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Quality Control Analysis Using Statistical Quality Control (SQC) And Failure Mode Effect Analysis (FMEA) In The Production Process Of Za Plus Fertilizer

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Abstract. The company PT.XYZ is an industrial logistics entity that has a main division in the field of warehousing and MBU, with a special focus on fertilizer bagging activities. The problems faced by this company are related to defects that occur in the fertilizer bagging process. This research aims to identify the most common defects, the factors that cause defects, and develop proposed corrective actions to improve the quality of fertilizer bagging. The research methodology applied involves Statistical Quality Control (SQC) and Failure Mode Effect Analysis (FMEA), using tools such as check sheets, pareto diagrams, control maps, and fishbone diagrams. The results of the research using the Statistical Quality Control (SQC) method showed that the most significant defect in the fertilizer bagging process was the tear defect, reaching a percentage of 58%, followed by the seam defect at 27%, and the underweight defect at 15%. Meanwhile, analysis with the Failure Mode Effect Analysis (FMEA) method shows that the type of tear defect has the highest Risk Priority Number (RPN) value, caused by a lack of caution when carrying out the process of putting fertilizer into pallets. As a recommendation for improvement, it is recommended to organize training on work procedures for employees to improve their understanding of the work procedures that apply at PT.XYZ. This step is expected to address the main problems identified in the study, especially related to the lack of care in the process of bagging fertilizer into pallets, so as to improve the quality of fertilizer bagging in the company.
Keywords: Quality Control, Statistical Quality Control, Failure Mode Effect Analysis

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1. Introduction

The manufacturing industry evolved from the need to improve product quality, process efficiency, and fulfill customer satisfaction. Each company is required to have its own quality standards to ensure that the products produced are acceptable to consumers. One strategy to improve quality is to reduce or suppress the number of product defects and improve the overall quality level[1]. From the results of the initial survey, the researcher found that in the production process of bagging ZA Plus fertilizer at PT.XYZ there were still defects in the bagging results, such as torn fertilizer bags. This situation has the potential to cause losses for the company, especially if the delivered fertilizer products do not match the specifications of consumer orders, which can result in product returns for further repairs. Therefore, this study aims to identify the most dominant percentage of defects and provide recommended actions to improve bagging quality[2].

The results of this study are expected to provide useful input for companies in analyzing the quality of products produced and designing production quality control policies to achieve company standards

[3]. One method that can be applied is Statistical Quality Control (SQC), which is an effective tool for maintaining product quality standards. As explained by[4], the SQC method and Failure Mode and Effect Analysis (FMEA) can help identify the root cause of defects in products and provide appropriate improvement suggestions[5]. Therefore, in accordance with the context described, this study adopts the SQC method to uncover the causes of defects in fertilizer products and uses FMEA analysis to formulate improvement recommendations on the quality control of ZA Plus fertilizer bagging."

2. Methods

Customer satisfaction is fundamentally influenced by quality factors [6]. Therefore, quality control is very important to maintain the quality of a product[7]. This research on quality control in ZA Plus fertilizer products is carried out through several main stages, namely the preliminary stage, data collection, data processing, and conclusion drawing. The preliminary stage includes field studies and literature studies to understand the existing situation, which is then put together with theories related to Statistical Quality Control (SQC) and Failure Mode and Effects Analysis (FMEA) methods. At this stage, problem formulation is also carried out. Furthermore, the data collection stage involves production data and the number of defects of ZA Plus fertilizer at PT XYZ. The data is then processed using the Statistical Quality Control method, an industrial approach to measure, monitor, and regulate the quality of products or services through statistical tools and data analysis techniques such as Check sheets, Histograms, Pareto charts, Control Charts, and Fishbone diagrams[8].

Furthermore, prioritization of improvements is done with the help of the Failure Mode and Effects Analysis (FMEA) method, a structured and systematic method for analyzing failures, identifying potential failures, and providing priorities[9]. In FMEA risk assessment, a parameter known as RPN (Risk Priority Number) is used, calculated by multiplying the severity, frequency of occurrence, and detectability of the failure [10]. The severity rating scale is presented in Table 1[11]."

Table 1 RPN severity rating scale

Ranking	Severity	Description
10	Hazardous without warning	System failures that cause very serious impacts.
9	Hazardous with warning	System failures that cause harmful effects
8	Very High	The system cannot operate
7	High	Although the system can operate, it does not reach its full capacity
6	Moderate	Operational and safe, but experiencing performance degradation affecting output.
5	Low	Progressive decline in performance
4	Very Low	Minimal impact on system performance.
3	Small	Affects system performance to a small degree
2	Very Small	Mempengaruhi kinerja sistem pada tingkat yang kecil
1	No Effect	No impact on system performance.

In the context of the analysis, the O value reflects the degree of likelihood or probability of a failure occurring. To determine this occurrence value, a rating scale from 1 to 10 is used. This occurrence rating scale can be found in Table 2 [11].

Table 2 RPN occurrence rating scale

Ranking	*Occurrence*	*Description*
10 - 9	*Very High*	*Frequent failures*
8 - 7	*High*	*Repetitive failures*
3 - 2	*Low*	*Very rare instances of failure*
1	*No impact*	*Almost no failures*

The D value indicates the probability of detecting a failure before it occurs. The detection assessment uses a scale from 1 to 10. This detection assessment can be found in Table 3, as evaluated based on McDermott 2009 found in reference [11].

Table 3 RPN detection scale

Ranking	*Detection*	*Description*
10	*Uncertain*	*Conducting inspections consistently lacks the capacity to identify potential causes or failure mechanisms and failure modes.*
9	*Very Small*	*Very limited checking opportunities in detecting potential causes, failure mechanisms, and failure modes.*
8	*Small*	*The probability of inspection to identify potential causes, failure mechanisms, and failure modes is very low.*
7	*Very Low*	*Low inspection probability in identifying potential causes and failure modes.*
6	*Low*	*Inspection opportunities to identify potential causes, failure mechanisms, and failure modes are low..*
5	*Moderate*	*Inspection capacity in identifying potential causes, failure mechanisms, and failure modes has a moderate level.*
4	*Intermediate to high*	*The probability of checking to identify potential causes, failure mechanisms, and failure modes is high.*
3	*High*	*The probability of inspection to identify potential causes, failure mechanisms, and failure modes can be considered high.*
2	*Very High*	*The probability of checking in identifying potential causes, failure mechanisms, and failure modes is very high.*
1	*Almost certain*	*Consistency in checking has the capacity to identify potential causes, failure mechanisms, and failure modes.*

3. Results and Discussion

3.1 Statistical Quality Control (SQC)

Data management was performed using five statistical tools for quality control, followed by analysis using the Statistical Quality Control (SQC) method.

3.1.1 Check Sheet

In implementing quality control using the Statistical Quality Control method, there are several steps that need to be followed. The first step involves creating and filling out a check sheet. A check sheet is a simply designed inspection form that lists elements that need to be recorded both qualitatively and quantitatively. Its function is to structure and organize the data collection process in a systematic and structured manner as data appears on the scene[12]. Details of the check sheet can be found in Table 4.

Table 4 data chect sheet

NO	WEEK	JUMLAH PRODUKSI(BEG)	TYPES OF DAMAGE			AMOUNT OF DAMAGE (BEGS)
			RIPPED	SEWING	BALANCE	
1	Week 1	354	49	29	15	93
2	Week 2	377	59	20	13	92
3	Week 3	377	50	20	10	80
4	Week 4	377	60	25	12	97
5	Week 5	375	40	19	15	74
6	Week 6	375	44	30	17	91
7	Week 7	375	55	29	14	98
8	Week 8	377	56	23	11	90
	TOTAL	2987	413	195	107	715

Based on Table 4. Check sheet above there are 3 types of defects. Torn defects as many as 413 bags, not sewn as many as 195 bags, and the size of the scales is less as many as 107 bags.

3.1.2 Histogram

Once the inspection form has been compiled, the next stage involves creating a histogram. A histogram is a useful tool in identifying variation in a process. Histograms are bar graphs that illustrate the grouping of data based on its values[13].

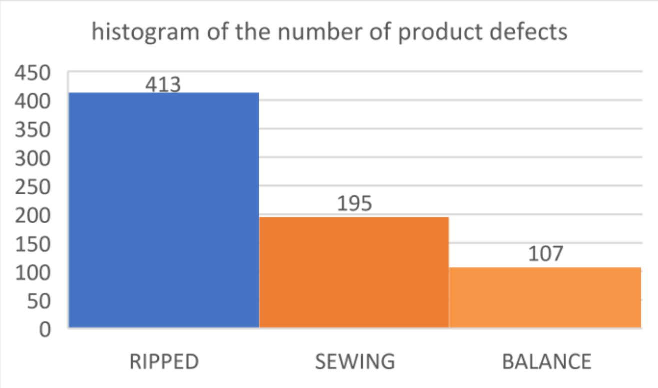

Figure 1 histogram of product defects

Based on the histogram graph in Figure 1 above, it can be concluded that the most common type of damage is torn fertilizer packaging, with the number of damaged products reaching 413 bags. The second most common type of damage is unstitching of the packaging, which caused damage to 195 bags of product. Meanwhile, the damage that ranked third in frequency was underweight, with a total damage of 107 bags.

3.1.3 Control Map

After identifying the type of defect through the use of histograms, the next action involves creating a control map to evaluate whether a particular defect crosses the control limits. A control map is a visual tool used to monitor and evaluate whether an activity or process is in quality control, on the basis of statistical analysis[14]. The steps in creating a control map are as follows[15]:

Calculating the Percentage of Damage $[P = \frac{np}{n}]$ (1)

$P = \frac{np}{n} = \frac{93}{354} = 0{,}2627$ (2)

Calculating the Centerline The centerline is the average of product damage $[CL = \text{p} = \frac{\sum np}{\sum \text{n}}]$ (3)

CL= $\text{p} = \frac{\sum np}{\sum \text{n}}$ (4)

CL= $\text{p} = \frac{715}{2987} = 0{,}239$ (5)

Calculating the Upper Control Limit $[UCL = \text{p} + 3\,\frac{\sqrt{p(1-p)}}{n}]$ (6)

$UCL = p + 3\,\frac{\sqrt{p(1-p)}}{n}$ (7)

$UCL = 0{,}259 + 3\,\frac{\sqrt{0{,}259\,(1-0{,}259)}}{2987} = 0{,}263$ (8)

Calculating the lower control limit $[LCL = p - 3\,\frac{\sqrt{p(1-p)}}{n}]$ (9)

$LCL = p - 3\frac{\sqrt{p(1-p)}}{n}$ (10)

$LCL = 0{,}259 - 3\,\frac{\sqrt{0{,}259\,(1-0{,}259)}}{2987} = 0{,}216$ (11)

Table 5 control map p

NO	PRODUCTION QUANTITY (BEGS)	AMOUNT OF DAMAGE (BEGS)	BROKEN PERCENTAGE %	CL	UCL	LCL
1	354	93	0.26	0.239	0.263	0.216
2	377	92	0.24	0.239	0.262	0.216
3	377	80	0.21	0.239	0.262	0.216
4	377	97	0.26	0.239	0.262	0.216
5	375	74	0.20	0.239	0.262	0.216
6	375	91	0.24	0.239	0.262	0.216
7	375	98	0.26	0.239	0.262	0.216
8	377	90	0.24	0.239	0.262	0.216
TOTAL	2987	715	0.24	0.239	0.262	0.216

After knowing the percentage value of each subgroup, including the center line (CL), upper limit (UCL), and lower limit (LCL) values from table 5, the next step is to generate a p-control map (p-chart), which can be observed in figure 2.

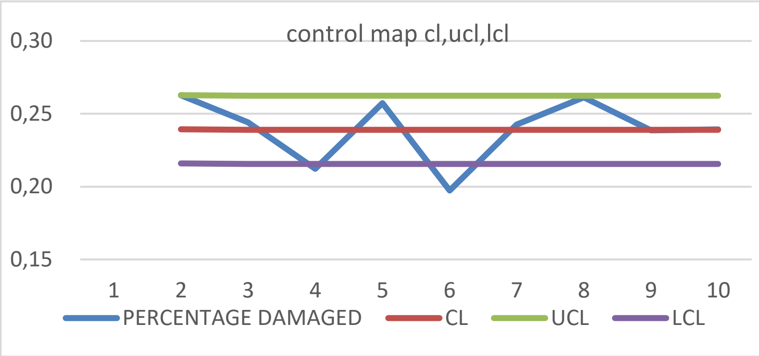

Figure 2 control map cl,lcl,ucl

From the image on the p control map above, it can be noted that the data still shows a point outside the control limits at point 6, and the most significant factor in this case is the presence of damage or defects in the torn packaging. Therefore, it can be concluded that this process is out of control or has deviations[16]. The presence of points outside the control limits indicates that there are still problems that need to be addressed in the production process. Therefore, further analysis is required to understand the causes of deviations in the production process at PT.XYZ. The approach to be used involves the use of a fishbone diagram to explore the factors that cause deviations in the product.

3.1.4 Pareto diagram

After obtaining information about the type of product damage, a pareto diagram is prepared. Pareto diagram is a form of graphical representation in the form of bars that show the frequency distribution of attribute data that has been classified, helping in identifying the types of product damage[17].

Table 6 damage data, damage percentage and cumulative percentage

NO	DAMAGE TYPE	QUANTITY OF DAMAGE (BAGS)	BROKEN PERCENTAGE	CUMULATIVE PERCENTAGE
1	RIPPED PACKAGING	413	58%	58%
2	UNSEWN PACKAGING	195	27%	85%
3	LESS FERTILIZER WEIGHT	107	15%	100%
	TOTAL	715	100%	

Based on the results of data calculations in table 6, it can be depicted in a pareto diagram showing the comparison of the types of damage that occur

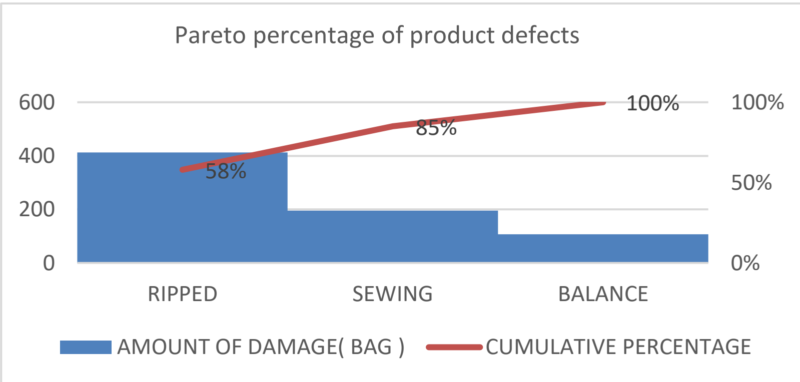

Figure 3 pareto percentage of product defects

By referring to the Pareto Chart in Figure 3, it can be identified that the most common type of damage is torn packaging, with a total damage of 413 units or 58%. Furthermore, the second most common type of damage is unsewn packaging, with a total damage of 195 units or around 27%. Meanwhile, the third most common damage is the lack of scales, with a total damage of 107 units or around 15%.

3.1.5 Cause-and-effect Diagram

After knowing the types of defects that occur most often, then identify what factors affect these defects using a fishbone diagram. Fishbone diagrams, also known as cause-and-effect diagrams, are used to uncover and identify the triggering factors underlying the failure or defect[18]. The causal factors of the three types of defects (defective products) in ZA plus fertilizer products are depicted using the fishbone diagram below:

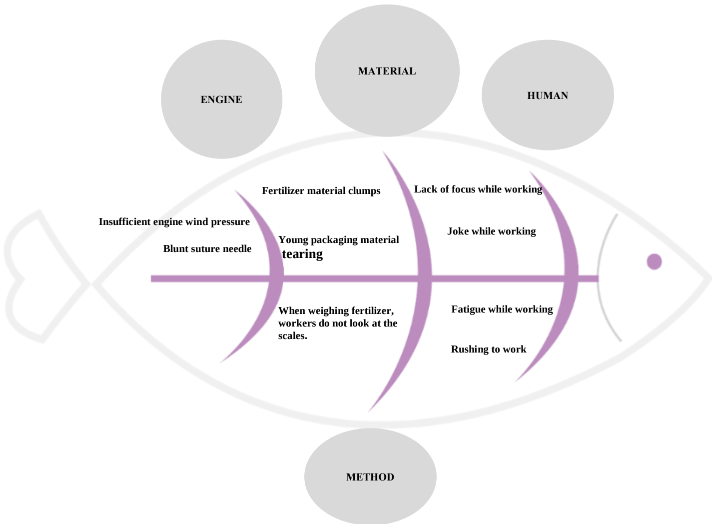

Figure 4 cause-and-effect diagram

If we observe the Cause-and-Effect Diagram in Figure 4 above, there are four factors that cause defects identified, namely humans, machines, materials, and methods.

3.2 Failure Mode Effect Analysis (FMEA)

After the data was processed using Statistical Quality Control, it was found that the most frequent defects were tear defects, followed by stitch defects and crust defects. Then, by referring to the cause-and-effect diagram, the causes of defects in jimbe drum production can be identified[19]. Thus, corrective actions can be proposed through Failure Mode Effect Analysis (FMEA), by assigning Risk Priority Number (RPN) values, as listed in the following table

Table 7 RPN assessment

Potential Failure Mode	*Potential Effect of Failure*	S	*Potential Cause*	O	*Current Control*	D	RPN
Ripped packaging	Fertilizer products will not be able to be sold and will do the work twice because they have to change the packaging	**9**	1.workers lack focus when arranging pallets 2. workers are in a hurry when placing fertilizer on pallets 3.workers talking to fellow workers 4.worker fatigue due to heavy fertilizer load 5.compressor wind pressure to hydraulic less	**5** **9** **5** **6** **8**	1.Always supervise workers so that they do not focus on other things. 2.Supervise workers not to be hasty in arranging fertilizer onto pallets. 3.reprimand workers who talk 4.implementing changes every few minutes to avoid fatigue 5.perform regular maintenance to the compressor	**2** **4** **2** **2** **3**	**90** **324** **90** **108** **216**
Unsewn packaging	Fertilizer will spill and scatter and the fertilizer will have to be re-sewn.	**7**	1.the stitches wear out so that there is often a jam when sewing 2.workers are in a hurry when sewing so they do not pay attention to the position of the sack when sewing 3.talking to fellow workers so as not to pay attention to the position of the sack when sewing	**6** **7** **5**	1.change sutures at regular intervals 2.inspect the stitches when they are completed 3.reprimand workers who talk	**3** **4** **3**	**126** **196** **105**
Weighing the packaging scales less	Workers have to repackage until the weight matches the size	**5**	1.less wind pressure makes the automatic weighing machine inaccurate 2.haste - haste does not see the indicator scales 3.less thorough when looking at the weighing indicator	**5** **4** **4**	1.always check the pressure indicator 2.check the scale again 3.make sure the scale indicator is correct	**3** **1** **2**	**75** **20** **40**

Table 8 RPN rank assessment

Priority	*Potential Failure Mode*	*Potential Cause*	RPN	*Recommendation*
1	Ripped packaging	workers are in a hurry when putting fertilizer onto pallets	**324**	Provide them with work procedure training
2	Ripped packaging	compressor to hydraulic air pressure is less	**216**	Before carrying out work activities, you should check the work tools.
3	Unsewn packaging	workers are in a hurry when sewing so they do not pay attention to the position of the sack when sewing.	**196**	Provide them with training on work procedures
4	Unsewn packaging	stitches wear out so there is often slippage when sewing	**126**	Check the condition of the sewing needle when it will be used and replace it regularly

5	Ripped packaging	worker fatigue due to heavy fertilizer load	**108**	Changing workers to avoid fatigue
6	Unsewn packaging	talking to fellow workers so that they do not pay attention to the position of the sack when sewing	**105**	Briefing workers on work procedures and supervising them.
7	Weighing the packaging scales less	insufficient wind pressure makes the automatais machine scales inaccurate.	**75**	Look at the pressure indicator first to see if it is correct before doing the work.
8	Ripped packaging	workers talk to fellow workers while working	**90**	Reprimand and give witnesses to workers who violate the rules.
9	Ripped packaging	workers lack focus when arranging palet	**90**	Give one kind of workload so that workers are more focused.
10	Weighing the packaging scales less	less careful when looking at the weighing indicator	**40**	Rechecking fertilizer weights
11	Weighing the packaging scales less	in a hurry not looking at the scale indicator	**20**	Rechecking fertilizer weights

Based on the results of the Risk Priority Number (RPN) calculation in Tables 7 and 8, it is revealed that the causes of failure that are significant in causing product defects have been sorted in order based on the calculation value, starting from the highest to the lowest. Next, improvement recommendations were made for each potential cause of failure according to the order of the RPN values in the table. The table highlights the defect cause with the highest RPN, i.e. 324, which is caused by tearing of the packaging due to workers rushing to put the fertilizer into the pallets to achieve the target, causing the fertilizer to slam. The proposed improvement recommendations include setting targets that match the capacity of workers to ensure optimal performance and prevent damage from occurring due to rushing.

4. Conclusion

Based on research conducted by researchers in the production sector of PT.XYZ related to ZA Plus fertilizer products, it can be stated that the dominating defect in the fertilizer production process is tearing, reaching a percentage of 58%. Furthermore, seam defects reached 27%, while crust defects amounted to 15%. Some of the factors causing tear defects include the lack of human accuracy in the process of arranging fertilizers on pallets, the state of the hagit needle that has been mechanically worn or blunted, and the condition of the packaging that is too worn out so that it is prone to tearing in terms of material[20].

Through the calculation of Risk Priority Number (RPN) in the Failure Mode Effect Analysis (FMEA) for fertilizer products, certain risks were identified, with some of them having the highest priority requiring improvement to reduce potential errors. The highest RPN recorded was 324, related to tear defects caused by a lack of caution in the process of arranging fertilizer on pallets or bouncing, causing fertilizer to fall off. Nonetheless, further research with a more comprehensive dataset and longer research period is required for validation and deeper understanding.

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