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QUALITY IMPROVEMENTS IN THE PACKAGING OF MSR RICE PRODUCT USING SIX SIGMA METHOD AND FUZZY ANALYTICAL HIERARCHY PROCESS

PERBAIKAN KUALITAS PADA KEMASAN PRODUK BERAS MSR MENGGUNAKAN METODE SIX SIGMA DAN FUZZY ANALYTICAL HIERARCHY PROCESS

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ABSTRAK

Perusahaan mempunyai permasalahan dalam produksi salah satunya ialah terdapat kemasan yang cacat pada produk. Produk yang menjadi objek penelitian adalah kemasan produk beras MSR yang paling sering retur atau dikembalikan dari distributor karena tidak sesuai dengan kualitas yang ditetapkan dengan rata-rata persentase sebesar 1,08%. Tujuan penelitian ini ialah mengidentifikasi faktor penyebab cacat produk MSR dan memberikan usulan perbaikan untuk minimasi kecacatan. Perbaikan kualitas dilakukan dengan menggunakan metode six sigma dengan tahapan Define, Measure, Analyze, Improve dan Control dan Fuzzy Analytical Hierarchy Process. Nilai DPMO yang diperoleh sebesar 8211,43 dengan tingkat sigma sebesar 3,899. Pada perhitungan Failure Mode Effect Analysis didapatkan empat penyebab tertinggi yaitu packaging tidak memenuhi syarat, mesin sealer terlalu panas, penumpukan beras ketika penyimpanan dan mesin print mengalami kerusakan. Alternatif terbaik ditentukan menggunakan Fuzzy Analytical Hierarchy Process dengan kriteria biaya, material, maintenance dan storaging. Usulan perbaikan yang terpilih ialah pembuatan form untuk pemeriksaan, pembersihan mesin untuk packaging secara rutin dan membuat alarm untuk setiap 730 produk dan pembuatan rak untuk penyimpanan produk.

Kata Kunci : define measure analyze improve control, fuzzy analytical hierarchy process, failure mode effect analysis, six sigma

ABSTRACT

The company has problems in production, one of which is that there is defective packaging on the product. The product that became the object of research was Packaging of Product MSR, which was most often returned from distributors because it did not comply with the specified quality with an average percentage of 1.08%. This study aims to identify the factors that cause defects in MSR products and provide suggestions for improvements to minimize defects and improve the quality of the production process. Quality improvement is carried out using the Six Sigma method with the stages of Define, Measure, Analyze, Improve, and Control and the Fuzzy Analytical Hierarchy Process. the DPMO value obtained was 8211.43 with a sigma level of 3.899. In the Failure Mode Effect Analysis calculation, the four highest causes were found namely packaging that did not meet the requirements, the sealer machine was too hot, rice buildup during storage and the printing machine was damaged. The best alternative is determined using the Fuzzy Analytical Hierarchy Process with the criteria of cost, materials, maintenance and storage. The selected improvement proposals are the creation of a form for routine inspection, cleaning of packaging machines and creating an alarm for every 730 products, and manufacturing of shelves for product storage.

Keywords: define measure analyze improve control, fuzzy analytical hierarchy process, failure mode effect analysis, six sigma

INTRODUCTION

The research was conducted at a company engaged in production of packaging for food products such as rice. However, in the production process, quality problems sometimes occur, such as products that are defect or do not meet the quality set by the company. This has a negative impact on the company. The problem experienced by his company in producing one of its products was a defect in the product packaging. One type of product that is often returned due to damaged packaging is MSR products with the highest return value from May to August 2022, totaling 4647 products. In Table 1, it can be seen that MSR products experienced the most returns with packaging defects from May to August 2022 among 4 products.

Many studies have been carried out to reduce defects in product packaging. In research conducted (Angelica *et al.*, 2022), the quality control process for instant coffee packaging uses the Six Sigma method with proposed improvements using the Five Step Plan tool.

**Coressponding Author*

Table 1. Percentage of MSR product defects

Month	Number of Production (pcs)	Number of Defective products (pcs)	Percentage of Defects
Mei	65872	970	1,47%
Juni	75027	1149	1,53%
Juli	61350	448	0,73%
Agustus	96977	570	0,59%
Average			1,08%

In research (Sanjaya dan Susiana, 2017) applied the DMAIC Six Sigma method to repair packaging defects in mineral water products. There are three types of defects; lid, container, and volume defects. In this study, ANOVA was used to see whether there were differences between the number of defective products for the three packages. Furthermore, in this research (Mukminin dan Dahda, 2022), there were types of failure like uneven packaging print, packaging not closed tightly and brand glue peeling off.

This research uses failure mode effect analysis and fault tree analysis methods. It was found that the cause of failure with the highest RPN was an environment that was too hot and suggestions for improvement were changing the layout or adding rooms to make it less stuffy. This research uses the method Failure Mode Effect Analysis dan Fault Tree Analys*is*. Then, in research (Gamindra, 2016) applying Define, Measure, Analyze, Improve, Control (DMAIC), the percentage of defects was obtained at 0.78%. This method can also be used to reduce wasted quality costs. This research uses FMEA and FTA methods in tofu factories to improve quality (Fitriana *et.,al*,2023). This research uses Good Manufacturing Practices (GMP), FMEA, and laboratory tests on Betawi dodol production process (Fitriana *et al.*,2020). The research uses business intelligence, Fuzzy FMEA, Olap Cube in the medium scale dairy agroindustry (Fitriana *et al.*, 2012). This research uses the six sigma method, data mining, FMEA on product pacakaging. (Ramadhani *et al.*,2023). Research using six sigma method, data mining, FMEA on Yamalube bottle products to improve quality (Fitriana *et al.*, 2021).

Based on these problems, the aim of this research is to identify types of defects in product packaging, identify factors causing defects, determine the DPMO value and sigma level, and provide suggestions for improvements to minimize defects and improve production quality. This research uses several methods, such as six sigma which consists of the DMAIC, FMEA and Fuzzy Analytical Hierarchy Process.

RESEARCH AND METHODS

In this research, there are two data, namely secondary data and primary data. Primary data is data obtained directly in the field by researchers. Primary data obtained from direct observations and interviews with the company is the production process flow, types of raw materials, machines used, and types of defects in the product. Secondary data is data obtained indirectly. Secondary data is obtained from existing sources in the form of historical data on total production and rejects for the period May to August 2022, as well as actual data for October 2022. Data processing is the process of obtaining information through data that has been previously collected using certain methods. This data processing uses the DMAIC methodology which consists of Define, Measure, Analyze, Improve, Control. Figure 1 is the flowchart of Define and Measure Stages

Define Stage

The Define stage is the first step in the Six Sigma quality improvement program. At this stage, the production process is explained through determining Critical to Quality and creating a SIPOC diagram.

Measure Stage

The Measure stage is the second step in the Six Sigma quality improvement program which aims to evaluate and understand the current condition of the process. At this stage, measurements are carried out in the process that wants to be improved by collecting all data for analysis. If any data is out of control, the data will be retrieved until all data is in control. At this stage, the steps for the measurement system are creating p and u control charts, calculating DPO and DPMO, and converting the company's current sigma level. The formula for control limits used in the p-control chart is as follows (Fitriana *et al.*, 2021) :

$$\text{CL} = \bar{p} = \frac{\sum defective\ proportions}{\sum number\ of\ samples}$$

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

The formula for control chart u is as follows :

$$\text{LCL} = \bar{\text{U}} - 3\sqrt{\frac{\bar{\text{U}}}{n}}$$

$$CL = \bar{\text{U}} = \frac{total\ defective\ product}{total\ product\ inspected}$$

$$UCL = \bar{\text{U}} + 3\sqrt{\frac{\bar{\text{U}}}{n}}$$

Information:

LCL : Lower Control Limit

UCL : Upper Control Limit

CL : Center Line
n : number of samples taken

The formula required to calculate DPMO is as follows:

$$DPU = \frac{Defects}{Unit}$$

$$DPO = \frac{DPU}{CTQ}$$

$$DPMO = DPO \times 1.000.000$$

Analyze Stage

Figure 2 is the flowchart of the analyze stages. At this stage, analyze the dominant causal factors that need to be controlled. The tools used at this stage are Pareto Diagrams, Ishikawa Diagrams, and Failure Mode Effect and Analysis (FMEA). FMEA is used to determine the most potential causes by observing and analyzing problems through interviews and observations so that the most potential problems can be identified based on the highest RPN value. (Fitriana *et al.*, 2021).Calculation of the Risk Priority Number (RPN) value using the Failure Mode Effect and Analysis method using the formula:

$$RPN = S \times O \times D$$

Information:
S : Severity
O : Occurrence
D : Detection

Improve Stage

The Improve stage is a stage carried out after analyzing the causes of existing problems. Figure 3 is the flowchart of Improve Stages. This stage aims to provide solutions and implement solutions using Fuzzy Analytical Hierarchy Process tools. Fuzzy AHP is carried out to get the best alternative suggestions. The stages of the Fuzzy Analytical Hierarchy Process are to compile a hierarchical structure, then proceed with compiling the membership degrees of the Triangular Fuzzy Number, compiling a pairwise comparison matrix, after that carrying out fuzzification (converting the assessment results into fuzzy numbers) and calculating the consistency ratio value. The proposed improvements aim to fix the problem by increasing process capabilities so that the products produced comply with the standards and quality set by the company.

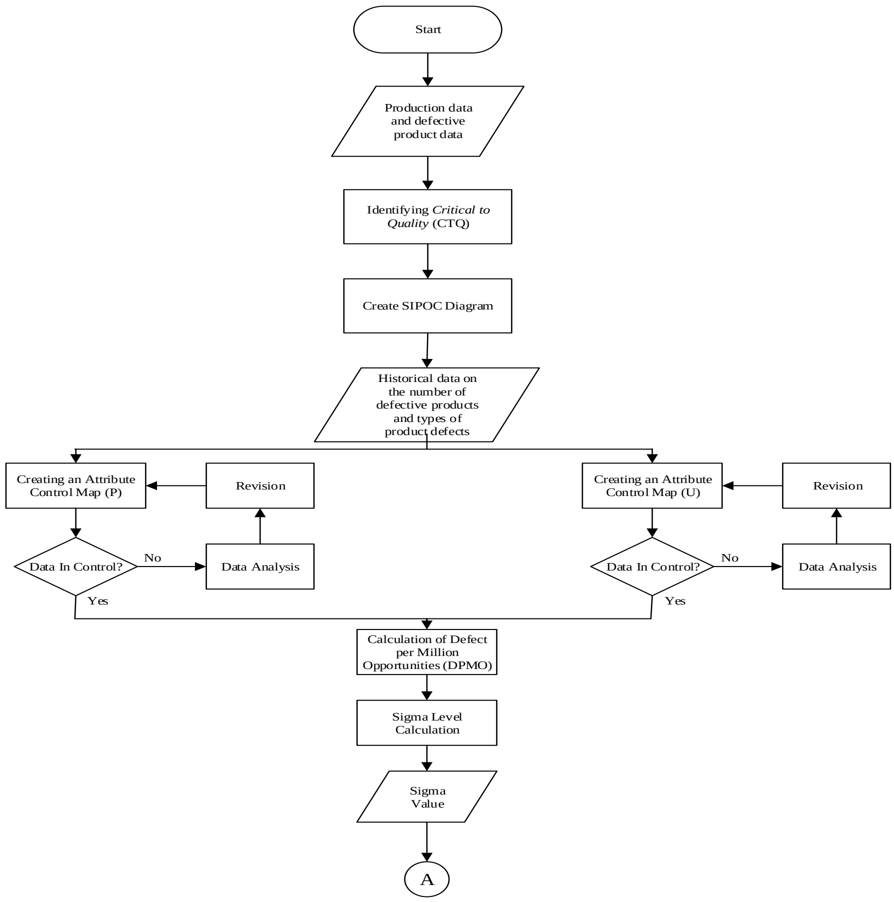


Figure 1. Flowchart of define and measure stages

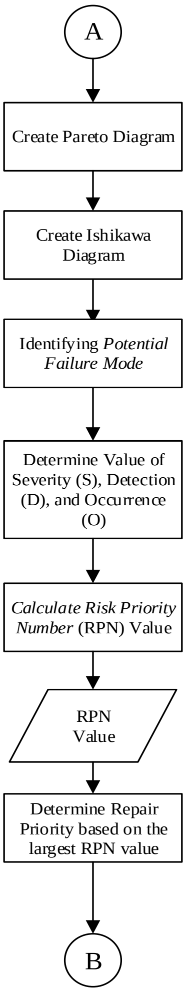


Figure 2. Flowchart of Analysis Stages

Control Stage

The control stage is the stage that carries out quality control by implementing proposed improvements to increase the sigma level and minimize the number of defective products. Figure 3 is a flowchart of control stages. At this stage, implement the proposed improvements, and after that create an attribute control map to check whether the data is in control, then through DPMO and sigma level calculations to determine changes that occur after the improvements are made.

RESULTS AND DISCUSSION

Environment, workers, procedures, and other factors are part of quality. The ability of a product to satisfy customer needs, both explicit and implicit, is referred to as product quality. High-quality products are products that meet or exceed expectations in terms of service, human resources, processes, and the environment.

Among the most frequently used packaging materials are flexible packaging materials which are often made of plastic, paper, multilayer, nylon/vacuum, and aluminum foil. The Ministry of Cooperatives and SMEs of the Republic of Indonesia lists several things that must be included on a package: product name, brand, logo, information about food additives, ingredients used (composition), net weight or net contents, information about expiry date, name, and address, information about nutritional content, information about food production codes, food registration numbers, halal claims, and barcodes.

A statistical concept called Six Sigma evaluates a process in terms of hazards or errors. The more defects a process has, the lower the quality standards it can achieve. The six sigma concept is to develop processes that are as close to the ideal as possible.

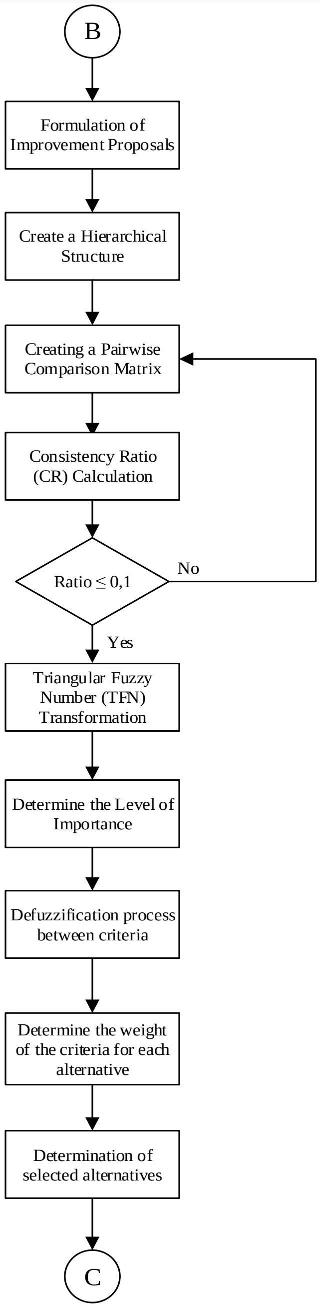


Figure 3. Flowchart of Improve Stages

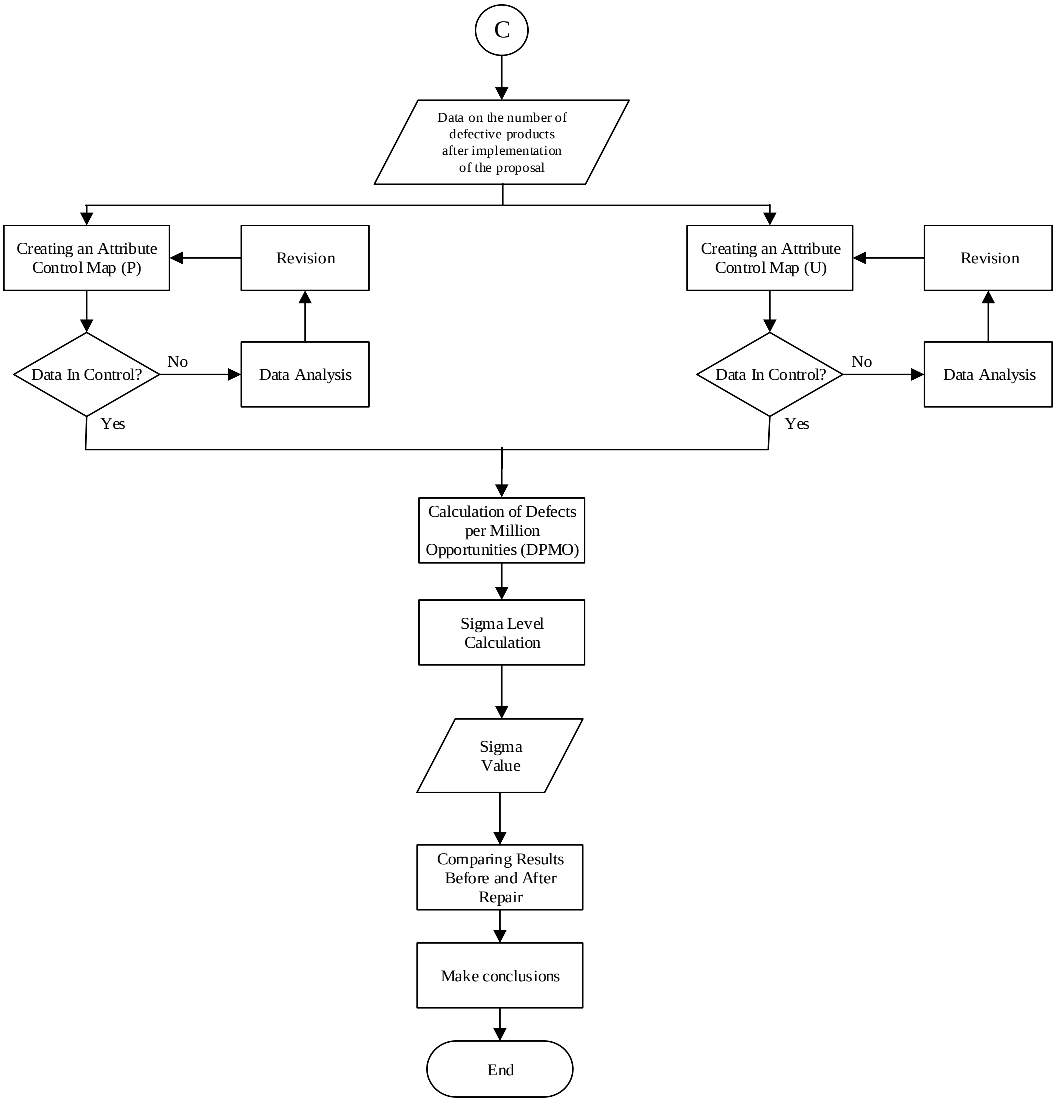


Figure 4. Flowchart of control stages

In the Define Stage, customer needs and the production process are discussed. In this step, use the SIPOC diagram to explain the production process flow and critical to quality to explain the criteria for a good product. The SIPOC (Supplier, Input, Process, Output, Customer) diagram is a diagram used to display workflow at a glance. The Measure stage is a stage that collects data to measure and evaluate the performance of the specified process or problem. At this measuring stage, tools of 7 quality tools are used, calculating DMPO values, process capabilities and mapping with control charts. At this stage, analyze the dominant causal factors that need to be controlled. The tools used at this stage are Pareto Diagrams, Ishikawa Diagrams, and Failure Mode Effect and Analysis (FMEA). The Improve stage is a stage carried out after analyzing the causes of existing problems. This stage aims to provide solutions and implement solutions using Fuzzy Analytical Hierarchy Process tools. The control stage is the stage that carries out quality control by implementing proposed improvements to increase the sigma level and minimize the number of defective products.

Table 2 are the data on defective products from September 2022 for the Setra Ramos 5Kg Jasmine Rice product. For each day of production, there are different defects in the MSR 5Kg product that occur in the finished product. Defects in the MSR 5Kg Rice packaging include leaking packaging, expired defects, loose seams, and folded packaging

The SIPOC diagram is a tool that aims to understand the production process flow in detail. The SIPOC Diagram can be seen in Table 3. Suppliers are people who provide information or materials needed by the process. Input is material or Labor provided for the process. The process is the steps to change raw materials into finished products. Output is the goods produced by the process. Customers are people or systems that receive output from the process.

Table 2. Data on type and number of product defects

Date	Number of samples	Types of Defects				Number of Defects
		Packaging Leaked	**Defect Exp**	**Loose Stitching**	**Folded Packaging**	
01-Sep	300	6	3	0	3	12
02-Sep	400	8	0	2	2	12
03-Sep	350	5	3	0	0	8
04-Sep	500	10	0	4	3	17
05-Sep	240	3	4	0	2	9
06-Sep	260	6	2	0	0	8
07-Sep	400	4	0	0	4	8
08-Sep	500	14	4	0	5	23
09-Sep	300	3	0	2	3	8
12-Sep	400	4	0	3	0	7
13-Sep	440	13	3	0	0	16
14-Sep	500	12	5	0	4	21
15-Sep	520	12	3	0	2	17
16-Sep	360	12	0	0	0	12
19-Sep	300	5	0	2	0	7
20-Sep	270	0	5	0	3	8
21-Sep	320	10	3	0	3	16
22-Sep	360	3	0	6	0	9
23-Sep	380	14	2	0	2	18
26-Sep	420	8	0	3	0	11

Table 3. SIPOC diagram

Supplier	Input	Process	Output	Customer
PPIC Div	Production Needs	Request for quantity of packaging	Delivery Order Packaging	Procurement Div
Procurement Div	Delivery Order Packaging	Order the number of packaging	Rice Packaging	Packaging Supplier
Packaging Supplier	Rice Packaging	Packaging Delivery	Rice Packaging	Warehouse Div
Warehouse Div	Rice Packaging	Packaging Storage	Rice Packaging in Warehouse	Operator
Operator	Rice Packaging in Warehouse	Packaging Collection	Rice Packaging	Printing Operator
Printing Operator	Rice Packaging	Packaging Printing	Packaging with Expired Date	Packaging Operators
Packaging Operator	Packaging with Expired Date	Collection of packaging with expired date	Packaging with Expired Date	Packaging Operators
Packaging Operator	Packaging with Expired Date	Product packaging process	MSR Product 5Kg	Finished Goods Warehouse

Then analyze using the P control chart, where the P control chart is used to see whether the product defects produced are still within the required limits.

$$CL = \bar{p} = \frac{total\ defective\ product}{total\ product\ inspected} = \frac{247}{7520} = 0.0328$$

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

$$= 0.0328 + 3\sqrt{\frac{0.0328(1-0.0328)}{420}}$$

$$= 0.0589$$

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

$$= 0.0328 - 3\sqrt{\frac{0.0328(1-0.0328)}{420}}$$

$$= 0.0067$$

U control chart data plot can be seen in Figure 5. The data is in control limit.

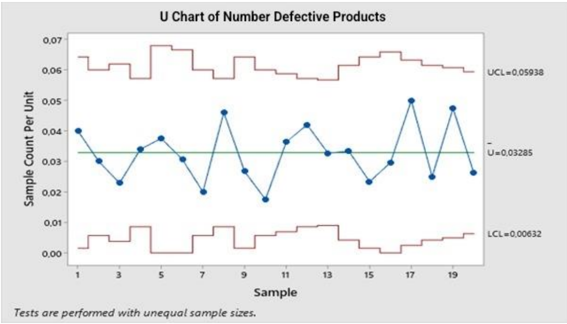


Figure 5. U control chart data plot

Defects Per Million Opportunities or DPMO is a process capability assessment to measure how good a production process is. The DPMO value calculation for the MSR 5Kg product is as follows:

Total Number of Units (U) = 7520

Total Number of Defects (D) = 247

Type of Defects = 4

DPU = $\frac{total\ number\ of\ defect}{total\ number\ of\ unit} = \frac{247}{7520} = 0.0328$

DPO = $\frac{total\ number\ of\ defect}{total\ number\ of\ unit\ x\ number\ of\ opportunities} = \frac{247}{7520\ x\ 4} = 0.008211$

DPMO = DPO x 1,000,000 = 0.008211 x 1,000,0000 = 8211.4316

Sigma Level = normsinv ((1,000,000 – DPMO) / 1,000,000) + 1.5 = 3.899

The Pareto diagram aims to determine the most dominant types of defects in the MSR 5Kg product. Pareto is known as the 80/20 principle. This principle explains that 80% of defective products are caused by 20% of problems in production that can be corrected. Pareto Diagram in Figure 6 it can be concluded that the most dominant type of defect in the packaging of the MSR 5Kg product is 61.5% and Exp defects are 15%. The causes of these defects need to be analyzed to reduce these defects.

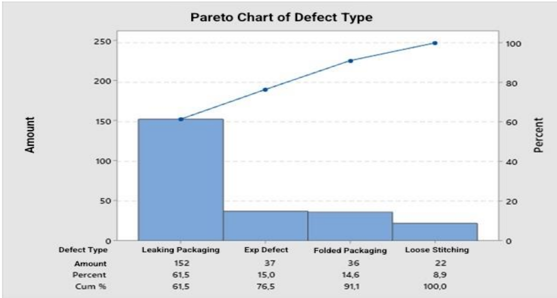


Figure 6. Pareto diagram

The Ishikawa diagram is a structured visual representation of the various causes and factors that influence each other's processes and was developed using data from the field. Figure 7 shows the Ishikawa diagram for packaging leaking defects. There are 4 factors that cause this disability. The first factor is a method, where the operator is in a hurry to open the packaging when he wants to package it so that it leaks or becomes vulnerable. Apart from that, the packaging material does not meet the requirements. Even though it was checked before it was received, some of the packaging did not meet the requirements.

Figure 8 explains the causes of exp defects which occur from 4 factors. The first factor is man, the error in setting up the exp date printing machine. Then the ink material used is almost gone, so the exp writing is unclear or unreadable. The next factor is the machine where the printing machine is damaged due to lack of care or maintenance. And the printing method is not suitable for placing the packaging.

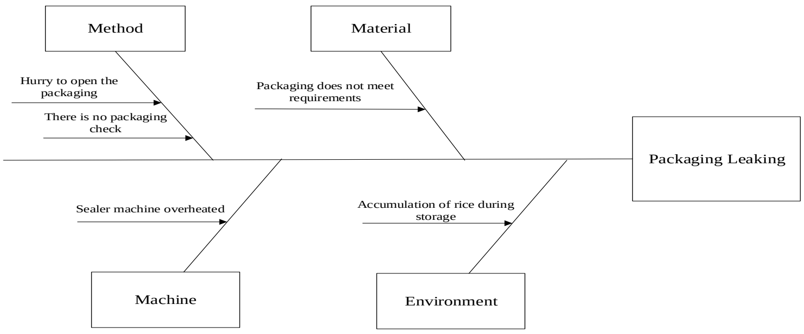


Figure 7. Ishikawa diagram packaging leaking

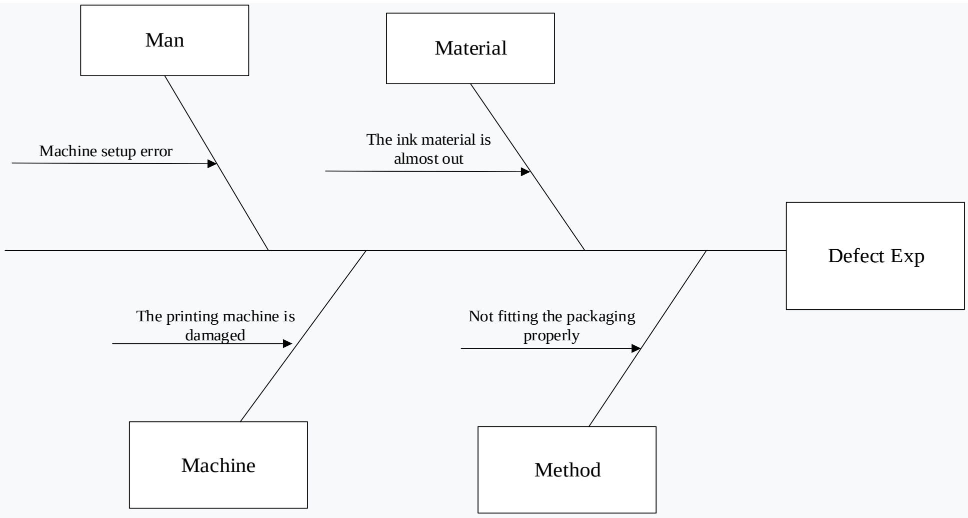


Figure 8. Ishikawa diagram of defects Exp

Table 4. Failure mode and effect analysis

Process	Types of Defects	Effect of Failure	S	Cause of Failure	O	Current Process Control	D	RPN
Packaging	Packaging Leaks	Product must be repacked	3	Hurry to open the packaging	2	Monitoring employee performance	3	18
				There is no packaging check	2	Have a quality packaging form before being accepted	3	18
				Packaging does not meet requirements	4	Have a quality packaging form before being accepted	3	36
				Sealer machine overheated	5	Checking according to SOP provisions	5	75
				Accumulation of rice during storage	6	Storage based on SOP	5	90
				Machine setup error	2	Checking according to SOP provisions	3	18
	Defect Exp	Product must be repacked	3	The ink material is almost out	3	Checking ink availability on the machine	4	36
				The printing machine is damaged	5	Checking machine condition regularly	3	45
				Not fitting the packaging properly	2	Monitoring employee performance	3	18

The next factor is the machine where the sealer machine is too hot due to being used too often. Then for environmental factors, the storage area for finished products accumulates, causing pressure on the product, causing leaks in the product.

An Ishikawa diagram is used to determine the underlying cause of a fault and a Failure Mode and Effect Analysis. FMEA table is generated to investigate the most significant sources of defects. To create the FMEA table, an interview process was carried out with the company regarding three indicators, namely severity for the severity of each consequence, occurrence for each level of potential failure, and detection for the extent to which failure can be identified. The table of FMEA can be seen in Table 4.

After getting the values for the three indicators, multiply the three values to determine the Risk Priority Number (RPN). The highest RPN value will proceed to the Fuzzy Analytical Hierarchy Process (FAHP) stage to provide suggestions for improvement. Recommended actions can be seen in Table 5.

Table 5. Recommended actions based on the cause of defects

Causes of Defects	Improvement Recommendations
Sealer machine overheated	Create an alarm when every 730 products have been packaged
The printing machine is damaged	Regular cleaning of printing machines for packaging
A place where products are stored	Making shelves for product storage
The packaging does not meet the requirements	Create a packaging quality form for checking

For the cause of the sealer machine overheating defect, it is recommended to create an alarm when the packaging reaches 730 products with the following calculation. There is a population of 20 days of data with 10 days of sampling. The following is production data for 10 days; 1200, 1600, 1400, 2000, 960, 1040, 1600, 2000, 1200, and 1600. So the calculation is as follows:

N = 20
n = 10

y1 = 1200, y2 = 1600, y3 = 1400, y4 = 2000, y5 = 960, y6 = 1040, y7 = 1600, y8 = 2000, y9 = 1200, y10 = 1600.

$$\bar{y} = \frac{\sum_1^n yi}{n} = \frac{14600}{10} = 1460$$

$$s^2 = \frac{\sum_1^n (yi - \bar{y})^2}{n-1} = \frac{1207200}{9} = 13412{,}33$$

Standard error = $\sqrt{\frac{s^2}{n}} = \sqrt{\frac{13412{,}33}{10}} = 36{,}624$

From the calculation above, the average daily production is 1460 products, so the proposed alternative is to create an alarm when packaging reaches 730 products, which is half of the daily production with a standard error of 36,624.

The first step in the improvement stage with the Fuzzy Analytical Hierarchy Process is to create a hierarchical structure for improving packaging defects. Hierarchical Structure can be seen in Figure 9. The criteria contained in the structure are costs, materials, maintenance, and storage. There are 4 alternative improvements, namely making an alarm when every 100 products have been packaged, cleaning the printing machine for packaging regularly, making shelves for product storage, and making packaging quality forms for checking.

The next stage is to compile a pairwise comparison matrix between criteria in order to obtain the criteria weights. Because it uses 2 experts, we carry out a combined matrix calculation by averaging the results from the two experts, so that the results of the calculation are as in Table 6.

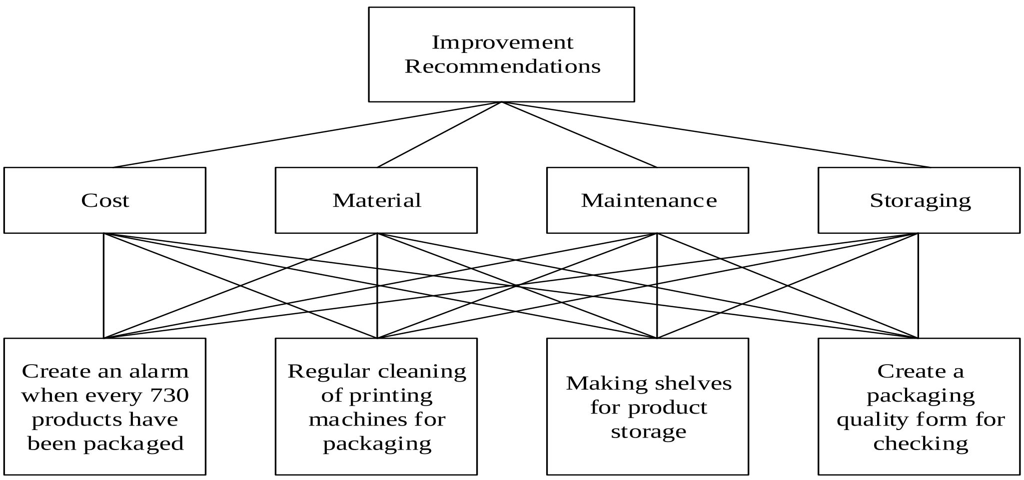


Figure 9. Hierarchical Structure

The next step is to get priority value for every performance with share every line with the amount column. Then add the line total. Then count vector priority with method share line total with amount criteria which can be seen in Table 7. The calculation of combined expert priority vectors can be seen in Table 8. Table 9 is a combined matrix comparison of expert fee criteria 1 and 2.

The pairwise comparison matrix is multiplied by the priority vector to obtain the total weights, which are then used in the consistency calculation. The eigenvalues are then calculated by dividing the total weight by the priority vector. Once these eigenvalues are added together and divided by the total number of criteria, the result is known as the max value. The consistency index (CI) value is calculated from the max value by dividing the max value by the number of criteria minus 1. The consistency ratio (CR) value is then obtained by dividing the CI value by the RI of 0.89.

$$\begin{bmatrix} 1.00 & 0.26 & 0.26 & 1.66 \\ 4.00 & 1.00 & 0.66 & 3.00 \\ 4.00 & 2.00 & 1.00 & 5.00 \\ 1.66 & 0.33 & 0.20 & 1.00 \end{bmatrix} \times \begin{bmatrix} 0.112 \\ 0.311 \\ 0.467 \\ 0.109 \end{bmatrix} = \begin{bmatrix} 0.41 \\ 1.39 \\ 2.08 \\ 0.49 \end{bmatrix}$$

$$\text{Nilai Eigen} = \begin{bmatrix} \frac{0.41}{0.112} & \frac{1.39}{0.311} & \frac{2.08}{0.467} & \frac{0.49}{0.109} \end{bmatrix} = \begin{bmatrix} 3.56 & 4.46 & 4.45 & 4.50 \end{bmatrix}$$

$$\lambda\text{maks} = \frac{3.56+4.46+4.45+4.50}{4} = 4.24$$

$$\text{CI} = \frac{\lambda\text{maks}-\text{n}}{n-1} = \frac{4.24-4}{4-1} = 0.082$$

$$\text{CR} = \frac{CI}{RI} = \frac{0.082}{0.89} = 0.092$$

Score CR which obtained as big as 0.092 It means the mark matrix comparison pair between criteria is consistent because CR is smaller than 0.1. The geometric mean significance level for each row is calculated by taking the root n of the product of the bottom, median, and top. The lower score is divided by the sum of the upper, the median value is divided by the median value, and the upper value is divided by the lower value. Then normalizing the fuzzy numbers from the average synthetic fuzzy value is called the deffuzification process. The defuzzification process for cost criteria 1 and 2 can be seen in Table 11.

Then determine the alternative priority weights based on the criteria. The first criterion that will be compared with the four alternatives is the cost criterion. Combined matrix comparison of expert material criteria 1 and 2 can be seen in table 12.

Table 6. Combined comparison matrix between expert criteria 1 and 2

Criteria	**Cost**	**Material**	**Maintenance**	**Storage**
Cost	1	0.2665	0.2665	1.6665
Material	4	1	0.6665	3
Maintenance	4	2	1	5
Storage	1.6665	0.333	0.2	1
Total	10.6665	3.5995	2.133	10.6665

Table 7. Calculation of combined priority vectors for experts 1 and 2

Criteria	**Cost**	**Material**	**Maintenance**	**Storage**	**Total Row**	**Vektor Priorities**
Cost	0.0938	0.0740	0.1249	0.1562	0.4490	0.1122
Material	0.3750	0.2778	0.3125	0.2813	1.2465	0.3116
Maintenance	0.3750	0.5556	0.4688	0.4688	1.8682	0.4671
Storage	0.1562	0.0925	0.0938	0.0938	0.4363	0.1091
Total	1	1	1	1	4	1

Table 8. Calculation of combined expert priority vectors

Criteria	**Importance Fuzzy Number**			**Norm Fuzzy Number**			**Mi**	**Defuzzification**
	l	**m**	**u**	**l**	**m**	**u**		
Cost	0.3345	0.5062	0.9268	0.0479	0.1069	0.3182	0.15768	0.124
Material	0.7337	1.3144	2.0303	0.1050	0.2777	0.6971	0.35994	0.283
Maintenance	1.5098	2.4065	3.1021	0.2161	0.5084	1.0651	0.59653	0.469
Storage	0.3345	0.5062	0.9268	0.0479	0.1069	0.3182	0.15768	0.124
Total	2.9126	4.7334	6.9861	0.4169	1	2.3986	1.27184	1

Table 9. Combined matrix comparison of expert fee criteria 1 and 2

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Alternative 1	1	3	3	5
Alternative 2	0.333	1	1.6665	3
Alternative 3	0.333	1.6	1	3
Alternative 4	0.2	0.6665	0.333	1
Total	1.866	6.2665	5.9995	12

Table 10. Calculation of combined priority vectors for experts 1 and 2

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Total Baris	Vektor Priorities
Alternative 1	0.5359	0.4787	0.5.00	0.4167	1.9314	0.4828
Alternative 2	0.1785	0.1596	0.2778	0.2500	0.8658	0.2165
Alternative 3	0.1785	0.2553	0.1667	0.2500	0.8505	0.2126
Alternative 4	0.1072	0.1064	0.0555	0.0833	0.3524	0.0881
Total	1	1	1	1	4	1

Table 11. Defuzzification process for cost criteria 1 and 2

Criteria	Importance Fuzzy Number			Norm Fuzzy Number			Mi	Defuzzification
	l	m	u	l	m	u		
Alternative 1	1.3161	2.5900	3.6371	0.1725	0.5197	1.2802	0.6574	0.486
Alternative 2	0.4472	0.5745	1	0.0586	0.1153	0.3520	0.1753	0.130
Alternative 3	0.6687	1.3128	2.2361	0.0876	0.2634	0.7870	0.3794	0.280
Alternative 4	0.4091	0.5069	0.7579	0.0536	0.1017	0.2668	0.1407	0.104
Total	2.8411	4.9841	7.6311	0.3723	1	2.6860	1.3528	1

Then determine alternative priority weights based on material criteria.

Table 12. Combined matrix comparison of expert material criteria 1 and 2

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Alternative 1	1	0.333	3	0.333
Alternative 2	3	1	5	3
Alternative 3	0.333	0.2	1	0.2665
Alternative 4	3	0.333	4	1
Total	7.333	1.866	13	4.5995

The next step furthermore is to get the priority value for every performance with share every line with the amount column. Then add the line total. Then count vector priority with method share line total with amount criteria Which There is like in Table 10.

$$\begin{bmatrix} 1.00 & 3.00 & 3.00 & 5.00 \\ 0.33 & 1.00 & 1.66 & 3.00 \\ 0.33 & 1.60 & 1.00 & 3.00 \\ 0.20 & 0.66 & 0.33 & 1.00 \end{bmatrix} \times \begin{bmatrix} 0.482 \\ 0.216 \\ 0.213 \\ 0.088 \end{bmatrix} = \begin{bmatrix} 2.11 \\ 0.89 \\ 0.88 \\ 0.39 \end{bmatrix}$$

$$\text{Eigen Score} = \begin{bmatrix} \frac{2.11}{0.482} & \frac{0.89}{0.216} & \frac{0.88}{0.213} & \frac{0.39}{0.088} \end{bmatrix} = \begin{bmatrix} 4.36 & 4.11 & 4.13 & 4.43 \end{bmatrix}$$

$$\lambda\text{maks} = \frac{4.36+4.11+4.13+4.43}{4} = 4.25$$

$$\text{CI} = \frac{\lambda\text{maks}-\text{n}}{n-1} = \frac{4.25-4}{4-1} = 0.086$$

$$\text{CR} = \frac{CI}{RI} = \frac{0.086}{0.89} = 0.097$$

CR Value which obtained as big as 0.097 It means mark matrix comparison pair between criteria consistent Because CR smaller than 0.1. Then proceed with the defuzzification process.

The next step is to obtain the priority value for each performance by dividing each row by the number of columns. Then add a total line. Then calculate the priority vector by dividing the total line by the number of existing criteria as in Table 13.

$$\begin{bmatrix}1.00 & 0.33 & 3.00 & 0.33\\3.00 & 1.00 & 5.00 & 3.00\\0.33 & 0.20 & 1.00 & 0.26\\3.00 & 0.33 & 4.00 & 1.00\end{bmatrix} \times \begin{bmatrix}0.154\\0.495\\0.071\\0.278\end{bmatrix} = \begin{bmatrix}0.62\\2.14\\0.29\\1.19\end{bmatrix}$$

Eigen Score= $\begin{bmatrix}\frac{0.62}{0.154} & \frac{2.14}{0.495} & \frac{0.29}{0.071} & \frac{1.19}{0.278}\end{bmatrix}$ = $\begin{bmatrix}4.01 & 4.31 & 4.03 & 4.27\end{bmatrix}$

λmaks = $\frac{4.01+4.31+4.03+4.27}{4}$ = 4.16

CI = $\frac{\lambda\text{maks}-\text{n}}{n-1} = \frac{4.16-4}{4-1} = 0.053$

CR = $\frac{CI}{RI} = \frac{0.053}{0.89} = 0.060$

Mark CR which obtained as big as 0.06 It means the mark matrix comparison pair between criteria is consistent Because CR is smaller than 0.1. Then proceed with the defuzzification process.

$$\begin{bmatrix}1.00 & 0.33 & 3.00 & 0.33\\3.00 & 1.00 & 5.00 & 3.00\\0.33 & 0.20 & 1.00 & 0.26\\3.00 & 0.33 & 4.00 & 1.00\end{bmatrix} \times \begin{bmatrix}0.154\\0.495\\0.071\\0.278\end{bmatrix} = \begin{bmatrix}0.62\\2.14\\0.29\\1.19\end{bmatrix}$$

Eigen Score= $\begin{bmatrix}\frac{0.62}{0.154} & \frac{2.14}{0.495} & \frac{0.29}{0.071} & \frac{1.19}{0.278}\end{bmatrix}$ = $\begin{bmatrix}4.01 & 4.31 & 4.03 & 4.27\end{bmatrix}$

λmaks = $\frac{4.01+4.31+4.03+4.27}{4}$ = 4.16

CI = $\frac{\lambda\text{maks}-\text{n}}{n-1} = \frac{4.16-4}{4-1} = 0.053$

CR = $\frac{CI}{RI} = \frac{0.053}{0.89} = 0.060$

Score CR which obtained as big as 0.06 It means the mark matrix comparison pair between criteria is consistent because CR is smaller than 0.1. Then proceed with the defuzzification process. The defuzzification process for material criteria 1 and 2 can be seen in Table 14.

The next step furthermore is to get priority value for every performance with sharing every line with the amount column. Then add the line total. Then count vector priority with method share line total with amount criteria. Then determine alternative priority weights based on maintenance criteria. A combined matrix comparison of expert maintenance criteria 1 and 2 can be seen in Table 15.

Table 13. Calculation of combined priority vectors for experts 1 and 2

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Total Row	Vektor Priorities
Alternative 1	0.1364	0.1785	0.2308	0.0724	0.6180	0.1545
Alternative 2	0.4091	0.5359	0.3846	0.6522	1.9819	0.4955
Alternative 3	0.0454	0.1072	0.0769	0.0579	0.2875	0.0719
Alternative 4	0.4091	0.1785	0.3077	0.2174	1.1127	0.2782
Total	1	1	1	1	4	1

Table 14. Defuzzification process for material criteria 1 and 2

Criteria	Importance Fuzzy Number			Norm Fuzzy Number			Mi	Defuzzification
	l	m	U	l	m	u		
Alternative 1	0.4472	0.7560	1.4953	0.0558	0.1473	0.5518	0.2517	0.176
Alternative 2	1.1472	2.5900	3.6371	0.1433	0.5047	1.3423	0.6634	0.464
Alternative 3	0.2736	0.3842	0.7579	0.0342	0.0749	0.2797	0.1296	0.091
Alternative 4	0.8417	1.4011	2.1175	0.1051	0.2730	0.7815	0.3865	0.270
Total	2.7097	5.1313	8.0080	0.3384	1	2.9553	1.4312	1

Table 15. Combined matrix comparison of expert maintenance criteria 1 and 2

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Alternative 1	1	2	3	3
Alternative 2	0.6665	1	1	4
Alternative 3	0.333	1	1	5
Alternative 4	0.333	0.2665	0.2	1
Total	2.3325	4.2665	5.2	13

$$\begin{bmatrix} 1.00 & 2.00 & 3.00 & 3.00 \\ 0.66 & 1.00 & 1.00 & 4.00 \\ 0.33 & 1.00 & 1.00 & 5.00 \\ 0.33 & 0.26 & 0.20 & 1.00 \end{bmatrix} \times \begin{bmatrix} 0.426 \\ 0.255 \\ 0.238 \\ 0.080 \end{bmatrix} = \begin{bmatrix} 1.86 \\ 1.08 \\ 1.02 \\ 0.33 \end{bmatrix}$$

Eigen Score = $\begin{bmatrix} \frac{1.86}{0.426} & \frac{1.08}{0.255} & \frac{1.02}{0.238} & \frac{0.33}{0.080} \end{bmatrix}$ = $[4.37 \quad 4.23 \quad 4.27 \quad 4.12]$

λmaks = $\frac{4.37+4.23+4.27+4.12}{4}$ = 4.251

CI = $\frac{\lambda\text{maks}-\text{n}}{n-1} = \frac{4.251-4}{4-1} = 0.083$

CR = $\frac{CI}{RI} = \frac{0.083}{0.89} = 0.094$

Score CR which obtained is 0.094 means the mark matrix comparison pair between criteria is consistent. Because CR is smaller than 0.1. Next, the defuzzification process of the maintenance criteria is carried out.

The next step is to get a priority value for every performance and share every line with the amount column. Then add the line total. Then count vector priority with method share line total with amount criteria.

$$\begin{bmatrix} 1.00 & 0.33 & 0.26 & 0.33 \\ 3.00 & 1.00 & 2.00 & 0.33 \\ 4.00 & 0.65 & 1.00 & 0.33 \\ 3.00 & 3.00 & 3.00 & 1.00 \end{bmatrix} \times \begin{bmatrix} 0.092 \\ 0.239 \\ 0.206 \\ 0.463 \end{bmatrix} = \begin{bmatrix} 0.37 \\ 1.06 \\ 0.85 \\ 2.07 \end{bmatrix}$$

Eigen Score = $\begin{bmatrix} \frac{0.37}{0.092} & \frac{1.06}{0.239} & \frac{0.85}{0.206} & \frac{2.07}{0.463} \end{bmatrix}$ = $[4.03 \quad 4.42 \quad 4.13 \quad 4.47]$

λmaks = $\frac{4.03+4.42+4.13+4.47}{4}$ = 4.265

CI = $\frac{\lambda\text{maks}-\text{n}}{n-1} = \frac{4.265-4}{4-1} = 0.088$

CR = $\frac{CI}{RI} = \frac{0.088}{0.89} = 0.099$

Mark CR Which obtained as big as 0.099 It means the mark matrix comparison pair between criteria is consistent Because CR is smaller than 0.1. Next, the defuzzification process of the maintenance criteria is carried out. The defuzzification process for maintenance criteria 1 and 2 can be seen in Table 16. A combined matrix comparison of expert storage criteria 1 and 2 can be seen in Table 17. Table 18 is a combined priority vector calculation of experts 1 and 2. Table 19 is a defuzzification Process for Maintenance Criteria 1 and 2.

Table 16. Defuzzification process for maintenance criteria 1 and 2

Criteria	**Importance Fuzzy Number**			**Norm Fuzzy Number**			**Mi**	**Defuzzification**
	l	**m**	**U**	**l**	**m**	**u**		
Alternative 1	1	1.7321	2.2361	0.1644	0.3894	0.7260	0.42663	0.368
Alternative 2	0.9381	1.2213	1.5596	0.1542	0.2746	0.5064	0.31174	0.269
Alternative 3	0.8801	1.1334	1.6266	0.1447	0.2548	0.5281	0.30922	0.266
Alternative 4	0.2616	0.3609	0.6598	0.0430	0.0811	0.2142	0.1128	0.097
Total	3.0799	4.4476	6.0821	0.5064	1	1.9748	1.16039	1

The next step is to calculate alternative weights based on storage criteria.

Table 17. Combined matrix comparison of expert storage criteria 1 and 2

Criteria	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**
Alternative 1	1	0.333	0.2665	0.333
Alternative 2	3	1	2	0.333
Alternative 3	4	0.6665	1	0.333
Alternative 4	3	3	3	1
Total	11	4.9995	6.2665	

Table 18. Combined priority vector calculation of experts 1 and 2

Criteria	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Total Row**	**Vektor Priority**
Alternative 1	0.0909	0.0666	0.0425	0.1666	0.3666	0.0917
Alternative 2	0.2727	0.2000	0.3192	0.1666	0.9585	0.2396
Alternative 3	0.3636	0.1333	0.1596	0.1666	0.8231	0.2058
Alternative 4	0.2727	0.6001	0.4787	0.5003	1.8518	0.4629
Total	1	1	1	1	4	1

Table 19. Defuzzification process for maintenance Criteria 1 and 2

Criteria	Importance Fuzzy Number			Norm Fuzzy Number			Mi	Defuzifikasi
	l	**m**	**U**	**l**	**m**	**u**		
Alternative 1	0.2991	0.4354	1.0000	0.0387	0.0910	0.3853	0.1717	0.119
Alternative 2	0.6687	1.1443	1.8286	0.0865	0.2392	0.7046	0.3434	0.239
Alternative 3	0.6274	0.9257	1.5596	0.0811	0.1935	0.6010	0.2918	0.203
Alternative 4	1.0000	2.2795	3.3437	0.1293	0.4764	1.2884	0.6314	0.439
Total	2.5952	4.7849	7.7319	0.3356	1	2.9793	1.4383	1

Table 20. Combination of criteria and alternative weights

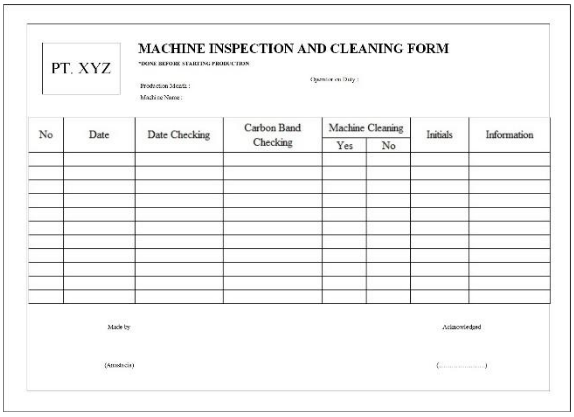
Criteria	Weight Criteria	Weight alternative				Weight Criteria x Weight Alternative			
		A1	**A2**	**A3**	**A4**	**A1**	**A2**	**A3**	**A4**
Cost	0.124	0.4860	0.1296	0.2804	0.1040	0.0603	0.0161	0.0348	0.0129
Material	0.283	0.1758	0.4635	0.0905	0.2701	0.0498	0.1312	0.0256	0.0764
Maintenance	0.469	0.3677	0.2687	0.2665	0.0972	0.1724	0.1260	0.1250	0.0456
Storage	0.124	0.1194	0.2388	0.2029	0.4390	0.0148	0.0296	0.0252	0.0544
Total Weight						0.2973	0.3029	0.2105	0.1893
Ranking						2	1	3	4

After calculating the criteria weights between alternative weights based on the criteria. Next, calculate the combination of criteria and alternative weights to get the best improvement proposal. Based on Table 20, alternative 1 is making an alarm when packaging every 730 products, alternative 2 is cleaning the printing machine for packaging regularly, alternative 3 is making shelves for product storage and alternative 4 is making a packaging quality form for checking. From the calculation above, it can be concluded that the highest weight is the first alternative with a value of 0.3029, the second alternative is 0.2973 and the third alternative is 0.2105. Using calculations using Fuzzy AHP, the proposed improvement to reduce the types of damaged packaging defects is to regularly clean the printing machine for packaging, create an alarm when every 730 products have been packaged, and create shelves for product storage.

Proposes Improvement

Based on Fuzzy-Analytical Hierarchy Process (FAHP) calculations, the alternative that has the highest weight is alternative 2, namely cleaning the printing machine for packaging regularly. Making the inspection form and cleaning the printing machine was carried out by brainstorming with the company. This form will be signed by the operator as the worker who will carry out the packaging production process.

It contains the month of production, name of the machine and operator on duty. The table contains the number, date, date checking activities, carbon band checking, and machine cleaning. Checking the carbon tape can be expected to minimize exp defects that are not clearly visible. Apart from that, checking the date before production is also important, to prevent incorrect expiration dates so that consumers are not mistaken. Then it will be signed by the operator on duty and provided with information if any. After filling in the form, the supervisor will sign the inspection and cleaning form. The machine inspection and cleaning form can be seen in Figure 10 below.


PT. XYZ

MACHINE INSPECTION AND CLEANING FORM

*DONE BEFORE STARTING PRODUCTION

Production Month :

Machine Name :

Operator on Duty :

No	Date	Date Checking	Carbon Band Checking	Machine Cleaning		Initials	Information
				Yes	No		

Made by

(Anastacia)

Acknowledged

(......................)

Figure 10. Machine inspection and cleaning form

Based on Fuzzy-Analytical Hierarchy Process (FAHP) calculations, the alternative that has the second highest weight is alternative 1, namely creating an alarm when every 730 products are packaged. This alarm is made using an infrared sensor to count the number of items that have been packed, then connected to a warning light siren which will be placed near the packaging machine to notify that the packaging has reached 730 products. Figure 11 is

Siren Warning Light. Apart from the warning light siren, this improvement uses sensors to detect each finished product. The alarm sensor will count the number of products that have been completed on the line. Numbers will appear on the sensor to indicate the number of items. For machine installation, the sensor will be placed near the packaging line and the alarm nearby. The type of tool used is an infrared goods counter sensor and the type of warning light siren used is LTD-5101J. The estimate issued is IDR 650,000 for the infrared sensor, IDR 200,000 for the warning light siren with a total cost of IDR 850,000. The item counter infrared sensor can be seen in Figure 12

Figure 11. Siren Warning Light

Figure 12. Item counter infrared sensor

PT.XYZ	STANDARD OPERATING PROCEDURE
USE OF ALARM MACHINES AND INFRARED SENSORS	
Objective	As a guide for operators in the use of alarm machines and infrared sensors
Procedure	1. Turn on the on button on the infrared sensor so that the sensor can count the number of items that have passed 2. Numbers will appear on the sensor 3. When the number reaches 730, an alarm will sound to remind the operator to rest the sealer machine 4. The sealer machine will rest for approximately 40 minutes before being used again 5. After the machine has been rested, turn on the reset button so that the sensor starts again from number 0. 6. If production for the day is finished, turn on the off button to turn off the machine.
Maintenance	The Infrared Sensor Machine must not be exposed to water, dust or falling
Related units	Infrared sensor machine and alarm
Made by :	Approved by :

Figure 13. SOP for using alarm machines

Figure 13 is a Standard Operating Procedure for using the alarm machine. This SOP is intended as a guideline for operators in the use of alarm machines and infrared sensors. The steps are to turn on the machine with the on button on the infrared sensor so that the sensor can count the number of items that have been completed, then numbers will appear on the sensor. When the number reaches 730, an alarm will sound to remind the operator to rest the sealer machine. The sealer machine will rest for approximately 40 minutes before being used again. After the machine has been rested, press the reset button so that the sensor starts again from number 0. If production is complete, turn on the off button to turn off the machine. The infrared sensor machine must not be exposed to water, dust or fall so that the machine remains well maintained. Operators in charge of the packaging section will receive training to use the machine. The SOP will be placed near the machine so that operators can see the procedures for using the alarm machine.

Figure 14 is a packaging inspection checklist table after the alarm sounds. In this table there is a column for production hours, namely the time when the product starts to be packaged, then there is a column for sounding alarm hours, namely the time at which the alarm sounds after 730 products. After the alarm sounds, check the quality of the packaging. The initial column is for the operator's signature and there is a description column if necessary.

PT.XYZ		Packaging Inspection Checklist Form					
		Production Month :					
		Operator on Duty					
No	Date	Production Hours	Alarm Sound Clock	Packaging Quality		Initials	Information
				Yes	No		
Operator				PIC Production			

Figure 14. Packaging inspection checklist table

Based on Fuzzy-Analytical Hierarchy Process (FAHP) calculations, the alternative that has the third highest weight is alternative 3, namely making shelves for product storage. This goods storage rack uses pallet media to make it easier to pick up products using material handling.

Figure 15 is the example of using a selective pallet rack. The Selective Pallet Rack in the picture has specifications with length x width x height, namely 2,500 x 1,000 x 6,000 mm. Pallet load 2,000 kg/level beam, and powder coating finishing. This pallet rack will be used in finished goods warehouses. The price per position pallet is IDR 950,000. This Pallet Rack is useful so that products do not fall on top of each other

Figure 15. Example of using a selective pallet rack

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

From the DMAIC method, it was found that the most common types of defects were leaking packaging and defects in the exp writing. The DPMO value for MSR production is 8211.4316 with a sigma level of 3.899. From the Failure Method Effect Analysis calculations, the biggest causes of defects were obtained. From FMEA, the four highest causes were taken to make suggestions for improvement, namely the sealer machine was too hot, the printing machine was damaged, the product storage area was piling up and packaging did not meet the requirements. In the Failure Mode Effect Analysis calculation, the four highest causes were obtained, then recommendations for improvement were made and the best alternative was selected using the Fuzzy Analytical Hierarchy Process with the criteria of cost, materials, maintenance and storage. The selected improvement proposals are forms for inspection, cleaning machines for packaging regularly and making alarms when every 730 products have been packaged and making shelves for product storage.

Recommendation

When controlling the number of products packaged with an alarm, the sealer machine should also be cleaned and maintained according to the machine's instructions. Then checking the quality of the company's packaging is also necessary so that the quality of the packaging is maintained before being stored in the warehouse.

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