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Implementation of the Six Sigma-DMAIC method in improving quality product scanning units in the electronics industry

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ABSTRACT

The current era of globalization demands that all sectors of the manufacturing industry can improve the quality of service to customers. The electronics industry sector in Indonesia still has several defective products received by distributors. One electronic product that still has defects in the product is the scanner unit product. This research aims to identify defects that occur in the scanner unit assembly process and improve product quality by controlling the process. This research method uses the Six Sigma method at the Define, Measure, Analyze, Improve, Control (DMAIC) stages. This research has found that there are dominant foreign material defects of 221 pcs (35.42%) of the total defects of 624 pcs from January to February 2024. The causal factor is that the man consisting of WI (Work Instruction) is not carried out properly and the operator is not careful. at the checkpoint, the method consists of installing the glass label in the glass box, there is no process of checking the glass box before reuse, the material consists of burrs on the lower housing material, the presence of dust and stains on the carriage cis components, and the machine consists of the vacuum device does not inhale optimally, and the air pressure in the blowing machine is not optimal. The results of this research show an improvement in total defects from 624 pcs in Jan - Feb 2024 to 229 pcs and in April - May 2024, with a percentage of 1.662% decreasing to 0.571%. Meanwhile, the sigma level percentage results increased by 0.33 from 4.39 to 4.72 sigma level.

Keywords: DMAIC; quality control; defective product; scanners; Six Sigma.

1. INTRODUCTION

The rapid growth of technology and changes in meeting consumer needs pressure the industry to always innovate in several sectors, including the electronics sector which is one of the leading sectors in the Making Indonesia 4.0 program [1]. Of course, in addition to ensuring the conformity of production output, it is important to understand the natural variability of a production process so that development does not only focus on the amount of production but also ensures that quality is guaranteed, which refers to customer trust. Quality control can be done by identifying problems or waste using one of the tools, namely Six Sigma, to identify, control, analyze and improve product quality [2].

Products can be interpreted as goods or services that go through a production process with added utility or value, resulting in a final product that is ready to use based on all aspects in attracting attention, demand, and consumption in the form of goods or services [3], [4]. The product itself has several levels, including core benefits, basic products, expected products, augmented products, and potential products [5]. Defective products are goods or services that are produced during the production process but have deficiencies in their quality, resulting in a quality value that falls short of the desired standard. At the production level itself, it is not uncommon for defective products to be produced, which will have an impact on the company through quality costs, company image, and consumer satisfaction because the more defective products there are, the more rework actions, return to vendors and so on [6].

Quality can be reviewed through two perspectives, namely, the consumer and producer sides, basically referring to the suitability, overall features or characteristics of a product desired by consumers [7]. Analysis related to quality can also be based on the amount of damage that occurs to the product so that the level of defects becomes an indicator of quality assessment [8]. Indicators in measuring quality variables, namely, product durability, product specialties, conformity to specifications, product aesthetics, and product reliability [9]. In general, the three main categories of quality control are off-line quality control, statistical process control, and acceptable sampling planning [10].

Some factors that affect the quality control process include process capability, applicable specifications, acceptable levels of conformity, and quality costs [11]. Of course, in this case, the quality department plays a role in implementing policies that will affect performance and quality so as to contribute to customer satisfaction [12]. PT. XYZ is one of the electronics sector companies in Indonesia. The usual problem that disrupts the company's profitability is the discovery of defective products every day, which fails to comply with the set standards, as shown in Figure 1.

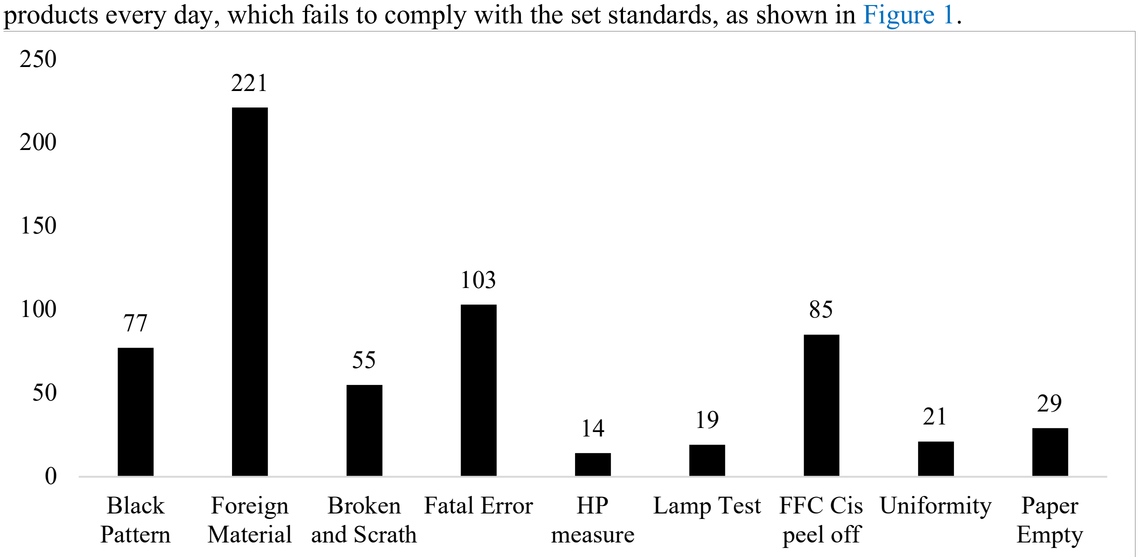

Figure 1. Number of defective scanner product units Jan – Feb 2024

Based on Figure 2, the most dominant defect is foreign material, so it needs further handling. This dominant defect greatly affects the percentage of defects and the reduction in the amount of production. The novelty of this research is the combination of the Six Sigma method in the DMAIC approach, where each stage of the process has a repair tool that will be used in handling defects [13]. The product that is the object of this research is a scanner product in the electronics industry, so it is interesting to analyze, and study in this study. This research aims to identify defects that occur in the scanner unit assembly process and improve product quality by controlling the process.

2. METHOD

This study uses a quantitative approach. This type of research uses observation and interview techniques to collect data on research objects with the aim of systematically and accurately describing a phenomenon of events, symptoms, and incidents that occur factually through mathematical calculations [14]. Quantitative research methods usually use many numbers or nominal data in the process [15]. One of the techniques used in research is triangulation. This technique is used to test the reliability of data by finding the truth of data against the same source through different techniques, such as crossing observation techniques, interviews, and documentation, then combined into a conclusion, such as Figure 2 [16].

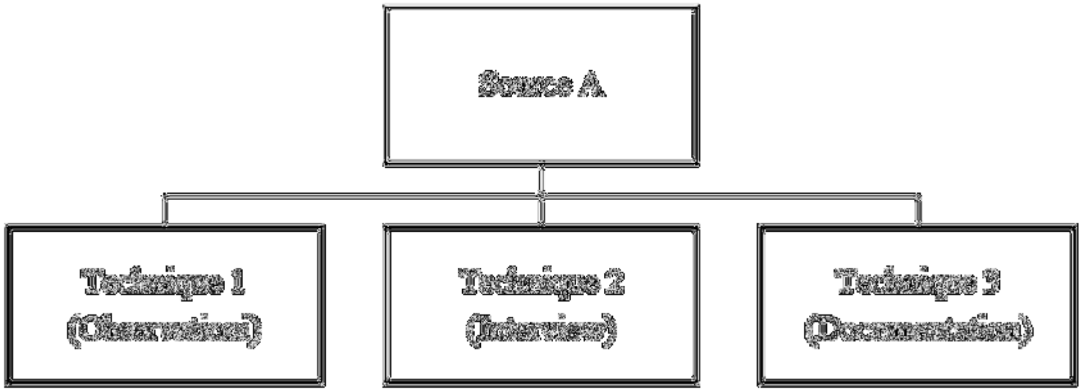

Figure 2. How to perform engineering triangulation

Based on Figure 2, the data collection technique consists of three events, namely observation, interviews, and documentation. The focus of this research is on sampling through observation in the assembly line scanner through the production process of incoming materials until it is focused on the output of the scanner product in the finished test (FT) and repair processes where these two processes assess whether a product is a good product or a defective product.

The research was conducted using the DMAIC methodology (Define, Measure, Analyse, Improve, Control) which is a structured and effective cycle in improving quality [17],[18]. The following are the steps in implementing the DMAIC methodology.

a) Define, identify problems, and determine project space through understanding company problems by identifying workstations, number of defects, and types of defects in a period [18].
b) The measure includes identifying factors (Critical to Quality (CTQ), calculating Defects per Unit (DPU), Defects per Opportunity (DPO), Defects per Million Opportunities (DPMO), and determining sigma values [19].
c) The analysis involves evaluating defects through data utilization and brainstorming with related parties to find the main root causes of prioritized defects using tools such as Fishbone and Pareto [20].
d) Improve, developing a rationale for improvement solutions to fix problems that have been previously measured, identified, and analyzed based on the cause of the problem, and evaluating the results of the improvement [21].
e) Control, evaluating the results of improvement to maintain quality through continuous improvement and monitoring using control charts [22].

The improvement process becomes effective through appropriate improvement actions on the main causes of the problem, which can also be determined through quality instruments, including check sheets, histograms, control charts, Pareto, and fishbone [23]. The following is the methodological framework carried out in this study, which can be reviewed in Figure 3.

Figure 3 explains the stages of research carried out in this study, starting from defining the identification of defect types in the product while creating a check sheet and displaying histogram data. A check sheet is a tool used to record certain events during data collection through a simple form that allows organizations to collect data to confirm the presence of defects in a process [10]. A histogram is a tabulation of data arranged based on a check sheet, aimed at facilitating understanding of defective products or defects that occur [24].

Then, the study continued at the measure stage by calculating DPMO and sigma value, which will later be used in identifying the most frequent types of defects [25]. A control chart is a statistical tool used in controlling and evaluating the quality of the manufacturing process that shows changes in data over time [26].

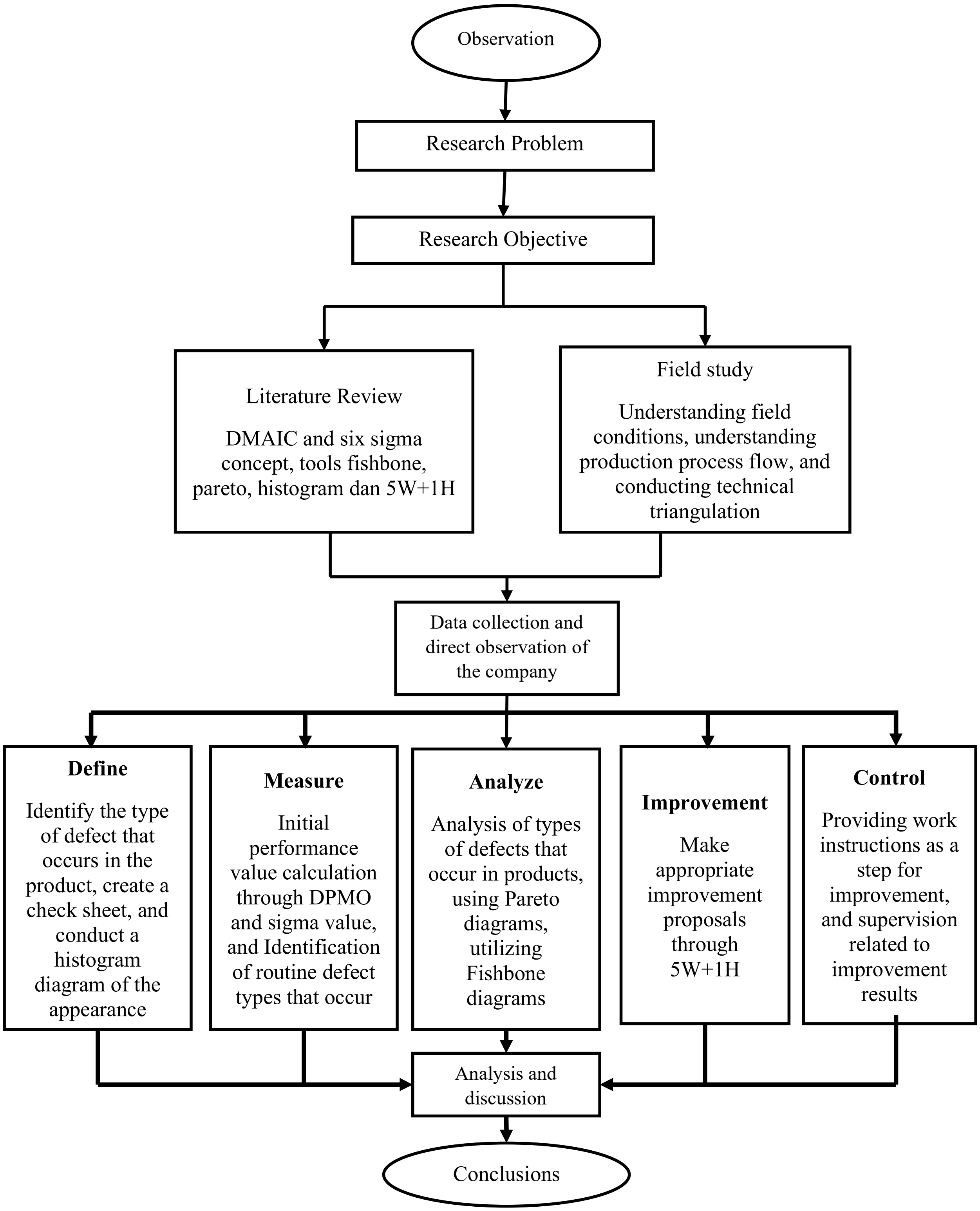

Figure 3. Research flowchart

Six sigma is a tool in business improvement through a management approach that focuses on minimizing defects and improving the quality of processes, goods, and services, which refers to statistical performance to achieve the target of 3.4 defects per million opportunities [27]. After the calculation of the sigma value and the most common types of defects are identified, an analysis is carried out using a Pareto diagram and a fishbone diagram. Pareto diagrams are referred to as diagrams that are usually used to identify, sort, and set aside unit damage by selecting problems from the largest to the smallest so that it can be known where the most dominant damage is [28].

A fishbone diagram is also known as a cause-effect diagram that shows the relationship between the problem faced with the possible causes and factors that influence the quality being studied with the fish head on the right, where the events influenced by the cause are listed as the topic of the problem being searched for and then in the fishbone section are listed categories that can influence the event such as man, method, material, and machine [29]. Corrective action through root cause analysis can be done with the 5W+1H approach, directly referring to the principle by asking, and then the problem is explained well and gets an answer. This approach is through 5 questions starting with W (What, Where, When, Who, Which) and 1 question, H (How), to formulate solutions and recommendations related to improving problems in the production process [30], [31].

3. RESULT AND DISCUSSION

Through observation and problem-solving in the field, the results of this study are described in the DMAIC stages, through the following sequence:

Define

The initial process carried out is to identify the production process flow before solving the root cause of the problem that arises to facilitate the investigation of the cause of the scanner production problem not reaching the target, so the process flow is displayed in Figure 4. Figure 4 illustrates the production process from raw materials to the product storage stage, where products are sorted into 'OK' or 'NG' at the final test process stage and undergo quality control checks. The presentation data of expenditure and types of defects can be seen in Table 1.

Table 1. Presentation of output and type of weekly defects

Week to-	Production quantity (pcs)	Black Pattern	Foreign Material	Broken and Scratched	Fatal Error	HP measure	Lamp Test	FFC Cis peel off	Uniformity	Paper Empty	Total (pcs)	% Defect
1	1820	6	14	7	13	0	0	0	2	2	44	2.42%
2	2928	6	17	20	9	1	3	7	3	0	66	2.25%
3	2860	11	18	0	13	1	0	10	2	0	55	1.92%
4	3820	5	9	1	3	1	2	3	2	1	27	0.71%
5	4202	6	5	2	6	0	5	3	1	11	39	0.93%
6	4802	7	31	0	16	1	0	3	0	9	67	1.40%
7	5260	8	51	7	23	1	3	23	2	3	121	2.30%
8	6500	11	18	10	5	0	4	20	2	2	72	1.11%
9	3902	17	58	8	15	9	2	16	7	1	133	3.41%
Total	36094	77	221	55	103	14	19	85	21	29	624	Average 1.47%

Table 1 shows that the weekly production data collection found an average defect value of 1.47% in the January-February 2024 data collection.

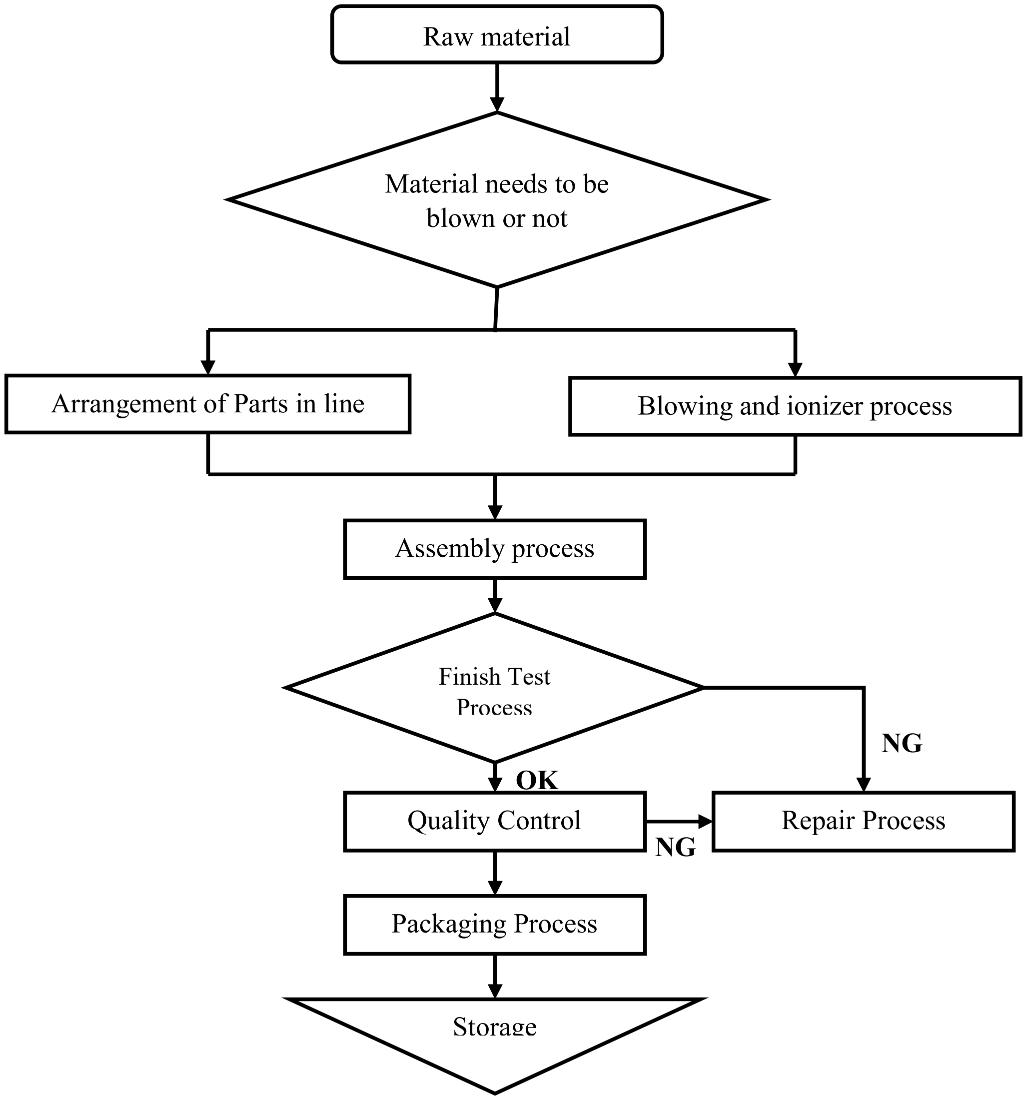

Figure 4. Scanner product production flow chart

Measure

At this stage, measurements are made through control chart analysis and DPMO value calculations [32]. The calculation results related to the average CL, UCL, and LCL values are obtained through the following calculations:

- Calculation Centerline (CL) = p $= \frac{624}{36094} = 0.01728$
- Calculation Upper Centerline (UCL) = $p + 3\sqrt{\frac{0.0173(1-0.0173)}{1127}} = 0.0289$
- Calculation Lower Centerline (LCL) = $p - 3\sqrt{\frac{0{,}0173(1-0.0173)}{1127}} = 0.0056$

Based on the control chart calculations before the improvements, the results were as follows: CL = 0.01728, UCL = 0.0289, and LCL = 0.0056. The results of the calculations above were transferred to a visual display as in Figure 5.

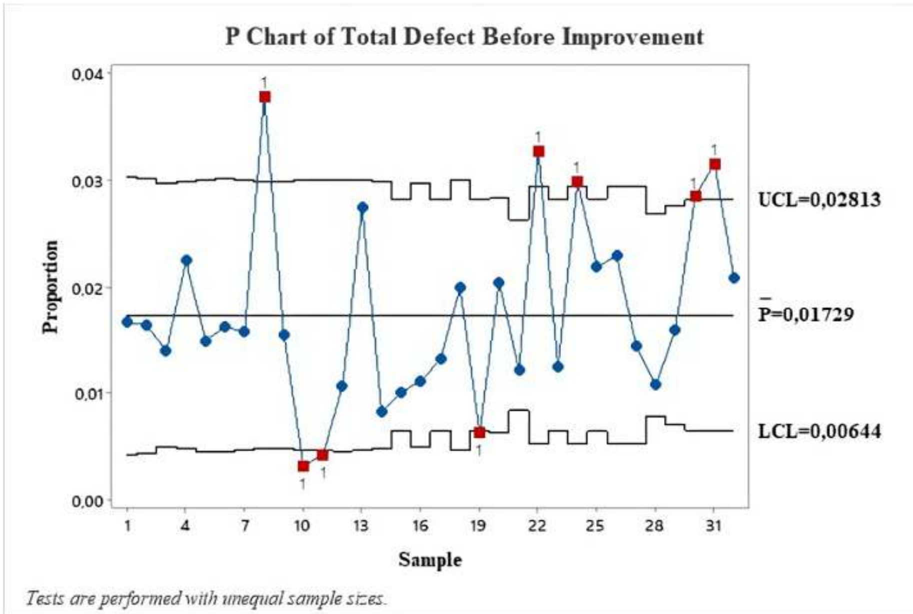

Figure 5. P-Chart attribute before improvement

Figure 5 shows that there are still results of defect percentage inspections that are outside the control limits, namely 8 times. This shows that the need for defect repairs to be addressed immediately so that all products are within the quality limit control. Through the results of the analysis, the Critical to Quality (CTQ) was identified on the scanner unit product using the calculation of the total defects for each defect, with the total defective products found in Table 1. In Table 1, the 3 main types of defects were found, namely foreign material (221 pcs), fatal error (103 pcs), and FFC CIS peel-off (85 pcs). According to the data obtained, the results of the sigma calculation are as follows: The following are the results of data measurements to obtain DPU, DPO, DPMO, and sigma levels as follows:

- $\text{DPU} = \frac{\text{Total defect}}{\text{Total production}} = \frac{624}{36094} = 0.01728$
- $\text{DPO} = \frac{\text{DPU}}{\text{CTQ}} = \frac{0{,}01728}{9} = 0.001921$
- $\text{DPMO} = \text{DPO x } 1.000.000 = 0.001921 \text{ x } 1.000.000 = 1921$
- $\text{Level sigma} = \text{NORMSINV}\,((\frac{1.000.000 - 1921}{1.000.000}) + 1.5) = 4.39$

Through the calculation above, it was found that the initial sigma value before the improvement was 4.39.

Analyze

In this process, further observations were made related to the most dominant defects to determine the cause of the defects through the use of Pareto diagrams and fishbone diagrams. Reviewing the CTQ results in Table I below, the data is displayed visually with a Pareto diagram using the help of Minitab-22 in *Figure 6*.

Based on *Figure 6*, the dominant defect in the Pareto diagram is foreign material at 35.4% and then by fatal errors and black patterns. Foreign material is the presence of defects in the under-glass area, upper housing, and lower housing in the form of dirt with various shapes such as leftover injection molding pieces (burrs), dust, and foreign objects that interfere with the scanner unit sensor reading process and this defect is the defect with the highest percentage. So, after being displayed in a Pareto diagram, problem identification is carried out using a fishbone diagram as shown in Figure 7.

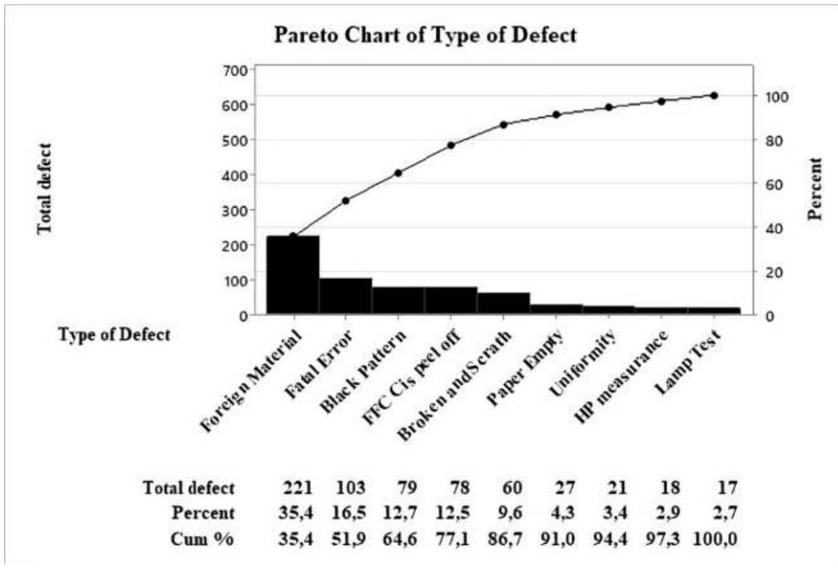

Figure 6. Pareto diagram of the defect scanner unit before improvement

Figure 7 shows some causes of foreign material, which are the highest defects in the machine section, such as the vacuum tool not inhaling optimally, the conveyor in the blowing process being too fast, and the air pressure in the blowing machine is not optimal. Material has burry on the upper housing material, and there are stains on the cis carriage component. The method found that the glass label installation was in the glass box; there was no glass box-checking process before being reused, and the glass label installation was in the glass box. Man, some operators were not careful at the checkpoint point, and the work instructions were not carried out properly.

Improve

At this stage, a design is carried out as a result of the discovery of problems found in the analysis stage in the form of proposals for improving the quality of Six Sigma using the 5W+1H tools. The 5W+1H analysis as a planning tool can be reviewed in Table 2.

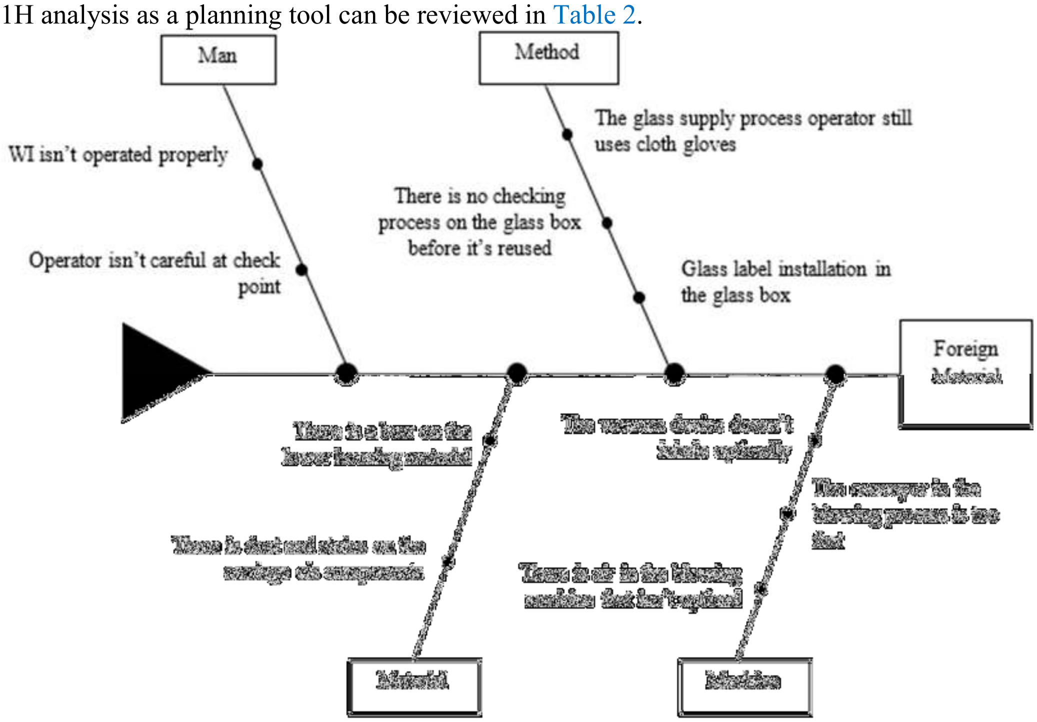

Figure 7. Fishbone diagram of foreign materials

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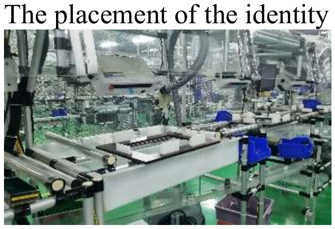
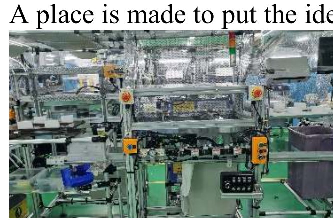
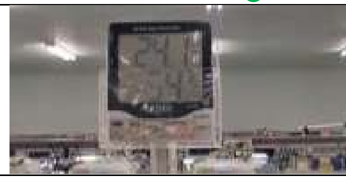
Table 2. 5W+1H results

No	What What is the problem?	Why Why does it need to be fixed?	How How is it handled?	Who Who is responsible?	When When will it be implemented?	Where Where will it be implemented?
1	The material supply process isn't optimal	To reduce the presence of scratches and foreign materials in the box	Making new wagons and periodically checking the wagons	Manda T	4 Maret 2024	Clean area scanner
2	Vacuum and blowing tools aren't optimal	To reduce the presence of foreign material	Make new blowing machines and regular vacuum maintenance	Usep H	1 Maret 2024	Stage join HU line assembly belt 1
3	The Cleanliness of glass boxes isn't given enough attention	Reduce the potential for foreign material	Carrying out new WI processes and monitoring cleaning boxes	Ifal A	27 Maret 2024	Warehouse & glass supply area
4	Raw materials don't meet standards	Guaranteeing the quality of the products produced	Communicating with vendors regarding raw materials	Iwan C	01-Apr-24	Communicating with suppliers

Table 2 shows 4 points that can be used in the defect improvement process with problems in the material supply process that are not optimal, vacuum and blowing tools that are not optimal, glass box cleanliness is not considered, and raw materials that are not up to standards. Of course, in its implementation, this improvement has several teams through representatives of people to monitor subsequent production activities and enter the control stage. Through the 5W+1H tools approach, several plans were found related to recommendations for handling to overcome the problem. The results of the improvements can be reviewed in Table 3. The details of the improvements that have been made can be seen in Table 3.

Table 3. Foreign material improvement

No	How to repair Foreign Material ✗ Before Improvement	 O After improvement
1	 The placement of the identity in a glass box	 A place is made to put the identity
2	 The HU joint process still uses manual vacuum	 Making blowing and ionizer at the HU and HL joint stage

No	How to repair Foreign Material ❌ Before Improvement	O After improvement
3		
	Monitoring the humidity level of the work area	

Control

After going through the improvement stages, monitoring of the production process was carried out in an effort to review the results of the improvements through the calculation of Six Sigma results, histograms, and statistics after the improvements. The following is a presentation of data before and after the improvements in the form of Table 4

Table 4. Sample before improvement and after improvement

Type of defect	Before improvement (January - February 2024)			After improvement (April - May 2024)		
	Total defect	Total production	percentage	Total defect	Total production	percentage
Black Pattern	79	36094	0.219%	37	40078	0.092%
Foreign Material	221	36094	0.612%	42	40078	0.105%
Broken and scratched	81	36094	0.224%	9	40078	0.022%
Fatal Error	103	36094	0.285%	10	40078	0.025%
HP measure	18	36094	0.050%	10	40078	0.025%
Lamp Test	17	36094	0.047%	16	40078	0.040%
FFC Cis peel off	57	36094	0.158%	38	40078	0.095%
Uniformity	21	36094	0.058%	33	40078	0.082%
Paper Empty	27	36094	0.075%	34	40078	0.085%
Total	624	36094	1.729%	229	40078	0.571%

Table 4 shows the results of changes that occurred before and after the improvement was carried out with a comparison of before the improvement. The number of defects found was 624 units with a production volume of 36,094 units, resulting in a percentage of 1.729%. After improvement, the number of defects found was 229 units with a production volume of 40,078 units, resulting in a percentage of 0.571%. Through the results of Table 4, the number of defects and the percentage before and after the improvement can be reviewed. The calculation results in the table can be visualized in a histogram as in Figure 8.

Based on Figure 8, a visual comparison is shown through a histogram that the highest defect, namely foreign material, has a significant decrease of 221 pcs to 42 pcs. The calculation results related to the CL, UCL, and LCL values are obtained through the following calculations:

- Calculation Centerline (CL) = $p = \frac{229}{44078} = 0.0057$ $u = \frac{229}{40078} = 0.0057$
- Calculation Upper Centerline (UCL) = $p + 3\sqrt{\frac{0.0057(1-0.0057)}{1252}} = 0.0120$
- Calculation Lower Centerline (LCL) = $p - 3\sqrt{\frac{0.0057(1-0.0057)}{1252}} = -0.0007$

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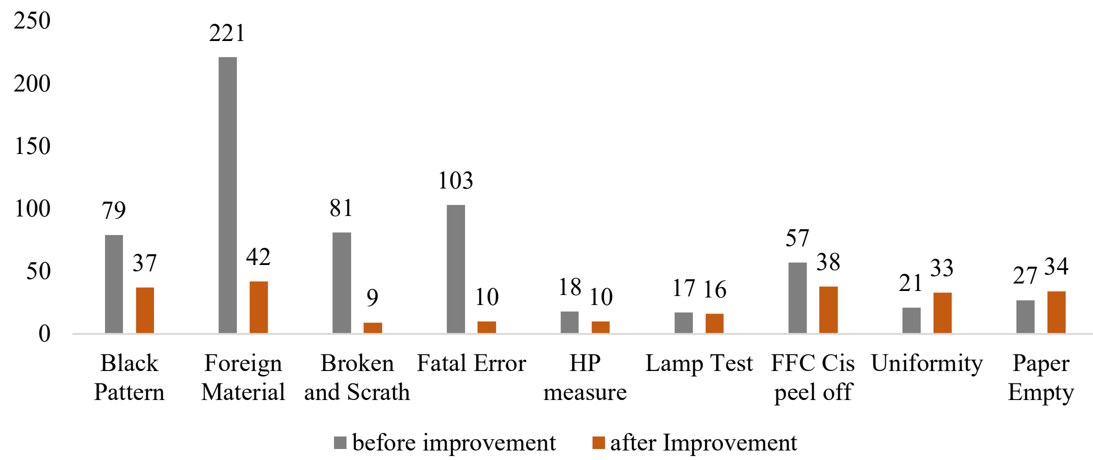

Figure 8. Total defects before and after improvement

Through the calculation results after the improvements, namely, CL = 0.0057, UCL = 0.0121, and LCL = -0.0007. Because LCL < 0, the LCL value is set to 0 [33]. The results of the calculations above were transferred to a visual display is obtained as in Figure 9.

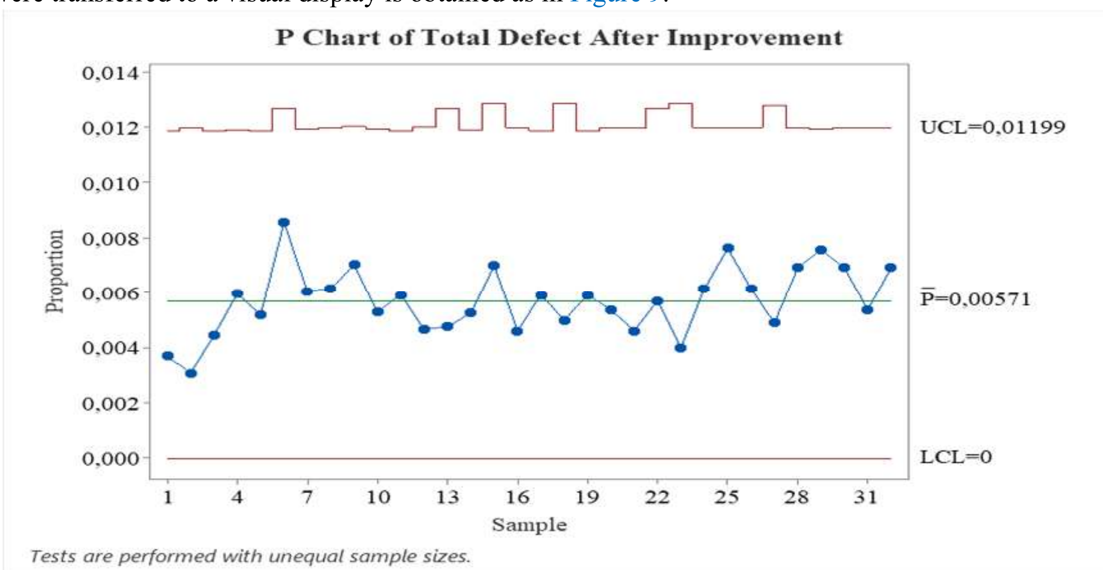

Figure 9. P-chart attribute after improvement

Looking at the improvement results, the sigma calculation results can be seen as follows:

- $\text{DPU} = \frac{\text{Total defect}}{\text{Total production}} = \frac{229}{40078} = 0.00571$
- $\text{DPO} = \frac{\text{DPU}}{\text{CTQ}} = \frac{0{,}00571}{9} = 0.00063$
- $\text{DPMO} = \text{DPO x } 1.000.000 = 0.00063 \text{ x } 1.000.000 = 630$
- $\text{Level sigma} = \text{NORMSINV}\left(\left(\frac{1.000.000 - 1630}{1.000.000}\right) + 1.5\right) = 4.72$

It can also be seen in the comparison of the number of defects before and after repair in Table IV, 624 pcs to 229 pcs, which, if present, is 1.662% to 0.571%. In addition to the percentage results, there is a comparison of the sigma value before repair at 4.39, increasing after repair to 4.72.

Discussion

Through the results of the defect data processing that has been calculated, an analysis of the improvement process is carried out through DMAIC in the Six Sigma concept. Following the statement [2], the implementation of DMAIC is one of the strategies for identifying problems in manufacturing companies by producing recommendations for improvement through the coordination of those responsible for each division.

The monitoring process is also needed to ensure that the improvement objectives can be achieved [22]. In this study, the Six Sigma analysis resulted in a decrease in the number of defects while the amount of production increased, namely, the number of defects previously 624 pcs became 229 pcs with a comparison of the previous production of 36094 pcs to 40078 pcs.

4. CONCLUSION

The results of the study showed that 9 types of defects were found in the production of scanner unit products, namely, black pattern, foreign material, broken and scratch, fatal error, HP measure, lamp test, ffc cis peel off, uniformity, and paper empty. Through the analysis carried out, it was found that foreign material was the most dominant type of defect with the causative factors consisting of WI (Work Instruction) not being carried out properly and the operator being less careful at the checkpoint, the method consisting of installing the glass label in the glass box, there was no process of checking the glass box before it was reused, the material consisting of burry on the lower housing material, dust and stains on the cis carriage components, and the machine consisting of a vacuum tool not sucking optimally, and the air pressure on the blowing machine was not optimal. Improvements made in order to handle dominant defects include creating a place to place the glass identity, making blowing & ionizers at the joint HU & HL stages, and monitoring the humidity level of the work area. Through the application of Six Sigma with the DMAIC cycle in measuring the magnitude of scanner product defects. The results of the study showed an improvement in total defects from 624 pcs in January - February 2024 to 229 pcs in April - May 2024, with a decrease of 1.662% to 0.571%. In addition, the sigma level percentage results increased by 0.33 from 4.39 to 4.72.

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