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(Research) Article

Evaluation of the Causes of Defects in Woven Sarongs at PT Ibrahim Bin Manrapi Using the Six Sigma Method

Abdul Kholiq [1]*, Rahmat Agus Santoso [2]

[1] Universitas Muhammadiyah Gresik 1; e-mail : kholiq9558@gmail.com
[2] Universitas Muhammadiyah Gresik 2; e-mail : ra_santoso@umg.ac.id

* Corresponding Author : Abdul Kholiq

Abstract: This study aims to trigger the causes of defects in woven sarong products at PT Ibrahim Bin Manrapi and provide improvement solutions through the application of the Six Sigma method with the DMAIC (Define, Measure, Analyze, Improve, Control) approach. The main problem faced by the company is the high level of product defects which reaches an average of 4.21% of total production, with the dominant types of defects including sewing defects (46.36%), color defects (24.96%), size defects (16.53%), and torn fabric (12.15%). Data were obtained through in-depth interviews, observations, and documentation in the production department. The measurement results show a Defects Per Million Opportunities (DPMO) value of 42,100 with a sigma level of 3.36, which indicates that production quality is still below Six Sigma standards. Analysis of the causes of defects using the 5M approach (Man, Machine, Method, Material, Measurement) shows that the main factors causing defects come from old ATBM weaving machines, lack of operator accuracy and skills, complicated manual work methods, and the absence of consistent quality control standards at the end of the process. Recommended improvement efforts include machine rejuvenation, workforce training, implementation of standard operating procedures (SOPs), and continuous quality monitoring through the use of control charts. The application of the Six Sigma method has proven effective in helping companies identify problem sources and develop strategies for systematic and sustainable product quality improvement.

Keywords: DMAIC; product defects; quality; Six Sigma; woven sarong.

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1. Introduction

The manufacturing industry is one of the strategic sectors that plays an important role in the national economy, both as a provider of employment and a driver of non-oil and gas exports. In this sector, product quality is a major factor in determining a company's competitiveness amid global competition. According to Yulistria (2023), quality is an important indicator that distinguishes a business from its competitors and illustrates the ability of products to meet consumer needs. Meanwhile, Islachiyana (2023) explains that defective products can have a serious impact on operational efficiency and production costs, so good quality management is key to achieving effectiveness, efficiency, and competitive advantage for companies.

One manufacturing sub-sector that strongly emphasizes the importance of quality is the traditional textile industry, particularly the production of woven sarongs. These products have high economic and cultural value. In Gresik Regency, woven sarongs are an important part of the community's tradition, and the area is known as a center for sarong craftsmen with various motifs and qualities, one of which is the Lamiri brand woven sarong produced by PT Ibrahim Bin Manrapi. This company was established in 1939 in Wajo Regency, South Sulawesi, and has become widely known throughout Madura and the Middle Eastern market through individual distribution. To expand its market reach, the company has also developed a digital platform through the Lamiri Online Shop with three main types of products, namely full silk, 50% silk, and mesres.

Despite being known for its high-quality products, PT Ibrahim Bin Manrapi still faces product defect issues in its production process, such as broken threads, uneven colors, asymmetrical patterns, and inconsistent sizes. Based on 2024 production data, there were a total of 593 defective pieces out of 12,779 woven sarongs (4.21%), with the highest defect rate in August at 6.06%. The most common type of defect was stitching defects (275 pieces), followed by color, size, and torn fabric defects. Interviews with the Head of Production revealed that the use of old ATBM weaving machines was one of the main causes of the increase in product defects. This condition indicates the need for a comprehensive evaluation of the production process so that the causes of defects can be systematically identified.

To illustrate the production defect conditions at PT Ibrahim Bin Manrapi, the following data shows the number of woven sarong product defects during the period from June to December 2024.

Tabel 1. Data Cacat Produksi PT Ibrahim Bin Manrapi (2024).

Month	Production Quantity (pieces)	Sewing Defects (pieces)	Color Defects (pieces)	Size Defects (pieces)	Fabric Torn (pieces)	Total Defects (pieces)	Percentage (%)
Jun	1.669	35	20	15	10	80	4,79%
Jul	1.491	40	18	12	8	78	5,23%
Augs	1.485	38	22	17	13	90	6,06%
Sept	1.672	42	25	10	9	86	5,14%
Okt	1.784	36	19	14	11	80	4,48%
Nov	1.508	39	21	13	10	83	5,50%
Des	1.679	45	23	16	12	96	5,71%
Total	12.779	275	148	97	73	593	4,21%

Sumber: Data Perusahaan (2024)

Based on the data in Table 1.1, it can be seen that during the period from June to December, the number of defects in the production of woven sarongs using non-machine weaving tools (ATBM) fluctuated, with a total of 593 defective items out of a total production of 12,779 items. The highest defect rate occurred in August at 6.06%, while the lowest occurred in October at 4.48%. The most common type of defect was stitching defects (275 pieces), followed by color defects (148 pieces), size defects (97 pieces), and torn fabric (73 pieces).

One relevant method to address this problem is Six Sigma, which uses the DMAIC (Define, Measure, Analyze, Improve, Control) approach. According to Ahmad (2019), Six Sigma aims to achieve a maximum error rate of 3.4 defects per million opportunities through process control and continuous quality improvement. Garpersz (2011) also states that Six

Sigma plays an important role in reducing process variation and improving product quality through measurable and data-driven steps. In the context of PT Ibrahim Bin Manrapi, the application of Six Sigma can help identify the main causes of defects, improve worker skills, and optimize the quality control system so that the production process is more efficient and the product meets quality standards.

Several previous studies support the effectiveness of the DMAIC method in reducing production defect rates. Nugroho (2024) proved that the application of Six Sigma can reduce product defects by up to 50% and significantly reduce operational costs. Eliza (2025) explained that the DMAIC method helps with a systematic improvement process, from problem identification to result control. Meanwhile, Alvionita's (2024) research shows that Six Sigma is effective in finding the causes of defects based on human, machine, method, material, and environmental factors. These research results indicate that the Six Sigma approach is relevant for application in traditional textile industries such as woven sarongs.

Based on this description, it can be concluded that the high level of product defects in the Lamiri woven sarong production process requires a systematic and measurable evaluation to improve production quality and efficiency. The application of the Six Sigma method with the DMAIC approach is expected to assist PT Ibrahim Bin Manrapi in identifying the main causes of defects, reducing process variation, and improving product quality in a sustainable manner. Therefore, this study is titled "Evaluation of the Causes of Woven Sarong Product Defects at PT Ibrahim Bin Manrapi Using the Six Sigma Method."

2. Preliminaries or Related Work or Literature Review

Literature

Previous studies have shown that the application of the Six Sigma method is effective in reducing product defects and improving production quality in various industrial sectors.

Suhartini & Ramadhan (2021) found that human, machine, material, method, and environmental factors influence product failure during the production process, with human factors being the dominant cause due to a lack of discipline and precision in work.

Subahagia Ningsih & Zaharuddin (2021) studied defects in cooking oil jerry cans at PT. ABC, where out of 1,456,671 units, 30,511 units were defective with a sigma value of 3.54 and a DPMO of 20,942. The dominant type of defect was damage to the jerrycan body (57%), which became the top priority for improvement.

Hizbullah & Wahyuni (2023) applied Six Sigma and RCA at PT. XYZ and succeeded in increasing production efficiency from 53.4% to 61.2%. Human factors, skills, and component quality were the main causes of defects, with three dominant CTQs, namely Backstay Miring, Broken Emboss, and Bad Logo.

Furthermore, Puji (2024) at UD. Berkah Fajar found six types of product defects, with a DPMO value of 89,711.65 and a sigma level of 2.843. After improvements using the DMAIC method, the DPMO value decreased to 20,486.11 and the sigma increased to 3.544.

Putri (2022) applied Six Sigma to the combination batik industry and found three main defects, namely broken wax, colors outside the theme, and uneven colors, with an average

DPMO value of 250,708.92 and a sigma level of 2.18, indicating the need for improved discipline and standardization of the production process.

Fajar (2025) proved that the application of DMAIC in the X MSME shoe industry reduced the defect rate from 5.5–7.1% through operator training and machine maintenance.

Meanwhile, Multidisiplin (2025) at the Alfitra Bakery Factory found two main defects, namely burnt bread (RPN 490) and under-risen bread (RPN 210), with the dominant causes being human and equipment factors.

In general, these studies confirm that the Six Sigma approach with DMAIC stages can help companies identify the root causes of defects, reduce DPMO values, and significantly improve sigma levels. The main factors that most influence product quality are people, machines, methods, and the environment.

Quality

Quality is an important indicator of a business's success in facing various challenges and meeting customer needs. In general, quality can be defined as a product's ability to meet established requirements and expectations. According to Epilinus Hulu1, Yupiter Mendrofa2, (2022), quality is a major concern for consumers in determining their purchasing decisions because it is directly related to customer satisfaction and company profitability. Thus, quality reflects customers' perceptions of the performance of the products and services they receive.

In modern quality systems, there are several key characteristics, namely focusing on customer satisfaction, involving active participation from top management, emphasizing individual responsibility for quality, and prioritizing damage prevention over mere detection. By applying these principles, companies can create high-quality products that can increase competitiveness and consumer trust.

Quality

Quality control is a process that aims to ensure that production results meet established standards. According to Ivanda & Suliantoro (2019), quality control is an effort to assess and evaluate performance in maintaining product quality so that it remains in accordance with standards, as well as improving business capabilities in reducing product non-conformities through effective supervision. With quality control, companies can detect deviations in the production process earlier and minimize the potential for errors.

Taufik Alfin Ashari (2022) adds that quality control is an important factor in the production process, where each stage involves checking and assessing product characteristics to ensure they meet the specified requirements. The main objective of quality control is to ensure customer satisfaction through products that meet their needs and expectations. According to Tambunan (2020), the objectives of quality control include:

1. Ensuring that products comply with established quality standards,
2. Keeping quality costs as low as possible,
3. Streamlining the production process without reducing product quality, and
4. Ensuring that product quality remains stable at a reasonable cost.

Thus, quality control does not only focus on the end result, but also on the processes that ensure efficiency and effectiveness in production.

Furthermore, Adi Juwito & Ari Zaqi Al-Faritsy (2022) explain that there are several factors that influence a company's quality control, including:

1. Process capability, which is the extent to which production procedures and steps are capable of producing products that meet established standards.
2. Level of specialization, which relates to expertise in producing products according to consumer needs and production process capabilities.
3. Control objectives, which are to reduce the number of defective products to below the quality tolerance limit.
4. Quality costs, which are expenses that significantly affect product quality; the more attention paid to quality costs, the better the quality of the products produced.

Thus, quality control is an important aspect that not only ensures product conformity to standards but also improves cost efficiency and company productivity. In the context of PT Ibrahim Bin Manrapi's woven sarong industry, the effective implementation of quality control is essential to minimize product defects, maintain quality consistency, and enhance customer satisfaction.

Six Sigma

The Six Sigma method is a data-based management strategy developed by Motorola in 1986 as an effort to improve product quality through control of production process variation (Adi Juwito & Ari Zaqi Al-Faritsy, 2022). Six Sigma focuses on achieving a very low error rate, namely only 3.4 defects per million opportunities (DPMO), which means that the process success rate reaches 99.99966%. This approach emphasizes the importance of continuous improvement to achieve near-perfect product quality.

According to Tambunan (2020), Six Sigma is a structured and fact-based method with the main objective of improving operational efficiency and organizational growth. Its application focuses on three main aspects, namely reducing production cycle time, reducing the number of defective products, and increasing customer satisfaction. In line with this, Angga Adi Pratama (2020) explains that Six Sigma has five main stages known as the DMAIC (Define, Measure, Analyze, Improve, Control) concept, which is used to improve processes and maintain quality stability systematically.

Utami (2023) adds that the Six Sigma method has a high level of accuracy in measuring process performance through sigma and DPMO values. The higher the sigma level, the lower the defect rate in the production process. One of the advantages of Six Sigma is its ability to link statistical analysis results with real actions in the field for continuous improvement. According to Arifin (2019), the DMAIC stages in Six Sigma consist of:

1. **Definition**

   Identify problems, set project goals, and determine critical to quality (CTQ) characteristics related to customer needs.

2. **Measurement**

   Collect data, analyze process capabilities, and calculate the DPMO value using the formula:

   DPOM = (D / (U x O)) x 1,000,000
   DPOM = (number of defects)/(total number of units x opportunity)
   D = Number of Defects
   U = Number of Units
   O = Opportunity

At this stage, tools such as control charts, Pareto charts, and scatter plots are used to understand the process conditions quantitatively J.Alfani Yanto Sulistyo1 (2022).

1. **Analyze**
   Identify the root causes of problems using tools such as Pareto charts to determine the priority of the most significant defects and cause-and-effect diagrams (fishbone diagrams) to find the main contributing factors Nasrun (2020).
2. **Improve**
   Design and implement solutions to eliminate the root causes of defects and ensure that processes run more efficiently and consistently.
3. **Control**
   Establish control procedures and operational standards so that the improvements made can be maintained and do not cause new variations in the future.

The Six Sigma method with the DMAIC approach has been widely applied in the textile and garment industry to reduce product defect rates. Research by Ananda & Puspitasari (2024) shows a sigma value of 4.58 in the garment printing process, with the root causes of defects identified through a fishbone diagram. Meanwhile, Fitria (2023) found a sigma value of 3.15 in polyester fabric production at PT Sukuntex with the support of the FMEA and AHP methods in determining improvement priorities. Kurnia's (2022) research also proves that the application of Six Sigma with the addition of benchmarking strategies and Key Performance Indicators (KPI) is effective in improving the quality of formal suit products. In addition, Fibriani (2023) proves that the application of Lean Six Sigma can identify waste and significantly reduce process variation in the garment industry.

Based on these various research results, it can be concluded that the Six Sigma method, particularly through the DMAIC approach, is an effective tool for improving the quality and efficiency of production processes. The application of this method in the woven sarong industry, such as at PT Ibrahim Bin Manrapi, is expected to reduce defect rates, improve product quality, and increase the company's competitiveness in both domestic and international markets.

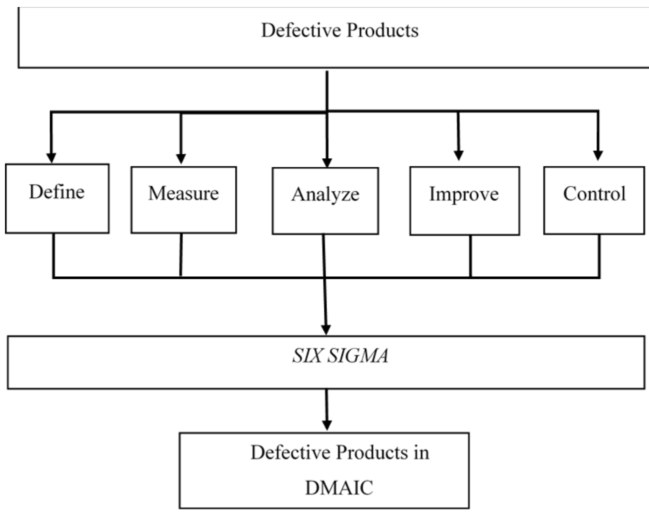

Figure 1. Thought Flow.

Source: Processed Researcher, 2025

3. Proposed Method

This study uses a descriptive qualitative approach with the aim of analyzing the causes of defects in woven sarongs at PT. Ibrahim Bin Manrapi using the Six Sigma method. A qualitative approach was chosen because it is able to describe the actual conditions in the field in depth without manipulating the research variables. According to Hanyfah (2022), qualitative research aims to clarify existing phenomena through direct data collection, while according to Charismana (2022), this approach uses descriptive language to explain social situations contextually.

This research was conducted at PT. Ibrahim Bin Manrapi, located at Jl. Malik Ibrahim No. 24, Bedilan, Kebungson, Kec. Gresik, Kab. Gresik, East Java. This company is engaged in the production, distribution, and sale of woven sarongs both online and offline. This location was chosen because it is the main production center and a source of primary data related to the woven sarong production process.

The unit of analysis in this study was the woven sarong production department at PT. Ibrahim Bin Manrapi, with informants selected using purposive sampling. According to Lenaini (2021), purposive sampling is a non-random sampling technique that considers the relevance and competence of respondents to the research topic. Based on the criteria set, namely understanding product defect characteristics, having at least four years of experience, and being directly involved in the production process, four main informants were selected.

Tabel 2. Unit analisis.

NO	Informant	Departement	Years of Service
1	Director	Manajement	15 Years
2	Operational Manager	Operations	8 Years
3	Employee	Production Staff in the Dyeing Department	4 Years
4	Employee	Production Staff in the Weaving Department	5 Years

Source: Processed Researcher, 2025

These informants were selected because they play strategic and complementary roles in the woven sarong production system, enabling them to provide a comprehensive view of the causes of product defects.

The type of data used is subjective data, which is data obtained from individuals or groups who are the subjects of the study. This data includes opinions, experiences, and strategies for overcoming product defects. In addition, this study also uses quantitative data in the form of the number and frequency of product defects to support Six Sigma analysis.

The data sources consist of primary and secondary data. Primary data was obtained through interviews, observations, and direct documentation with parties involved in the production process, such as directors, operations managers, and production staff. Meanwhile, secondary data was obtained from internal company documents such as production reports, defect records, and relevant literature and previous studies.

Data collection techniques were carried out using three main methods. First, interviews, which are direct conversations between researchers and informants to explore information about the production process, obstacles, and causes of product defects. Second, observation, which is direct observation of work processes, machine conditions, and the working environment in the production area. Third, documentation, which is the collection of written and visual evidence such as defect reports, photos of the production process, and other operational documents.

Data analysis was carried out in three stages according to the Miles and Huberman model: data reduction, data presentation, and conclusion drawing. The data reduction stage was carried out by selecting and simplifying raw data into relevant and structured information. The data presentation stage was carried out by compiling the analysis results in the form of narratives, tables, and graphs for easy understanding. Finally, the conclusion drawing stage is carried out gradually from the data collection process until the final results explaining the main factors causing product defects are obtained.

To ensure data validity, this study uses the triangulation technique, which is comparing the results of various data collection methods from interviews, observations, and documentation to ensure the consistency and validity of the information. According to Wardatun & Khadavi (2025), triangulation is a strategy to increase the credibility of research results through cross-verification of methods and data sources. With the application of this triangulation technique, the data obtained becomes more accurate and credible, so that the research results can provide a comprehensive picture of the evaluation of the causes of woven sarong product defects at PT. Ibrahim Bin Manrapi using the Six Sigma method.

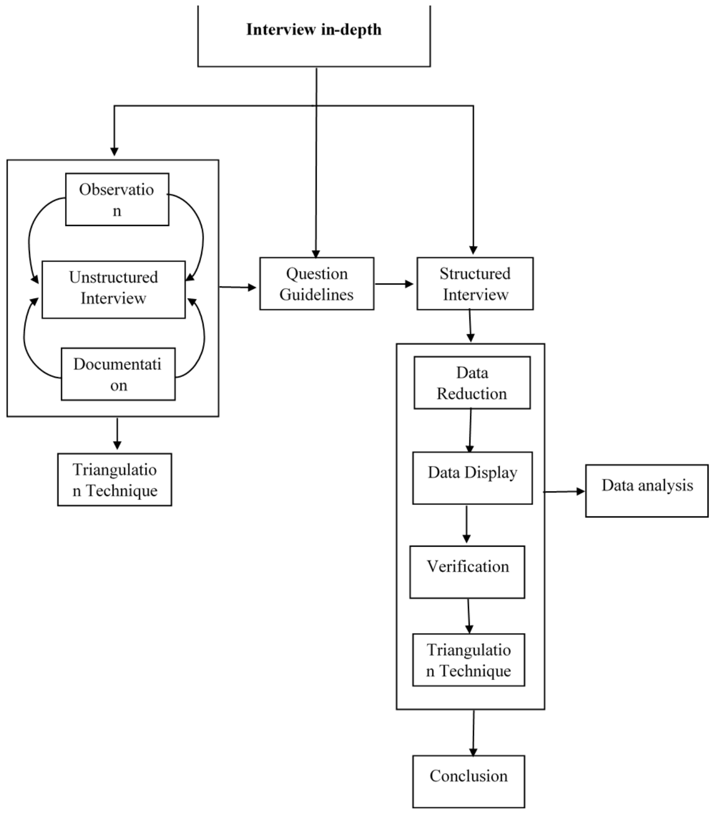

Figure 2. Research Stage.

4. Results and Discussion

Research Results

This research was conducted at PT. Ibrahim Bin Manrapi from April to June 2025, involving four key informants, namely the Director, Operations Manager, dyeing department employees, and weaving department employees. Data collection was carried out through in-depth interviews (unstructured and structured), direct observation, and production documentation. The main objective of this study was to identify and analyze the causes of defects in woven sarongs using the Six Sigma approach through the DMAIC (Define, Measure, Analyze, Improve, and Control) stages.

Based on the results of interviews, observations, and documentation, it was found that the woven sarong production process at PT. Ibrahim Bin Manrapi still relies on non-machine weaving tools (ATBM), which are manual and highly dependent on worker skills. This condition results in a high level of human error and impacts product quality variation. In addition, the old condition of the machines, the inconsistency of raw materials, and the absence of written SOPs worsen the consistency of the woven fabric quality.

According to Garpersz (2011), the causes of product defects can generally be traced to the factors of Man, Machine, Method, Material, and Measurement (5M). This is in line with the findings at PT. Ibrahim Bin Manrapi, where all of these factors have a mutual influence on the quality of the woven sarongs produced.

Analysis Based on the DMAIC Stages

Define

In the Define stage, this study found that the main problem at PT Ibrahim Bin Manrapi was the high number of defective woven sarongs, which included stitching defects, color defects, size defects, and torn fabric. Based on interviews and observations, the main factors causing defects were the limited skills of workers in operating non-machine looms (ATBM), the absence of written SOPs, and an unsupportive work environment. This stage aimed to establish a focus on quality improvement directed at reducing product defect rates to increase efficiency and maintain the quality of woven sarongs.

The identification results show four main characteristics that are Critical To Quality (CTQ), namely:

1. Stitching defects, characterized by untidy weaving patterns and loose threads due to the operator's lack of precision;
2. Color defects, in the form of uneven or mottled colors due to inconsistent manual dyeing processes;
3. Size defects, which occur when the dimensions of the sarong do not meet the standard length of 100 cm due to equipment setting errors; and
4. fabric, in the form of tears or holes in the fabric that render the product unsellable.

These four CTQs became the main focus of the research to be analyzed in the next stage, namely Measure, to determine the most dominant quality characteristics that affect the defect rate of woven sarongs.

Measure

In the Measure stage, product defect rates were measured to determine the quality characteristics that most influence the quality of woven sarongs at PT Ibrahim Bin Manrapi.

The analysis was carried out using a Pareto chart, DPMO and sigma level calculations, and a control chart (P-Chart) to monitor the stability of the production process.

a. Determination of Potential CTQs and Pareto Chart

Table 3. Percentage of Defect Types.

No	Type of Defect	Defect frequency	Cumulative Defect Frequency	Percentage of Defect Frequency	Cumulative Percentage of Defect Frequency
1	Stitching Defect	275	275	46,38 %	46,38 %
2	Color Defect	148	423	24,96 %	71,34 %
3	Size Defect	97	520	16,36 %	87,68 %
4	Torn Fabric	73	593	12,32 %	100 %
	Total	593		100 %	

Source: Data Processing Results, 2025

The measurement results in the table above show four main types of defects, namely stitching defects, color defects, size defects, and torn fabric. Based on the defect frequency data during the observation period, sewing defects were the most dominant with a percentage of 46.38%, followed by color defects at 24.96%, size defects at 16.36%, and torn fabric at 12.32%. The top two types of defects (stitching and color) account for more than 70% of total product defects, in accordance with the 80/20 Pareto principle, which shows that most quality problems are caused by a small number of major factors. Thus, these two types of defects are the main focus of quality improvement in the company.

b. DPMO and Sigma Value Calculations

Table 4. DPMO and Sigma Calculations.

Period (month)	Total Production (Pcs)	Total Defective Productive (Pcs)	CTQ	DPMO	Sigma Level
June	1.669	80	4	11.983,23	3,76
July	1.491	78	4	13.078,48	3,73
August	1.485	90	4	15.151,52	3,67
September	1.672	86	4	12.858,86	3,74
October	1.784	80	4	11.210,77	3,79
November	1.508	83	4	13.759,95	3,71
December	1.679	96	4	14.294,23	3,69
Total	12.779	593			
Average				13.191,01	3,73

Source: Data Processing Results (2025)

The measurement results in the table above were taken from June to December 2024, with a total production of 12,779 pieces and 593 defective products. Based on the average calculation, the DPMO value obtained was 13,191.01 and the sigma level was 3.73, indicating that the production process was in the medium quality category and still had room for improvement.

October was the period with the best quality (lowest DPMO of 11,210.77; sigma of 3.79), while August showed the lowest quality (highest DPMO of 15,151.52; sigma of 3.67). This fluctuating pattern indicates that the production process is not yet fully stable and requires evaluation in months with high defect rates.

c. Control Chart

To ensure the stability of the production process, a P-chart control chart was used to illustrate the proportion of defects in relation to total production. Based on the results of data processing using Minitab software, the upper control limit (UCL) was 0.0562, the lower control limit (LCL) was 0.0279, and the center line (CL) was 0.0421.

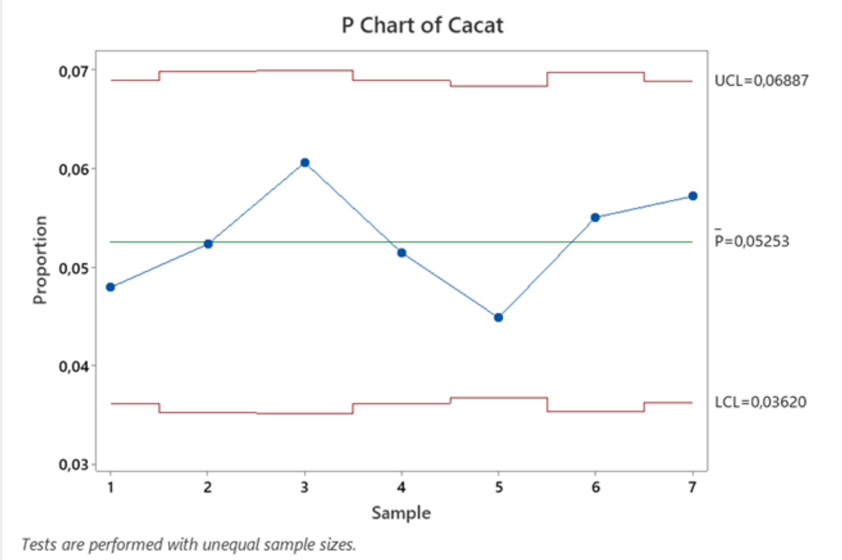

Figure 3. Results of the P-Chart control chart for product defects during one period from June to December 2024.
Source: Researcher's processing (2025)

Based on the analysis results above, all observation points are within the statistical control limits, indicating that the production process is stable. However, the average defect rate of 5.25% shows that the defect level is still relatively high. When converted to DPMO units, this value is equivalent to approximately 52,530 defects per million opportunities or equivalent to ±3.1 sigma.

Overall, the Measure stage shows that although the woven sarong production process at PT Ibrahim Bin Manrapi is statistically controlled, product quality still needs to be improved, especially by reducing the proportion of sewing and color defects, which are the largest contributors to total defects. Continuous improvement of these two types of defects is expected to increase the sigma value and reduce the DPMO level in the next production period.

Analyze

The Analyze stage aims to identify the main root causes of the high defect rate in woven sarongs at PT Ibrahim Bin Manrapi. Based on the Pareto analysis results, it was found that the most dominant types of defects were stitching defects at 46.38% and color defects at 24.96% of the total defects. These two types of defects were the main focus of the analysis because they contributed to more than 70% of the total product defects.

These results were reinforced by the Production Manager's statement, "The most frequent errors are indeed in the stitching. Because the process is manual using ATBM, sometimes the weaving is uneven or the threads come loose. Sometimes the colors are also not consistent because the dyeing is unstable." This shows that the skills of the workers and the condition of the manual machines greatly affect the quality of the weaving.

Through fishbone (Ishikawa) analysis, the root causes of stitching and color defects were grouped into five main factors: human, machine, method, material, and environment. In stitching defects, the human factor was the dominant cause due to the lack of operator skills and training. Non-standardized and poorly maintained manual machines (ATBM) also increased the risk of defects. In addition, the absence of standard operating procedures (SOPs), inconsistent thread quality, and poor lighting in the work area further worsened the weaving results.

Meanwhile, the main cause of color defects was the dyeing process, which was still done manually without standard time, temperature, or automatic dipping tools. Workers often dye based on personal experience without proper measuring tools. Material factors such as yarn with uneven color absorption and humid environmental conditions also worsen inconsistent color results.

Table 5. Severity, Occurrence, Detection, and RPN values for stitching and color defects.

Type of Defect	Effect of Defect	Factor	Cause of Defect	Severity	Occurrence	Detection	RPN
Stitching	Uneven stitching pattern, loose threads, reduces product aesthetics	Human	Lack of operator skills and training	8	7	6	336
		Machine	Non-standard manual sewing machines, no regular maintenance	6	6	5	180
		Method	No SOP for stitching quality inspection	7	6	5	210
		Material	Thread too thin, not meeting standard	6	6	5	180
		Environment	Poor lighting, narrow and noisy workspace	5	5	4	100
Color	Uneven color, faded, mismatched, reduces product value	Human	Coloring based on experience/estimation without training	9	6	6	324
		Machine	Coloring without proper dipping or stirring equipment	7	5	5	175
		Method	No SOP for dyeing process, color measurement not standardized	8	6	5	240
		Material	Thread with inconsistent absorbency	7	6	5	210
		Environment	Unstable drying, uncontrolled temperature and humidity	6	5	4	120

Source: Researcher's Compilation, 2025

To determine the priority of handling, the Failure Mode and Effect Analysis (FMEA) method was used by assessing the severity, occurrence, and detection capability of each type of defect. Based on the calculations in the table above, it shows that the human factor in stitching defects has the highest Risk Priority Number (RPN) value of 336, followed by color defects in the human factor with a value of 324. The method and material factors also have a fairly high RPN value, between 180-240, which indicates the need for improvements in the work system and control of raw material quality.

Overall, the total RPN value reaches 2,075, which indicates that the risk level of production defects is still high. The human factor is the main root cause that needs to be immediately addressed through operator training programs, standardization of work procedures, and improved quality control of materials and processes. In addition, machine maintenance and better work environment management are also necessary to ensure more consistent and higher quality weaving results.

Improve

The Improve stage is a follow-up step after the root causes of defects have been identified through Fishbone and FMEA analysis. At this stage, PT Ibrahim Bin Manrapi established various corrective actions to improve the quality of woven sarongs based on the highest Risk Priority Number (RPN) value. Improvement efforts focused on human factors, work methods, and production environment conditions that most influenced stitching and color defects.

At this stage, improvements are made using the 5W+1H approach, which includes improving operator skills through technical training, developing and implementing production SOPs, and improving work facilities such as lighting and enclosed drying rooms. The production manager is responsible for ensuring that SOPs are implemented consistently and for performing routine maintenance on equipment and inspecting raw materials. Meanwhile, weaving and dyeing operators are required to attend regular training, check the condition of tools and materials before production, and maintain stable temperatures and cleanliness in the workspace. These improvement efforts emphasize collaboration between management and workers to reduce product defect rates and continuously improve the quality of woven sarongs.

Overall, the Improve stage at PT Ibrahim Bin Manrapi emphasizes collaboration between management and workers to strengthen a culture of quality. With the consistent application of 5W+1H, it is hoped that product defect rates can be significantly reduced, production efficiency increased, and the competitiveness of Lamiri woven sarongs in the market maintained.

Control

The Control stage is the final step in the Six Sigma DMAIC method to ensure that the improvement results are consistent. After implementing corrective actions using the 5W+1H approach, an evaluation is carried out through DPMO calculations and sigma levels in the woven sarong production process at PT Ibrahim Bin Manrapi.

Table 6. DPMO and Sigma Calculation Results after 5W+1H.

Period (Month)	Total Production (pcs)	Total Defective Products (pcs)	CTQ	DPMO	Sigma Level
April	1,720	45	4	6,540.69	3.99
May	1,685	41	4	6,083.09	4.01
July	1,750	46	4	6,571.43	3.98
Total	**5,155**	**132**			
Average				**6,398.40**	**3.99**

Source: Researcher's Compilation, 2025

Based on the DPMO and Sigma calculations after 5W+1H in the table above, the average DPMO value is 6,398.40 with a sigma level of 3.99, which indicates an improvement in quality compared to before the improvement. May recorded the best performance with the lowest DPMO of 6,083.09 and a sigma level of 4.01, indicating a more controlled and efficient process.

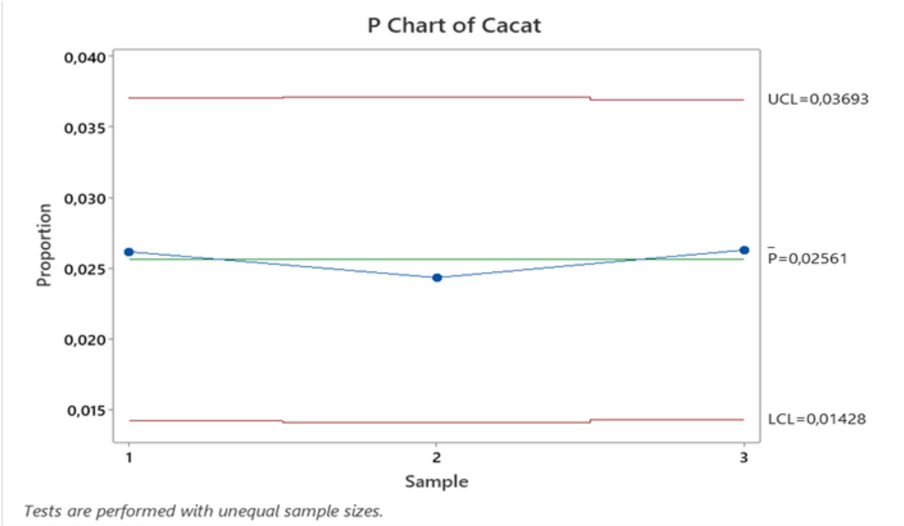

Figure 4. Results of the P-Chart control chart for product defects from April to June 2025 after 5W+1H.

Source: Researcher's processing, 2025

The results of the p-chart analysis in the figure above, using Minitab 22 software, show that all data points are within the upper control limit (UCL = 0.03703) and lower control limit (LCL = 0.01417) with a center line of 0.0256. This indicates that the variation in defects is still within normal limits (common cause variation) and does not show any special deviations.

Overall, the woven sarong production process is statistically controlled. However, the average defect rate of 2.56% can still be further reduced through improved operator training, regular machine maintenance, and raw material monitoring. With continuous control, the company has the potential to increase its sigma level and reduce DPMO to achieve higher quality standards.

Discussion

Based on the results of research at PT Ibrahim Bin Manrapi, the defect rate of woven sarongs in the period June–December 2024 reached an average of 4.21% of total production. The dominant type of defect was stitching defects (46.36%), followed by defects in color, size, and torn fabric. These findings indicate that the production process is not yet optimal. The main factors causing defects are human and machine-related, namely uneven operator skills, work fatigue, and the old condition of the non-machine weaving tools (ATBM). This is in line with the findings of Ananda & Puspitasari (2024), who stated that human and machine factors are the main contributors to defects in the textile industry.

Define

The Define stage identifies the main problem, which is the high defect rate in woven sarongs, especially in stitching and color. The main causes are dependence on the manual skills of operators, the absence of written SOPs, and an unsupportive work environment. Based on Garpersz's (2011) theory, determining Critical to Quality (CTQ) is very important to focus on improvements. In this study, CTQ includes stitching conformity, color accuracy, size, and fabric integrity.

Measure

The Measure stage is carried out to measure the defect rate and process capability. From a total production of 12,779 pieces, 593 defective pieces were found (an average of 4.21%). The DPMO value was 6,398.40 with a sigma level of 4.00, indicating that process performance was below the Six Sigma target. The Pareto chart shows that stitching and color defects were the largest contributors to total defects. The control chart (p-chart) results show that the process is still within statistical control limits, but fluctuations approaching the upper limit indicate potential process instability that requires close monitoring. This condition is in line with the findings of Ivanda & Suliantoro (2019), which state that fluctuations approaching control limits can be an early indicator of disturbances in the production process.

Analyze

At the Analyze stage, the 5M approach (Man, Machine, Material, Method, Environment) was used through a cause-and-effect diagram (fishbone). Human factors include carelessness and lack of technical training; machine factors are related to worn-out and poorly maintained ATBMs; material factors include variations in yarn and dye quality; method factors include the absence of SOPs; and environmental factors include lighting and humidity in the workspace. These findings are consistent with the research by Hizbullah & Wahyuni (2023), which cites human and machine factors as the dominant causes of textile defects.

Improve

Based on the analysis results, improvements were implemented using the 5W+1H approach, which focused on operator training, SOP development, regular machine maintenance, workspace layout improvements, and strict raw material selection. The production manager is responsible for implementing SOPs and monitoring operator performance. This effort is in line with Nugroho's (2024) view that consistent implementation of the Improve stage can reduce defects by up to 50%. After the implementation of improvements, the defect rate began to decline, especially in the stitching and color categories.

Control

The Control stage aims to maintain the improvement results so that they remain consistent. The evaluation after the implementation of 5W+1H showed an average DPMO of 6,398.40 and a sigma level of 3.99, which indicates an improvement in process quality. The p-chart analysis results show that all data are within the upper control limit (UCL = 0.03703) and lower control limit (LCL = 0.01417), indicating that the process is statistically controlled. Control is carried out through routine monitoring, internal quality audits, product defect reporting, periodic machine maintenance, and continuous evaluation. This step ensures that the quality of woven sleeves remains stable and supports the company's increased competitiveness. This opinion is also in line with the research by Ananda & Puspitasari (2024), which shows that continuous control using the Six Sigma method is able to maintain a reduction in defect rates in the long term.

5. Comparison

This study makes a significant contribution to the application of the Six Sigma method in the traditional textile industry, particularly in the production of woven sarongs that still rely on non-machine looms (ATBM). The results of the study show that before the improvement, the average defect rate reached 4.21% with a DPMO value of 13,191 and a sigma level of 3.73. After implementing the DMAIC approach and 5W+1H-based interventions, there was a significant decrease to an average DPMO of 6,398 and a sigma level of 3.99, equivalent to a defect rate reduction to 2.56%.

A comparison with recent studies shows the relevance and superiority of the approach used in this study:

1. Puji (2024) at UD. Berkah Fajar reported a decrease in DPMO from 89,711 to 20,486 (an increase in sigma from 2.84 to 3.54). Although the absolute reduction in DPMO is larger, this study achieved a higher final sigma level (3.99) despite operating in a more complex production environment (manual weaving with high dependence on human skills).
2. Putri (2022) in the combination batik industry noted a very high initial DPMO (250,708) with a sigma level of only 2.18, indicating that traditional textile industries generally have process quality far below Six Sigma standards. This study successfully maintained a sigma level above 3.7 even before improvement and reached nearly 4.0 after intervention—indicating better process maturity than the industry average.
3. Fajar (2025) in the MSME shoe industry successfully reduced the defect rate from 5.5–7.1% to around 3% through operator training and machine maintenance. This study achieved similar results (from 4.21% to 2.56%) despite the main challenges being technological limitations (ATBM) and the variability of natural raw materials—factors that were rarely addressed in previous Six Sigma studies.

Additionally, this study expands the application of Six Sigma by integrating FMEA analysis and the 5W+1H approach in the Improve stage, which is not always found in previous studies. This integration enables more systematic identification of improvement priorities and more structured implementation of solutions, especially in the context of limited resources such as traditional textile SMEs.

Thus, this study not only confirms the effectiveness of Six Sigma in reducing production defects but also demonstrates relevant methodological adaptations for skill-based craft industries—an important contribution that enriches the Six Sigma literature in the non-automated manufacturing sector.

6. Conclusions

This study used the Six Sigma (DMAIC) method to analyze defects in woven sarongs at PT Ibrahim Bin Manrapi. The results show an average defect rate of 4.21%, with the dominant type of defect being stitching (46.36%), as well as a DPMO value of 42,100 and a sigma level of 3.36. The main factors causing defects include old ATBM machines, worker accuracy, and the absence of quality control standards.

However, after improvements were made through worker training, machine replacement, and the implementation of SOPs and final inspections, the sigma value increased to 3.99 and the DPMO decreased to 6,398.40, indicating an improvement in the quality of the production process.

The company is advised to perform routine machine maintenance, provide ongoing training, and implement control charts for quality monitoring. Further research could compare the results between ATBM machines and modern machines, as well as deepen Creswell's qualitative research philosophy approach to understand the factors causing defects more comprehensively.

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