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Implementation of the six sigma approach for increasing the quality of formal men's jackets in the garment industry

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A B S T R A C T

This study aims to implement the Six Sigma method on formal men's jacket products in the garment industry to increase the level of sigma. The methodology is based on the Define, Measure, Analyze, Improve, and Control (DMAIC) approach. The new approach in this study is the determination of 5W+1H using a Focus Group Discussion (FGD) with five expert judgments. The design of this study has applied the Six Sigma method at the Measure stage. It is a measurement before improvement and after the Control stage as a measurement after improvement. The results of this study have increased the level of sigma from 3.5765 to 3.7839, so there is an increase of 5.48%. Increasing the sigma level contributes to a decrease in defects at the finish line by 44.09% every month. Implementing the Six Sigma method to the DMAIC approach has succeeded in increasing the level of sigma, automatically reducing the percentage of defects, and increasing the productivity of formal men's jackets in the garment industry.

1. INTRODUCTION

In this era of globalization, garment technology has advanced significantly with automated technology in pattern making, cutting, sewing, and finishing processes. With the increasingly advanced technology, it should be able to support productivity and quality. But in reality, productivity and quality are still low, not meeting the quality requirements the buyer or buyer sets. Products received by consumers are determined mainly by the quality of the products produced following consumer requirements [1]. Companies need to pay attention to, maintain and control and improve the quality of the products they produce by implementing and building a quality system [2]. Quality control and improvement seek to suppress defective products from getting into the hands of consumers [3]. One method that will be used to detect or suppress production defects as minor as possible is to use the Define Measure Analyze Improve Control (DMAIC) approach, which includes the Six Sigma method [4], [5]. Various fields of the manufacturing industry have investigated and applied the Six Sigma method and have produced several findings obtained by way of the application of Six Sigma, including in the textile manufacturing industry, where the desired quality has been successfully improved. [6], [7].

One of the garment companies in Bandung is a garment maker vendor from PT. Itochu Indonesia produces formal men's jackets (men's suit blazers). The garment company applies quality standards following buyer standards, namely Acceptable Quality Level (AQL) 2.5 military standard at the time of final inspection. The defects obtained for one month from the beginning to the end can be seen in Fig. 1.

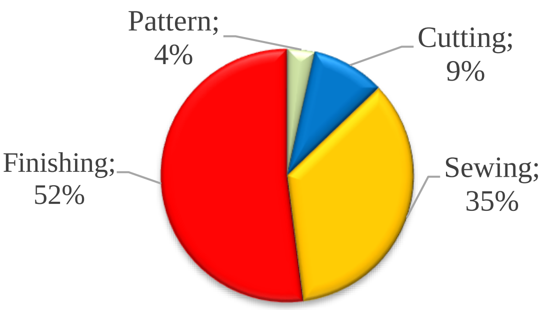

Fig. 1. Garment defects each stage of the process in Jan~Feb 2021

Based on Fig. 1, it can be seen that the largest percentage is at the finishing line of 52%, so it is necessary to research this section to correct these defects using the DMAIC method. The author is motivated to reduce defects in the Finishing section because if this research can reduce dominant defects, the number of productions that enter customer requirements will increase.

After knowing there are problems in the finishing section, the next step is to find the type of dominant defect in that section. Fig. 4, in the form of a Pareto diagram, shows the most dominant defect in the bubble defect, and this defect is critical to quality to be repaired immediately. Critical to Quality (CTQ), is a type of defect categorized in process or product attributes that significantly impact product quality [8], [9].

The phenomenon of the problems faced by the garment companies can be overcome with the seven Quality Control tools approach to control and minimize defective production [10], [11]. The use of Six Sigma and DMAIC methodologies in this home appliance company has reduced the number of defects in the number of defective aluminum parts, significantly affecting customer satisfaction and cost savings [12]. Based on X-bar Control, Six Sigma can keep the process average close to the target by reducing variance and improving quality [13]. The improvement stage is a plan of action to implement quality improvement with the Six Sigma approach after knowing the causes of each type of product defect that is most dominant [14], [15]. An established technique in the context of software production control that is often used with statistical tools that can be measured and targeted in its manufacture is called the Statistical Process Control (SPC) method approach [16], [17]. Kaizen is an organization making it an absolute priority until an emergency problem [18].

DMAIC approach can explore internal process optimization, which is considered an important factor in answering the problems in the mold industry [19]. A five-phase cycle in the DMAIC stages approaches process and quality improvement. This method is increasingly popular in quality improvement. This method is often called and is popular with implementing Six Sigma [20]. The Six Sigma method helps improve quality and reduce operational costs, and this method is practical in encouraging continuous improvement in product quality or production processes [21].

Hitoshi Yamada has redistributed the implementation of the Kaizen concept in quality improvement. In his book, The selection of quality improvement tools and techniques is different at each stage, and the selection of improvement tools and techniques depending on the type of problem is one of the keys to the successful implementation of Six Sigma [22]. The implementation of Six Sigma is part of total quality through its approach and by a continuous discussion with supporting data, attributes, and calculations in the application of continuous process analysis [23]. Implementing Six Sigma can boost or improve the performance of the traditional shipbuilding industry and reduce product failures. [2], [24]. The development of Six Sigma research using the DMAIC method is very rapid. Many manufacturing industries use it, including the garment industry. The implementtation of Six Sigma at the DMAIC stage will be able to reduce defects, increase the amount of production and gain efficiency [25], [26].

This study is almost the same as using quality tools as a method of improvement. Still, the improvement approach in this study uses the DMAIC concept approach so that each stage can use quality tools according to the stages of improvement. This study aims to implement the Six Sigma method on formal men's jacket products in the garment industry to increase the level of sigma. The new approach of this study is using the DMAIC concept at every stage using quality control tools such as Pareto diagrams, Control charts, Fishbone diagrams, and 5W+1H, and what

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is unique is using Focus Group Discussion (FGD) in determining the 5W+1H improvement plan using five different expert judgments or assessors.

2. RESEARCH METHODS

The research method in this study uses several data, namely primary data and secondary data. The data included in the primary data is an analysis of the causes of defects, direct observation of sample making, and an FGD report. In contrast, the secondary data includes production report data and documented monthly production defect data. The researchers used several data collection methods to obtain research data as mentioned above, namely documents and observations. Based on the phenomena described, this research uses the most appropriate type of mixed methods research, which combines quantitative and qualitative research methods to be used together [27].

Based on Fig. 2, qualitative research is a Fishbone diagram and 5W+1H, while others are included in quantitative research. This study uses systematic steps so that this research is focused and directed. The steps of this research consist of 4 stages, including:

Stage 1: Exploring the phenomena of problems in the garment industry, especially jacket formal products. Set research objectives to fix problems. Conduct a literature review on the DMAIC approach and Six Sigma methods. The literature study intends to deepen the theory used as a problem-solving method.

Stage 2: Collecting data from several production divisions, including the number of production and defects for four months, each month taking samples of 15 observations so for four months taking samples 60 times, with the AQL used for each observation amounting to 125 pieces. After knowing the percentage of defects, focus on the largest percentage, namely the finishing section.

Define stage: Defect problems that significantly affect the production process and often arise are called CTQ. Determining CTQ data by collecting production reports and defect data for four months as sampling on the finishing line, then input into Microsoft Excel, as shown in Table 1. A bar-shaped graph that shows problems based on the number of occurrences is called a Pareto diagram, with the order starting from the number of problems with the most (large bars) appearing to the least (little bars). This stage is called data collection analysis by taking several data reports on a check sheet for defects and types of defects filled in by the examiner for four months, then inputting them into the computer in Microsoft Excel. Finally, input the defect data and the type of defect into the Minitab-19 software, and a Pareto diagram will be formed.

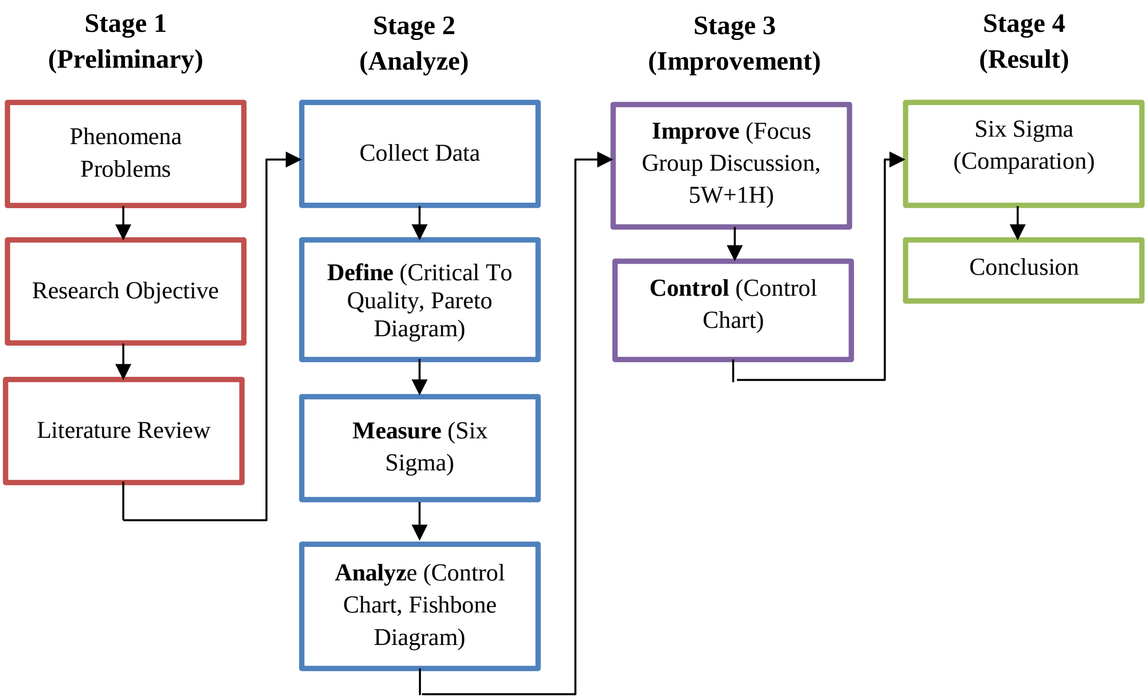

Fig. 2. Research Framework

Table 1. CTQ research method

No	Month – Year	Inspection (pieces) A	Total defect (pieces) B	Defect (%) C
1	Jan 21	Inspection	Defect	$\frac{B}{A} x100\%$
2	Feb 21	..	..	..
3	Mar 21	..	..	..
4	Apr 21	..	..	..
Grand Total		Total Inspection	Total Defect	Defect (%)

Determining the number of CTQs is known. The next step is to determine the types of defects that often appear for four months so that the number of critical defects will be known that often appear to be the number of CTQs.

Measure stage: Knowing the sigma level by taking production report data and defects on the final line for four months as before the repair and then inputting it into Microsoft Excel with successive formulas Defect Per Unit (DPU), Defect Per Opportunity (DPO), and Defect Per Million Opportunities (DPMO) as an aid in determining sigma levels.

$$DPU = \frac{Amount\ Defect}{Amount\ Unit} \quad (1)$$

$$DPO = \frac{DPU}{CTQ} \quad (2)$$

$$DPMO = DPO\ x\ 1{,}000{,}000 \quad (3)$$

$$Sigma\ Levels\ = NORM.S.INV\,\frac{(1{,}000{,}000-\mathrm{DPMO})}{1{,}000{,}000} + 1.5 \quad (4)$$

Analyze stage: Research determines the quality improvement target in this planning phase. The formal men's jackets Industry has determined that the monthly defect target is 12%. The methods used at this phase of the plan include: This study is more suitable to use control charts, similar to previous studies, which measure the number of defects or nonconformities in the units produced. This study uses the P-Chart to measure the number of defects or discrepancies in the units produced because the number of samples used is constant or fixed according to AQL. Make a control chart to show a map for controlling the proportion of garment product errors in the finishing line before improvement, then input them in Minitab 19 software to form a P-Chart including Control Limit (CL), Upper Control Limit (UCL), and Lower Control Limit (LCL).

$$\mathrm{CL\ or\ }\overline{\mathrm{P}} = \frac{\sum \mathrm{defect}}{\sum \mathrm{Inspection}} \quad (5)$$

$$\mathrm{UCL} = \overline{\mathrm{P}} + 3\left(\sqrt{\frac{\overline{\mathrm{P}}(1-\overline{\mathrm{P}})}{n}}\right) \quad (6)$$

$$\mathrm{LCL} = \overline{\mathrm{P}} - 3\left(\sqrt{\frac{\overline{\mathrm{P}}(1-\overline{\mathrm{P}})}{n}}\right) \quad (7)$$

The final stage uses Fishbone diagrams to analyze the root causes of the problem by starting with the consequences or problems that arise and then, in a structured way, looking for possible causes. In general, five factors are, consisting Material, Method, Machine, Man (4M), and Environment (1E), which cause deviations in business processes [28]. This method is carried out by direct observation of the production finishing line and conducting interviews or brainstorming with operators involved in the production process of each production line. After obtaining the cause data, then the data is entered into Microsoft Visio to form a Fishbone diagram.

Stage 3: Planning repairs and checking the results of repairs by controlling the results.

Improve stage: At this last stage, the tools used are 5W+1H and Control chart after repair before turning back to the initial stage. 5W+1H is a structured method to generate ideas using questions related to the problems or goals set [20] and use FGD to conduct improvement plants with 5W+1H methods [29]. In this study, the data analysis method was obtained during the FGD in a meeting where the content discussion determined 5W+1H with the results of mutual agreement. Perform analysis using the Root Analysis Method or why-why analysis to get the real cause of a problem. So, in this case, the explanation of the causes of the problem on the Fishbone diagram with Root Cause Analysis (RCA) is interrelated. If the Fishbone diagram describes all possible causes, then RCA conducts a deeper excavation of the cause to get to the real cause so that the improvements provided will be more effective and right on target.

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Table 2. Inspection and defect result

No	Month – Year	Inspection (pieces) A	Total defect (pieces) B	Defect (%) C
1	Jan 21	1,875	366	19.52%
2	Feb 21	1,875	343	18.29%
3	Mar 21	1,875	354	18.88%
4	Apr 21	1,875	315	16.80%
	Grand Total	7,500	1,378	18.37%

Control stage: This stage is the control process in the form of applying a weekly monitoring or evaluation method related to defects that occur in the form of a P-Chart. If a defect occurs outside the limit, corrective action must be taken as soon as possible to reduce the defect and according to the company's target. The steps for making P-Chart are almost the same as in Analyze stage.

Stage 4: The following stage measures the level of sigma and percentage defect (4 months before and four months after improvement). The corrected data is inputted into Microsoft Excel to determine the sigma level with the same formula in the Measure stage.

3. RESULTS AND DISCUSSION

3.1. DMAIC stages analysis

Define Stage: The test results in determining the CTQ or the number of types of defects that often appear are more accurate because formal men’s jacket defects vary significantly in the types of defects. The number of defects is 1,378 pieces for four months (Table 2). The next step is to break down the number of defects into the types of defects that often appear or are critical so that later the number of defects will be known or called CTQ.

Table 3. CTQ in Finishing Line

No	Defect Type	Total Defect (pieces)
1	Slanted Lapel	43
2	Poor Shape Lapel	88
3	Poor shape Shoulder	31
4	Twisting	112
5	Bubbling	438
6	Puckering	215
7	Lapel Too High/Low	218
8	Pressing Impression	143
9	Breaking Armhole/Sleev	100
	Total	1,378

Fig. 3. The dominant finishing lines defects

The CTQ in this study amounted to 9 types of defects that often appear (Table 3). The most dominant type of CTQ is the bubble defect on the formal men’s jacket because the finishing QC inspector will see this defect during a visual inspection of the formal men’s jacket that has just come out of the machine. The visual description of the dominant defect marked with a red circle is a bubbling defect (Fig. 3). The data processing results in the Pareto diagram's finishing section can be seen in Fig. 4. The highest defect in the production line of men's jackets is the finishing part with the name bubble defect of 31.8%.

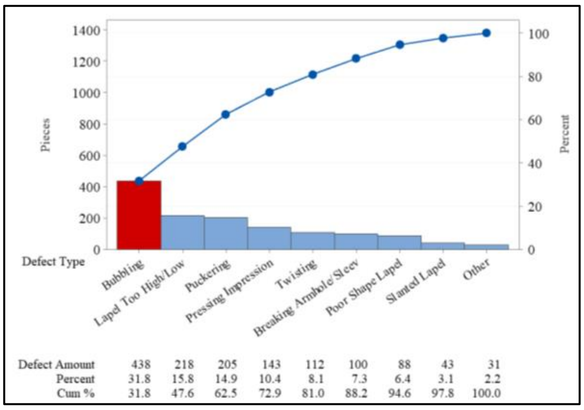

Fig. 4. Pareto diagram before improvement

Measure stage: The data processing results using Six Sigma before improvement. The data used is data from Jan~Apr 2021. The calculation of the sigma level before the improvement (January sample) using the formula (1) Defect Per Unit (DPU), (2) Defect Per Opportunities (DPO), (3) Defect Per Million Opportunities (DPMO), and (4) is as follows:

$\text{DPU} = \frac{366}{1,875} = 0.1952$

$\text{DPO} = \frac{0.1952}{9} = 0.02168$

$\text{DPMO} = 0.02168 \text{ x } 1,000,000 = 21,689$

$\text{Sigma Levels} = \text{NORM.S.INV} \frac{(1,000,000-21,688)}{1,000,000} + 1.5 = 3.5749$

Analysis stage: The result of the data processing using the Control P-Chart before improvement can be seen in Fig. 5. The calculation of Upper Control Limit (UCL), Control Limit (CL), and Lower Control Limit (LCL) before the improvement (Jan~Feb 2021 samples) using the formula (5), (6), and (7).

Based on Fig. 5 shows the results that there are still six samples outside the control limit (UCL = 0.2805), which means that the defect is out of control, so it is necessary to analyze the cause of the defect. The next analysis is to analyze bubbling defects with a causal diagram or Fishbone diagram, which determines the main causes of defects that occur at the finish line. The main causes of bubbling defects in the Finishing line. There are five factors Machine, Material, Method, Man, and Environment (Fig. 6).

$\text{CL or } \overline{\text{P}} = \frac{\sum \text{defect}}{\sum \text{Inspection}} = 0.1779$

$\text{UCL} = 0.1779 + 3\left(\sqrt{\frac{0.1779(1-0.1779)}{125}}\right) = 0.2805$

$\text{LCL} = 0.1779 - 3\left(\sqrt{\frac{0.1779\,(1-0.1779)}{125}}\right) = 0.0753$

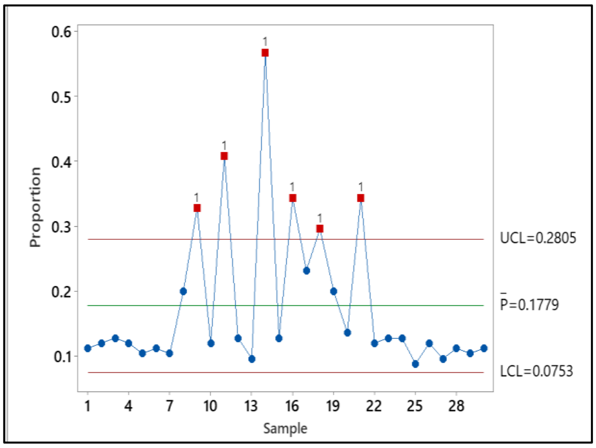

Fig. 5. Control chart before improvement

Improve stage: After knowing the cause of the bubbling defect, an FGD was conducted to determine 5W+1H corrective actions. Details of the profiles of the five expert judgments can be seen in Table 4. The results of data processing using RCA resulted from the why-why analysis during FGD with improvement plans using the 5W+1H method (Table 5).

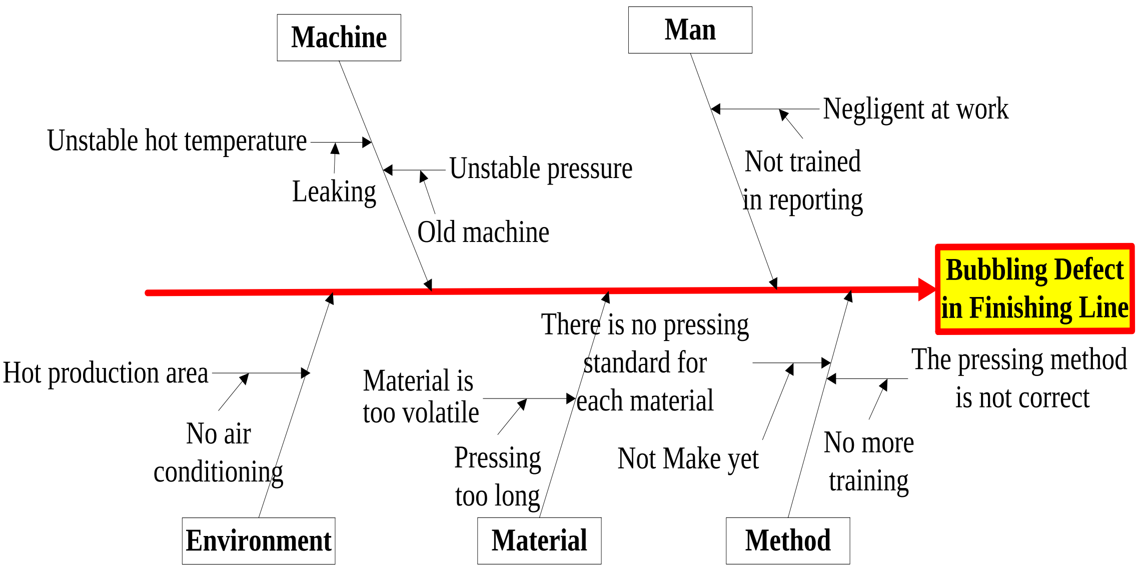

Fig. 6. Fishbone diagram of finishing line defect

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Table 4. An expert judgment or assessor profile

Expert	Age (years)	Work Experience (years)	Position	Special Skill	Remarks
Expert 1	52	18	Board of Director	Sustainability Development	Internal
Expert 2	49	23	General Manager	Lean Manufacturing	External
Expert 3	47	15	Production Manager	Lean Six Sigma (LSS) and Total Productive Maintenance (TPM)	External
Expert 4	45	18	Maintenance Manager	and Overall Equipment Effectiveness (OEE)	External
Expert 5	42	13	Spesialis	DMAIC and Kaizen	Consultant

Table 5. 5W+1H Result

No	What	Why	How	Who	When	Where
	What is the problem?	Why should it be dealt with?	How to deal with it?	Who is in charge?	When will it be implemented?	Where is it carried out?
1	Unstable hot temperature	The pressing machine is too old, and the spare part has been discontinued	Propose change of heater machine and maintenance once a month	Wahyu S	May 3rd, 2021	Pressing machine
2	Negligent at work	No warning sign related to WI	Placing work instruction documents or warning signs near the work area	Sukamto	May 15th, 2021	Near production area
3	No more training	New employees for the finishing line need SOP training	Every new employee needs to be given theoretical and practical training	Dating A	Jun, 2nd 2021	Finishing line area
4	Material is too volatile	No material inspection has arrived yet	A random inspection of every arrival lot	Himawari	Jun, 7th 2021	Laboratory
5	Hot production area	Employees are not comfortable working	Provide a fan and schedule a fan cleaning once a month	Asep G	Jun, 8th 2021	Production area

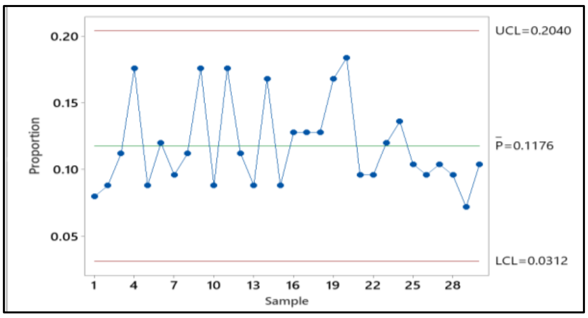

Fig. 7. Control chart after improvement

Control stage: Control P-Chart in data processing by sampling data after improvement can be seen in Fig. 7. The results that no samples are outside the control limits (UCL = 0.2040), which means that the defects are very controlled as the result of correct and continuous corrective actions. After taking corrective actions, the next step is to check the results of Six Sigma through the level of sigma and defect (%) before and after improvement (Table 6).

Table 6. Comparation six sigma

Month		DPU	DPO	DPMO	Sigma Level	Defect (%)
Before Improvement	Jan 21	0.1952	0.0217	21,689	3.5749	19.52
	Feb 21	0.1829	0.0203	20,326	3.5774	18.29
	Mar 21	0.1835	0.0204	20,385	3.5661	18.35
	Apr 21	0.1733	0.0193	19,259	3.5877	17.33
	Average	0.1837	0.0204	20,415	3.5765	18.37
After Improvement	Jul	0.1067	0.0119	11,852	3.7685	10.67
	Aug	0.1120	0.0124	12,444	3.7502	11.20
	Sep	0.0928	0.0124	10,311	3.8235	9.28
	Oct	0.0992	0.0110	11,022	3.7839	9.92
	Average	0.1027	0.0114	11,407	3.7839	10.27

3.2. Discussion

Previous literature reviews can be discussed due to the similarities with this study. Six Sigma is a method for reducing product variance and increasing productivity [30]. This method can also identify complex problems. In general, the implementation of Six Sigma is carried out in the DMAIC stage [31]. This methodology is a structured problem-solving step starting from determining the problem, measuring, identifying the cause of the problem, finding an improvement plan, and standardizing the improvement results [20]. Efforts to improve quality control can also be carried out using seven quality control tools applied to the manufacturing industry [32], [33].

Integrating Lean and Six Sigma through research approaches and studies can reduce waste and improve product and service quality [34]. Applying Six Sigma can reduce product defects by appropriate quality control of garment products. The dominant product defects in the garment industries are broken material, misprinting, shade variation, and button miss [35].

This methodology can provide effective results for optimizing product quality to obtain efficient production costs in the garment industry [36]. This research still uses DMAIC Approach, where the Six Sigma method is used at the Measure stage (before improvement) and after Control (after improvement). Meanwhile, for data analysis techniques, each stage uses Pareto diagrams, Control charts, and Fishbone diagrams to determine 5W+1H using FGD analysis with five expert judgments.

The advantages of this research, when compared to previous research, with the DMAIC method, each stage uses a quality improvement tool, so that this study can choose an appropriate and comprehensive quality improvement tool. In addition, implementing Six Sigma at the Measure stage gets a sigma level before the repair, and after the control stage, it increases the sigma level after the repair. Another advantage is that the FGD method, carried out before 5W + 1H, was determined by five experts who could decide the policy.

The contribution of this research by applying the Six Sigma method to the DMAIC approach on a regular and targeted basis by selecting several quality improvement tools as needed, this research has resulted in a sigma level of around 3.57 to 3.78, or an increase of 5.48% for the sigma level at garment industry. This research has also confirmed that for the garment industry with the type of formal product, men's jackets in Indonesia have obtained a reference level of sigma after improvement, which is 3.8 to 3.9.

3.3. Research Implication

The limitation of this research is that it focuses on formal men’s jacket products in the garment industry. The DMAIC approach at each process stage uses quality tools to analyze problems, their main causes, and improvements. This research increases the sigma level and reduces the defect percentage of formal men's jackets in the finishing section.

This study has added value to the garment industry, especially for formal men’s jackets. Every defect that occurs will be controlled through a control chart which will be corrected immediately by the technician. Implementation of Six Sigma with the DMAIC approach is a renewable method in the garment industry that is usually repaired using the PDCA method, which only knows the percentage of defects.

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3.4. Quality Improvement Recommendation

After making improvements by implementing Six Sigma in the DMAIC approach, the recommendations will be made. So that the quality of formal men's jackets can be maintained and even improved, the authors provide input for improvements, including the acceptance of fabric materials. There must be a random quality inspection of the fabric between arrival lots so that the material the fabric received will be selected for the quality of the fabric that has a non-volatile strength in tuning the jacket. While the condition of the pressing team, the temperature must be stable, and routine maintenance once a month is carried out so that the machine's condition does not have problems during the jacket pressing process on the machine. Furthermore, a comfortable environment with fans and adequate standard operating procedures will facilitate and motivate employees in their work.

4. CONCLUSION

The conclusion that can be put forward in this study related to how to implement the Six Sigma method in the DMAIC approach is by entering the Six Sigma measurement at the Measure stage as a measurement of the sigma level before the improvement. In contrast, after the improvement, the sigma level can be measured after the Control stage. The results of this study have succeeded in increasing the level of sigma from 3.5765 to 3.7839, an increase of 5.48%. This study also found that the dominant factor causing defects was bubbling defects in the finishing line, which consisted of the machine, man, material, method, and environmental factors. The factors that cause the machine consist of unstable hot temperatures, human causes including neglect at work, the lack of training repressing methods, the cause of material consisting of fabric material that is too volatile, and causing the environment consisting of a hot production area.

Improvements that have been made include: proposing the replacement of engine heaters and scheduling engine maintenance once a month, attaching Work Instructions (WI) documents or warning signs in the work area, every new employee needs to be given theoretical and practical training, random inspection of every arrival lot, and provide fans and schedule cleaning once a month. These improvements resulted in a reduction in finish line defects from 18.37% to 10.27%, which means defects decreasing at the finish line is 44.09% every month and achieving the target of 114%. So this study recommends that every part of the garment industry implement the Six Sigma method to reduce defects so that productivity will increase. For further research, the authors agree with the management's proposal to improve the production process by integrating the Lean Manufacturing (LM) and Green Manufacturing (GM) methods to increase productivity and reduce environmental waste so that it is environmentally friendly.

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