (%)	Cumulative Percentage (%)
April	500	10,71%	10,71%
February	491	10,51%	21,22%
January	440	9,42%	30,64%
November	398	8,52%	39,16%
September	390	8,35%	47,52%
October	371	7,94%	55,46%
July	360	7,71%	63,17%
December	355	7,60%	70,77%
March	354	7,58%	78,35%

May	344	7,37%	85,72%
August	342	7,32%	93,04%
June	325	6,96%	100,00%
∑ Total	4670		

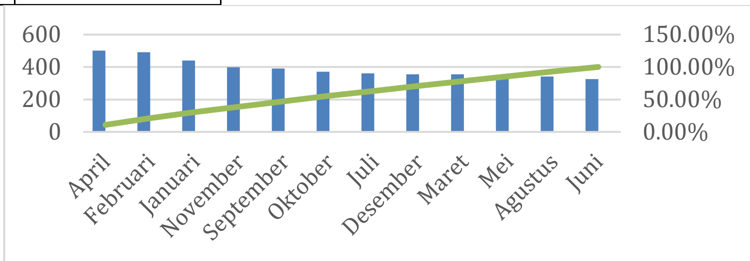

Figure 2. Pareto diagram of January - December 2024 defects

Based on table 3, it can be seen that the highest defect in this study was in April 2024, namely 500 units with a defect percentage of 10.71%.

1) Proportion Chontrol chart

A control map is a graph with maximum and minimum limits which are the boundaries of the control area [17]. According to [18] A control diagram is a graph that shows whether the performance of a process can maintain an acceptable level of quality and aims to monitor process shifts..

- Proportion chart of bubbly paint defects in 2024

Table 4. The result of the proportion of bubbly paint defects during 2024

Month	Inspection/Unit	Bubbly paint	p	CL	UCL	LCL
January	2383	144	0,060	0,041	0,053	0,029
February	3531	203	0,057	0,041	0,051	0,031
March	3661	182	0,050	0,041	0,051	0,031
April	3710	179	0,048	0,041	0,051	0,031
May	3794	137	0,036	0,041	0,051	0,031
June	4015	151	0,038	0,041	0,051	0,032
July	3870	130	0,034	0,041	0,051	0,032
August	3950	128	0,032	0,041	0,051	0,032
September	3805	145	0,038	0,041	0,051	0,032
October	3925	138	0,035	0,041	0,051	0,032
November	3760	152	0,040	0,041	0,051	0,031
December	3845	133	0,035	0,041	0,051	0,032
Total	44249	1822	0,504			

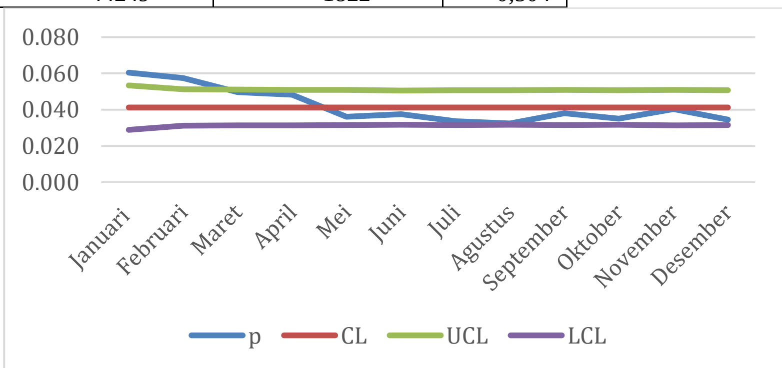

Figure 3. Graph of the results of calculating the proportion of bubbly paint defects

From the results of Figure 3, there are two points that come out of the lower control limit, namely in January and February. This shows that the control of bubbly paint defects is still experiencing problems.

- Proportion chart of Size not according to specifications defects in 2024

Table 5. The result of the proportion of Size not according to specifications defects during 2024

Month	Inspection/Unit	Size not according to specifications	p	CL	UCL	LCL
January	2383	120	0,050	0,026	0,035	0,016
February	3531	86	0,024	0,026	0,034	0,018
March	3661	73	0,020	0,026	0,033	0,018
April	3710	130	0,035	0,026	0,033	0,018
May	3794	95	0,025	0,026	0,033	0,018
June	4015	67	0,017	0,026	0,033	0,018
July	3870	92	0,024	0,026	0,033	0,018
August	3950	84	0,021	0,026	0,033	0,018
September	3805	101	0,027	0,026	0,033	0,018
October	3925	94	0,024	0,026	0,033	0,018
November	3760	102	0,027	0,026	0,033	0,018
December	3845	88	0,023	0,026	0,033	0,018
Total	44249	1132	0,317			

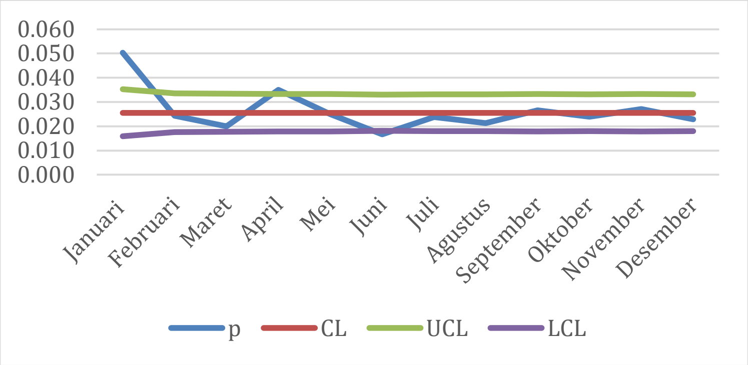

Figure 4. Graph of the results of calculating the proportion of Size not according to specifications defects

From the results of the figure 4 above, there are three points that come out of the lower control limit, namely in January, April and June. This shows that controlling size defects not according to specifications is still a problem.

- Proportion chart of List of loose rubber defect in 2024

Table 6. The result of the proportion of List of loose rubber defects during 2024

Month	Inspection/Unit	List of loose rubber	p	CL	UCL	LCL
January	2383	98	0,041	0,023	0,032	0,013
February	3531	135	0,038	0,023	0,030	0,015
March	3661	52	0,014	0,023	0,030	0,015
April	3710	98	0,026	0,023	0,030	0,015
May	3794	68	0,018	0,023	0,030	0,015
June	4015	54	0,013	0,023	0,030	0,016
July	3870	80	0,021	0,023	0,030	0,015
August	3950	76	0,019	0,023	0,030	0,016
September	3805	88	0,023	0,023	0,030	0,015
October	3925	86	0,022	0,023	0,030	0,015
November	3760	85	0,023	0,023	0,030	0,015
December	3845	80	0,021	0,023	0,030	0,015
Total	44249	1000	0,280			

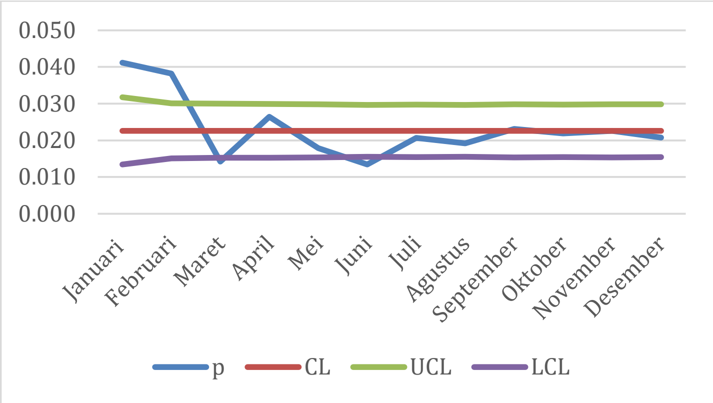

Figure 5. Graph of the results of calculating the proportion of List of loose rubber defects

From the results of Figure 5 above, there are three points that come out of the lower control limit, namely in January, March and June. This shows that the control of the loose rubber defect list is still experiencing problems.

- Proportion chart of Protective Foam Defects in 2024

Table 7. The result of the proportion of Protective Foam defects during 2024

Month	Inspection/Unit	Protective Foam	p	CL	UCL	LCL
January	2383	78	0,033	0,015	0,022	0,008
February	3531	67	0,019	0,015	0,021	0,009
March	3661	47	0,013	0,015	0,021	0,009
April	3710	93	0,025	0,015	0,021	0,009
May	3794	44	0,012	0,015	0,021	0,009
June	4015	53	0,013	0,015	0,021	0,009
July	3870	58	0,015	0,015	0,021	0,009
August	3950	54	0,014	0,015	0,021	0,009
September	3805	56	0,015	0,015	0,021	0,009
October	3925	53	0,014	0,015	0,021	0,009
November	3760	59	0,016	0,015	0,021	0,009
December	3845	54	0,014	0,015	0,021	0,009
Total	44249	716	0,201			

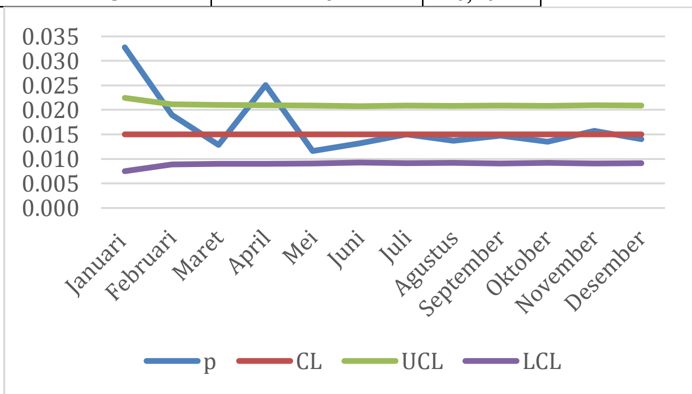

Figure 6. Graph of the results of calculating the proportion of Protective Foam defects

From the results of Figure 6 above, there are two points that come out of the lower control limit, namely in January and April. This shows that the control of protective foam defects is still experiencing problems.

2) Calculating DPMO Value and Sigma Value

Defect per Million Opportunities (DPMO) is to measure the performance of the company at this time, the calculation of DPMO and sigma value is done based on the determination of CTQ. The expected Quality Target in the application of Six Sigma methodology is to improve process capability by achieving 3.4 DPMO in the production process. DPMO stands for Defects Per Million Opportunities, which is defects per one million opportunities. So what is meant by 3.4 DPMO is 3.4 defects in 1 (one) million opportunities [19].

Table 8. DPMO and Sigma Level January – Desember 2024

Month	Inspection/Unit	Defect Product (Unit)	CTQ	DPO	DPMO	Sigma Level
January	2383	440	4	0,738564834	738.565	0,8611
February	3531	491	4	0,556216369	556.216	1,3586
March	3661	354	4	0,386779568	386.780	1,7877
April	3710	500	4	0,539083558	539.084	1,4019
May	3794	344	4	0,362677912	362.678	1,8513
June	4015	325	4	0,323785803	323.786	1,9571
July	3870	360	4	0,372093023	372.093	1,8263
August	3950	342	4	0,346329114	346.329	1,8953
September	3805	390	4	0,409986859	409.987	1,7276
October	3925	371	4	0,378089172	378.089	1,8105
November	3760	398	4	0,423404255	423.404	1,6932
December	3845	355	4	0,369310793	369.311	1,8337
∑ Total	44249	4670		5,206321263	5.206.321	20,0043

From table 8 above, it can be seen that the average value of DPMO and the average value of sigma for January - December 2024 are as follows:

$$\text{DPMO average value} = \frac{\text{number of DPMO months January-December2024}}{12} \quad (1)$$

$$= \frac{5{,}206{,}321}{12} = 433{,}860$$

Sigma average value

$$= \frac{\text{number of sigma months January-December 2024}}{12} \quad (2)$$

$$= \frac{20{,}00425}{12} = 1{,}6670$$

D. Analyze Phase

The analysis phase is the phase where the cause or causes of the problem are sought and determined. Analysis is the stage where the root cause of the problem is identified or root cause analysis is performed based on data analysis. A cause and effect diagram is used as the analysis phase, this is used to connect the data from the brainstorming with the root cause of the problem. This diagram is often called a fishbone diagram because it resembles a fishbone diagram [20].

- Fishbone diagram of bubbly paint defect

Figure 7. Fishbone diagram of bubbly paint defect

1) Human factors such as lack of operator skills, paint mixing errors, and inattention to environmental conditions can cause paint bubbling. These errors include applying the paint too thickly, improper mix ratios, and working environments that are not clean or suitable for temperature and humidity.
2) Machine factors such as broken spray nozzles, unstable air pressure, and poor ventilation can cause paint bubbles. These problems interfere with spraying and drying, so the paint does not adhere evenly and forms bubbles.
3) Environmental factors such as high humidity, dust, and unstable temperatures can interfere with the paint drying process, leading to the formation of bubbles.
4) Incorrect painting methods, such as too thick a layer of paint, improper drying time, or coating before the paint is dry, can cause bubbles on the surface.
5) Poor quality materials, such as paint that is too thick or thin, inappropriate thinner, and excessive water or oil content, can disrupt adhesion and trigger bubbles on the helmet surface.

- Fishbone diagram of Size not according to specifications defect

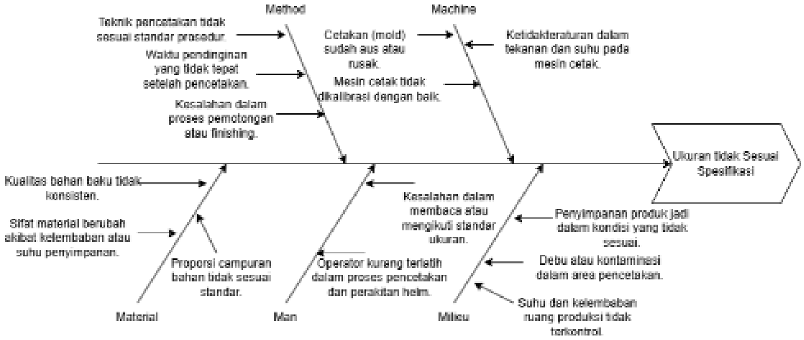

Figure 8. Fishbone diagram of Size not according to specifications defect

1) Lack of training and operator accuracy can lead to errors in molding and assembly, such as helmet sizes that are not up to standard and escape quality checks.
2) Damaged molds or uncalibrated molding machines can lead to imprecise helmet sizes. Unstable pressure and temperature can also trigger shrinkage or deformation.
3) Uncontrolled temperature, humidity and contamination can affect mold precision and cause changes in helmet size or shape, both during production and storage.

4) Inappropriate molding techniques, improper cooling, and cutting or finishing errors can lead to imprecise helmet sizes. Poor storage can also trigger deformation.
5) Inconsistent raw materials or stored in improper environmental conditions can affect the molding results. Incorrect material mixtures can also cause shrinkage or changes in helmet size.

- Fishbone diagram of List of loose rubber defect

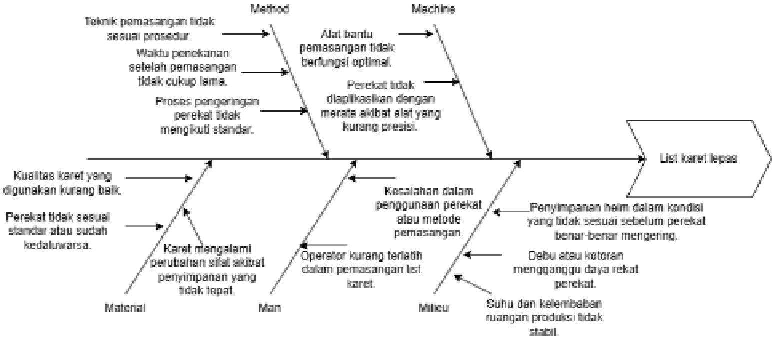

Figure 9. Fishbone diagram of List of loose rubber defect

1) Lack of operator skill can lead to poor or uneven installation of the rubber list, which can easily come loose. Low accuracy during inspection also risks allowing defects to pass to the next stage.
2) Less than optimal tools or a heating/pressing machine that is not functioning properly can cause the adhesive to not dry completely and the adhesion to decrease. Less precise tools can also make the adhesive uneven, so that the rubber list does not stick well.
3) Uncontrolled temperature, humidity and dust can interfere with drying and adhesion. Improper storage before the adhesive is dry can also cause the rubber list to come off.
4) Uneven pressure, improper tools, or insufficient pressing time can make the adhesive not stick perfectly. Improper curing also reduces adhesion.
5) List stiff or low-quality rubber and unsuitable or expired adhesives can reduce adhesion. Storage in extreme conditions can also reduce the elasticity of the rubber.

- . Fishbone diagram of Protective Foam Defects

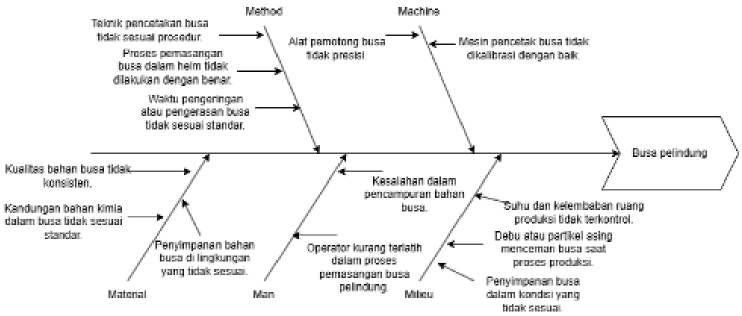

Figure 10. Fishbone diagram of Protective Foam defect

1) Unskilled operators or mixing the wrong ingredients can make the foam not set properly or have inappropriate hardness. Lack of accuracy during inspection can also cause defective foam to pass production.

2) An uncalibrated molding machine and unstable temperature or pressure can cause the foam to not be up to standard. Imprecise cutting tools can also make the foam size not fit the helmet design.
3) Temperature, humidity and dust contamination during production can compromise the structure and adhesion of the foam. Storage in extreme conditions can also make the foam brittle or less elastic.
4) Improper molding and errors in installation or use of glue can make the foam not stick well. Improper drying time can also cause the foam to be too soft or brittle.
5) Low-quality foam or nonconforming chemicals can make the foam stiff, less elastic or not absorb impact well. Storage in extreme conditions also affects quality before use

E. Improve Phase

The next stage in the DMAIC method is Improve, which includes a series of activities aimed at identifying, evaluating, and selecting various improvement alternatives to improve company performance [21]. The method used at this stage is FMEA. The filling of values in the FMEA table is carried out based on the results of discussions with internal company parties, especially with the head of the production department and operators, who have a deep understanding of the conditions of the problems in the field.

- FMEA analysis of bubbly paint defect

Table 9. FMEA Bubbling Paint Defect

No.	Potential Causes	Failure Effect	Value				Recommendation for Improvement
			S	O	D	RPN	
1.	Spray nozzle is not functioning optimally	Uneven / bubbly paint surface	6	6	5	180	Routine maintenance & nozzle calibration
2.	Unstable air pressure in the spray gun	Uneven paint thickness	5	5	5	150	Install a pressure regulator and perform regular checks
3.	Drying chamber is not well ventilated	Paint does not dry completely	7	5	5	175	Add ventilation & exhaust system
4.	Painting process is too thick in one application	Paint clumps and bubbles	6	6	4	144	Standardize the number of layers per application
5.	Drying time is not up to standard	Paint has not dried completely	5	5	5	125	Use automatic timer and drying SOP
6.	The sequence of paint layers is not correct	The bottom layer does not dry first	5	4	4	80	SOP for paint application sequence and operator training
7.	Poor paint quality (too thick/thin)	Uneven or non-adherent surface	7	5	6	210	QC paint before use; viscosity specifications in check list
8.	Inappropriate use of thinner	Paint is not homogeneously mixed	6	5	5	150	Solvent control and mixing training
9.	Paint contains too much water/oil	Paint is hard to stick and bubbles	6	4	5	120	Paint quality test and solvent mixture limitation
10.	Operators lack training in painting and mixing techniques	Inconsistency of painting results	6	6	5	180	Intensive training in painting and mixing

Table 9 is an FMEA analysis of the painting process, identifying causes of failure, their effects, and assessing Severity (S), Occurrence (O), and Detection (D). The RPN value is calculated to determine the priority of improvement. The highest example is a paint quality problem (too thick/thin) with an RPN of 210. Suggested corrective actions include routine calibration, SOPs, operator training, and painting environment control.

- FMEA analysis of Size not according to specifications defect

Table 10. FMEA Size Not According To Specifications Defect

No.	Potential Causes	Failure Effect	Value				Recommendation for Improvement
			S	O	D	RPN	
1.	Printing techniques are not in accordance with standard procedures	Product dimensions are not precise	7	6	5	210	Standardized print SOPs, operator training, and regular process audits
2.	Improper cooling time after molding	Product shrinks or deforms	6	6	6	216	Standardization of cooling time, automatic temperature and time control
3.	Errors in the cutting or finishing process	Inaccurate final dimensions	6	5	6	180	Use of precision measuring instruments and finishing training
4.	The mold is worn or damaged	Defective and inconsistent product results	7	5	5	175	Regular mold inspection & replacement schedule
5.	Molding machine is not well calibrated	Product dimensions vary	6	4	6	144	Routine machine calibration and print verification program
6.	Pressure and temperature irregularities in the molding machine	Shape change during printing	7	4	5	140	Automatic temperature & pressure control and alarm in case of anomalies
7.	Inconsistent raw material quality	Product defects or dimensional changes during printing	6	5	6	180	material sample test before production
8.	Material properties change due to storage humidity or temperature	Material does not match when printed	6	4	6	144	Use controlled storage space (air conditioning/dehumidifier)
9.	Material mix proportions are not up to standard	Incomplete reaction, size change	6	5	6	160	Mixing SOP and digital scales for propors control
10.	Operators are poorly trained in the molding and helmet assembly process	Inconsistent printout	6	5	6	180	Intensive training program and skills certification

Table 10 is the FMEA analysis of the product molding process, which identifies the causes of failure and calculates the RPN to determine the priority of risk handling. The problem with the highest RPN is improper cooling time (RPN 216), followed by machine pressure irregularities and poorly trained operators. Recommendations for improvement include the development of SOPs, operator training, machine calibration, temperature control, and the use of tools and automatic alarm systems.

- FMEA analysis of List of Loose Rubber defect

Table 11. FMEA List of Loose Rubber Defect

No.	Potential Causes	Failure Effect	Value				Recommendation for Improvement
			S	O	D	RPN	
1.	Installation technique is not in accordance with the procedure	Low adhesion, easy to detach list	7	6	5	252	Tightened installation SOP, direct supervision during the installation process

2.	Suppression time after installation is not long enough	The adhesive has not adhered perfectly	6	6	5	180	Standardize pressing time with automatic timer
3.	The adhesive curing process does not follow the standard	Adhesive does not dry completely	7	5	6	210	Set drying time and conditions according to adhesive specifications
4.	Installation aids are not functioning optimally	Imprecise installation	6	5	5	150	Regular calibration and maintenance of tools
5.	Adhesive is not applied evenly due to less precise tools	Adhesive does not stick evenly	6	4	6	144	Use precision applicator tools, application training
6.	The quality of the rubber used is not good	The surface cannot be fully bonded	7	5	5	175	Test raw material eligibility and conduct QC for suppliers
7.	Adhesive is not up to standard or expired	Does not stick or come off easily	8	4	5	160	Implementation of FIFO system, expiration control of adhesive materials
8.	Rubber undergoes changes in properties due to improper storage	Hard or inelastic rubber	6	5	6	180	Store rubber in controlled temperature & humidity
9.	Operators lack training in rubber list installation	Inconsistent and sloppy technique	6	6	5	180	Regular training and evaluation of operator skills
10.	Errors in adhesive use or installation method	The bond is not strong	7	6	5	210	SOP training and supervision during adhesive application

Table 11 is an FMEA analysis on the process of mounting the rubber list with adhesive, which identifies the causes of failure and calculates the RPN to determine the priority of improvement. The problem with the highest RPN is the installation technique not according to procedure (RPN 252), which causes low adhesion. Improvement recommendations include tightening SOPs, training operators, controlling temperature and humidity, and using precision tools to improve adhesion and prevent product failure.

- FMEA analysis of Protective Foam defect

Table 12. FMEA List of Protective Foam Defect

No.	Potential Causes	Failure Effect	Nilai				Recommendation for Improvement
			S	O	D	RPN	
1.	Foam molding technique not according to procedure	Foam is not dense, shape is not suitable	7	5	6	210	Standardization of foam molding SOPs and QC supervision
2.	The process of installing the foam in the helmet was not done properly	Foam comes off easily or doesn't fit well	6	6	5	180	Technical training for installation operators
3.	Foam drying/hardening time is not up to standard	Foam does not set completely	7	5	6	210	Set a standard drying duration and automatic timer device
4.	Foam cutting tool is not precise	Non-uniform foam size	5	4	6	129	Routine cutting tool calibration and periodic maintenance
5.	Foam molding machine is not well calibrated	Foam is not shaped according to the mold	6	5	6	180	Machine calibration schedule and yield control
6.	Inconsistent foam material quality	Non-uniform & unsafe foam yield	8	5	5	200	Regular raw material audits and batch tests

7.	Chemical content is not up to standard	Foam is fragile or dangerous	9	3	6	162	Verification of chemical composition from suppliers, internal lab tests
8.	Storage of foam materials in an unsuitable environment	Foam damaged before use	6	4	5	120	Verification of chemical composition from suppliers, internal lab tests
9.	Operators lack training in the foam installation process	Foam does not fit or is damaged during installation	6	5	6	180	Periodic training & visual installation SOP
10.	Errors in mixing foam materials	Foam is not dense or breaks down quickly	7	4	6	168	Documented mixing procedure, composition checklist

Table 12 summarizes the relationship between product defect types and their causes of failure based on the results of the previous analysis. Bubbling paint defects are caused by poor paint quality, such as being too thick or watery. Defects of size not according to specifications occur due to improper cooling process after molding. The loose rubber list problem came from installation techniques that did not follow the procedure. Meanwhile, defects in protective foam are caused by several factors, such as inappropriate molding techniques, non-standard drying time, and uncontrolled production room temperature.

F. Control Phase

The last stage of the six sigma stage is the control phase. After the results of the improvement are carried out, to maintain and monitor the process so that it continues to have good performance,. The process is controlled so that the same failure mode does not occur again. But in this study did not carry out control, the implementation of control was carried out by the Company and the improve stage was only limited to proposals to PT Sidoarjo Helmet.

V. CONCLUSION

Based on the analysis results, this study identified four main types of defects in the production of bogo helmets during January-December 2024, namely bubbled paint, improper size, loose rubber list, and protective foam. Of the 44,249 units of helmets inspected, 4,670 units were found to be defective, with the bubbled paint defect being the highest (39%). The average DPMO of 433,860 and sigma level of 1.6670 showed that the production process was still far from the Six Sigma standard (level 3), despite a gradual improvement trend during the year.To reduce defects and improve quality, root cause analysis using fishbone and FMEA was conducted. The causes with the highest RPN such as paint quality and molding techniques were prioritized for improvement. Proposed improvements include SOP enforcement and refreshment, operator training, routine machine maintenance, temperature control and ventilation, material storage according to standards, material quality monitoring, and work environment improvements such as additional lighting, blowers, and OHS tools.

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