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Implementation of Six Sigma to Reduce Defects In Batik Cap Products To Maximize Production Capacity

(Case Study: PT. Batik Banten Mukarnas)

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Abstract. PT. Batik Banten Mukarnas is a company that produces stamped batik designs with various patterns and varieties of batik. Problems frequently arise in the company due to increased stamped batik production capacity to meet the demand for stamped batik design products, which continues to rise from stamped batik suppliers. Another impact of growing demand capacity is the high number of defects in stamped batik cloth products, because overall, the company's management, including human resources, tools, and methods, is not prepared for the increase in production capacity to meet the surge in consumer demand, resulting in an impact on the quality of the products produced—consequently, the organization endeavors to regulate the quality of stamped batik cloth at PT. Batik Banten Mukarnas establishes objectives that employ Six Sigma with the DMAIC method (Define, Measure, Analyze, Improve, and Control) in the production of batik stamp designs to meet production objectives. The results of the data processing that has been done obtained a sigma value before improvement for 3 CTQ of 3.54. After improvement, the sigma value increased to 3.86. While for the sigma value before improvement for 1 CTQ of 3.04, the sigma value increased to 3.42 after improvement. The factors contributing to defective products, as illustrated by the fishbone diagram, include methods, personnel, materials, machinery, and environmental conditions. The division leader consistently oversees and regulates operations, enhances the number of brushes, and trains operators to ensure proficient adherence to standard operating procedures (SOP).

Keywords: Batik Cap, Production Quality, Six Sigma, DMAIC

1. INTRODUCTION

The batik industry is essential to Indonesia's national economy. In addition to being a unique culture of nationalism, batik is a legacy from our ancestors that is a characteristic of residents, particularly those in the Java region. However, batik is not only known to people in Java or the Javanese tribe but also to all Indonesians. As a result, batik is considered to be a part of Indonesia's national cultural heritage and is also considered to be a characteristic of the country of Indonesia. Batik itself is a product that can be exported abroad to be used as a source of foreign exchange; this can be seen based on data from the Central Statistics Agency (BPS) that Indonesian batik exports in 2023 amounted to USD 17.5 million or around IDR 283 billion (exchange rate 16,226 per USD). This figure shows the enormous potential of the batik industry to improve the Indonesian economy. The countries that are most interested in purchasing batik from Indonesia are the United States of America (which accounts for 74.75% of the total), Germany (which accounts for 3.61%), Singapore (which accounts for 3.23%), Malaysia (which accounts for 2.82%), and Canada

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(which accounts for 1.92%). The batik industry requires significant labor and employs millions of people overall. According to the Ministry of Industry (2023), the batik industry sector has contributed to millions of Indonesians' livelihoods.

PT. Batik Banten Mukarnas is one of the companies engaged in the garment industry that produces batik with 2 (two) types of batik: stamped batik and hand-drawn batik. The production of this batik cloth is based on the history of the Banten Sultanate by producing 12 motifs that UNESCO has patented, namely Datulaya, Pamalangen, Pasuraman, Kapurban, Pancaniti, Mandalikan, Pasepen, Surosowan, Kawansan, Srimanganti, Sabakingking, and Pejantren. The production capacity of stamped batik itself has better production capacity than the production capacity of hand-drawn batik; this can be seen from the data on the production of stamped batik, which can reach 36,000 dozen in a year, while the output of hand-drawn batik can only produce a production capacity of 1,000 - 3,000 dozens of batik in a year.

The decision made by the company to concentrate on stamped batik production to satisfy the requirements of the market share is the cause of the increase in the production capacity of stamped batik. Additionally, the increase is the result of competitive competition among batik producers. The increase in capacity has a dual impact: on the one hand, it affects the company's ability to increase its profits; on the other hand, it affects the decline in quality, characterized by the high number of product defects. These product defects are due to mass production, which causes uneven ink and color quality that is low standard and machine failure in operating batik motifs.

Based on data from the company's operational management, it can be seen that the number of defects in stamped batik cloth in the period May 2023 - April 2024 was 1,793 pcs or 6.33% of the total production of 28,310 pcs. The percentage of product defects has exceeded the tolerance limit set by the company of 5% of the total output. As a result of the high number of defective products that have been manufactured, production costs have increased, and there have been delays in the delivery of products to customers. It represents a substantial loss for the company regarding revenue and the trust customers place in it.

2. LITERATURE REVIEW

Along with serving as an attractive decoration, such as a framed painting, batik can also complement fashion motifs in everyday life, such as clothing. In addition, batik can serve as a complement to fashion motifs in everyday life. Researchers Nurcahyanie et al.

(2019). According to Sari et al. (2019), batik can be classified into three distinct types based on the manufacturing technique that goes into its production.

a) Hand-drawn Batik

Batik tulis is a fabric whose motifs are directly drawn by hand. Generally, making batik tulis can take 2-3 months, depending on the motif's complexity.

b) Stamped Batik

Stamped batik is a fabric whose motif is depicted using a stamp made of copper plate. In general, the process of making stamped batik takes less time than written batik, which is 2-3 days.

c) Combination Batik

Combination batik in the manufacturing process uses a combination of hand-drawn batik and stamped batik. To depict the basic motif, use a stamp tool and fill in the color using canting.

A. Six Sigma

Six Sigma is a method of problem-solving that is both structured and systematic, and it employs the standard DMAIC process (define, measure, analyze, improve, and control) as its process flow. Six Sigma's primary focus is improving quality to meet customer satisfaction.

According to Gaspersz (2002), the use of Six Sigma is accompanied by the DMAIC method (Define, Measure, Analyze, Improve, and Control), which is defining, measuring, analyzing, improving, and controlling a process that can be beneficial for the company by identifying and minimizing critical elements or called Critical to Quality (CTQ) in a process and aims to control the process to achieve the Six Sigma target. Six Sigma can be used to measure the industrial system's performance target regarding how good a product transaction process is between suppliers (industry) and customers (market). The higher the Sigma target achieved, the better the industrial system's performance. Six Sigma can also be considered as a breakthrough strategy that allows companies to make extraordinary (dramatic) improvements at the lower level. Six Sigma can also be viewed as industrial process control focused on customers by paying attention to process capability. Six key aspects need to be considered in the application of the Six Sigma concept, namely:

a) Customer identification
b) Product identification

c) Identify needs in producing products for customers
d) Define the process
e) Avoid errors in the process and eliminate all existing waste.
f) Continuously improve processes towards Six Sigma targets.

3. METHODS

a) *Define*

At this stage, problem determination and identification are carried out. The SIPOC diagram identifies vital aspects in the process and helps determine CTQ (Critical to Quality) factors to identify consumer needs.

b) *Measure*

At this stage, sampling was carried out at PT. Batik Banten Mukarnas during the period May 2023 - April 2024 as data collected and data processing was carried out before improvements were made. This measure stage aims to understand the company's current condition by calculating the P Map, DPMO (Defect Per Million Opportunities) value, and sigma value.

b) *Analyze*

*Analyz*ing is a stage in the Six Sigma quality improvement program that relates to determining the cause of the problem, identifying the root cause, and validating the hypothesis.

c) *Improve*

The stage is the improvement stage. This stage contains improvement proposals using the 5W+1H method (What, Who, Why, Where, When, and How) to analyze the root cause of the problem of defects in Stamped Batik Fabric.

d) Control

The Control stage is a stage carried out by the company to ensure that the proposed improvements from the 5W + 1H analysis can be implemented and to control / monitor related to the analysis and calculations of the P-Chart, DPMO, and FMEA as a preventive measure to prevent repeated errors. Creating process stability by calculating the sigma level after improvement; if successful, it is continued by making a Work Instruction (WI).

4. RESULTS and DISCUSSION

- Define Stage

The first step in enhancing quality through applying the Six Sigma methodology is the define stage, designed to identify the issues that arise and lead to the production of defective goods. This stage is characterized by the creation of the SIPOC diagram and the definition of the CTQ, which is an abbreviation for critical to quality.

Table 1. Types of Fabric Product Defects

Period	Production Quantity(pcs)	Types of Defects			Number of Defective Products	Percentage
		Uneven Color (Striped)	Broken Candle (Pattern Not Raised)	Color Out Motif		
May, 2023	2.336	46	58	87	191	8.18%
June, 2023	2.396	18	34	66	118	4.92%
July, 2023	2,442	17	35	59	111	4.55%
August, 2023	2.417	15	38	72	125	5.17%
September, 2023	2.432	37	54	89	180	7.40%
October, 2023	2.443	13	18	77	108	4.42%
November, 2023	2.313	20	27	89	136	5.88%
December, 2023	2.326	60	63	88	211	9.07%
January, 2023	2.333	40	70	113	223	9.56%
February, 2024	2.336	36	27	97	160	6.85%
March, 2024	2.215	12	15	73	100	4.51%
April, 2024	2,321	16	27	87	130	5.60%
Total	28,310	330	466	997	1,793	6.33%

Are three CTQs identified, including uneven color (striped), broken wax (motif not raised), and color out of motif. Explain each type of defect that occurs during the production process at PT. Batik Banten Mukarnas includes:

Figure 1. Types of Uneven Color Defects, Broken Wax Defects, Color Out of Motif

- Measure stage

In this second stage, the company is in the process of sampling, which is the stage in which data is collected and processed before any potential improvements are made by calculating the Control Chart value, DPMO, and sigma value on the Cap batik cloth product at PT. Batik Banten Mukarnas, the objective at this stage is to understand the company's current conditions.

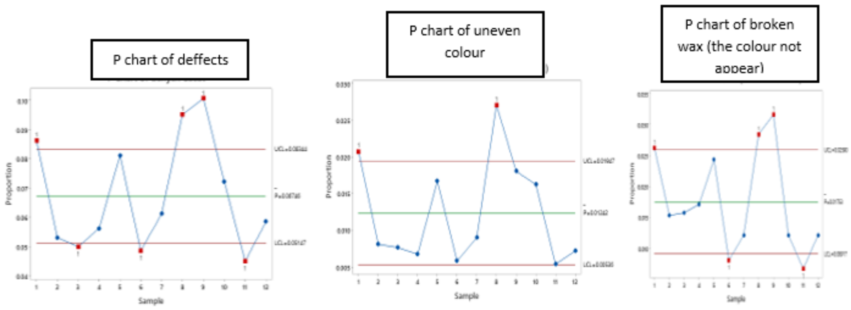

Figure 2. Control Chart

From the control chart image above, the number of production defects, uneven colors, and broken motifs in the batik motifs can be calculated; this can be seen in the table below.

Table 2. Results of Calculation of DPO, DPMO, and Sigma Values (3 CTQ)

No	Period	Production Quantity	Number of Defective Products(pcs)	CTQ	DPO Value	DPMO Value	*Level*Sigma
1	May, 2023	2.336	191	3	0.02725	27,254.6	3.42
2	June, 2023	2.396	118	3	0.01642	16,416.2	3.63
3	July, 2023	2,442	111	3	0.01515	15,151.5	3.67
4	August, 2023	2.417	125	3	0.01724	17,239.0	3.61
5	September, 2023	2.432	180	3	0.02467	24,671.1	3.47
6	October, 2023	2.443	108	3	0.01474	14,736.0	3.68
7	November, 2023	2.313	136	3	0.01960	19,599.4	3.56
8	December, 2023	2.326	211	3	0.03024	30,237.9	3.38
9	January, 2024	2.333	223	3	0.03186	31,861.7	3.35
10	February, 2024	2.336	160	3	0.02283	22,831.1	3.50
11	March, 2024	2.215	100	3	0.01505	15,048.9	3.67
12	April, 2024	2,321	130	3	0.01867	18,670.1	3.58
Total		**28,310**	**1,793**	**3**	**0.02114**	**21,143.1**	**3.54**

- Analyze Stage

The third stage in improving quality using Six Sigma is analysis. This stage aims to find the primary source of the problem, namely defective products. During this phase, a Pareto diagram, a fishbone diagram, and an FMEA (Failure Mode and Effect Analysis) are created to determine the underlying cause of the issues discovered during the stamped batik manufacturing process.

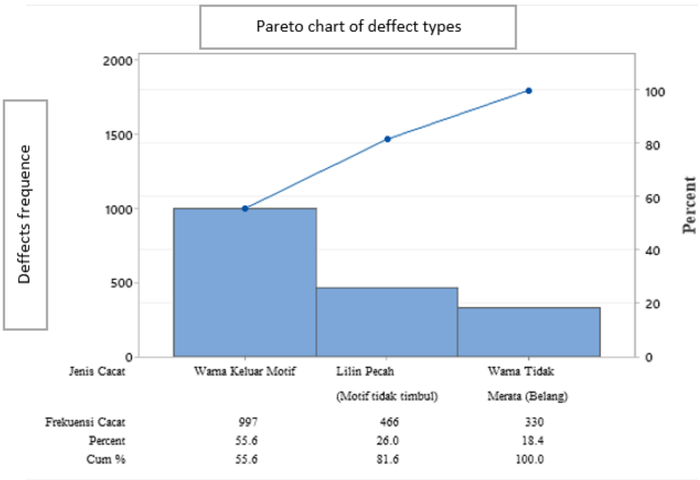

Figure 3.Pareto Chart

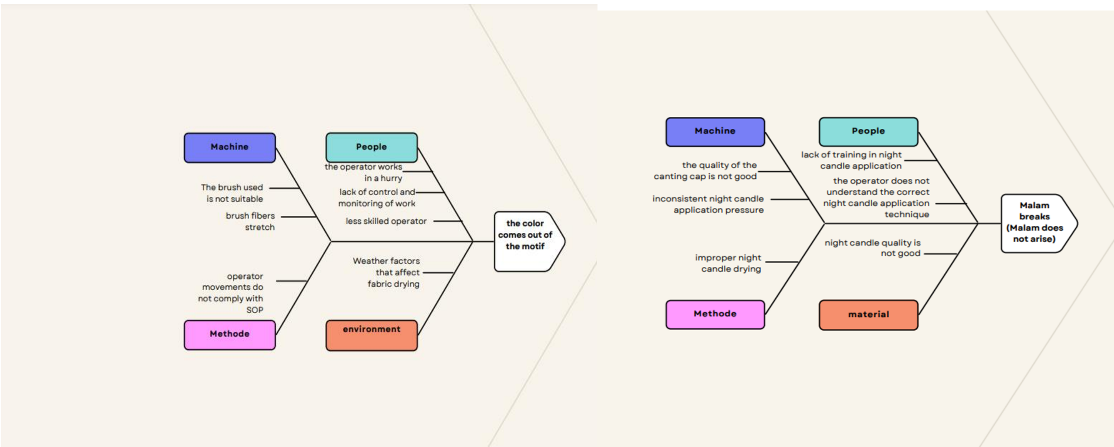

Figure 4. Fishbone diagram

Table 3. FMEA (Failure Mode and Effect Analysis) Results of the Exit Color of the Motif

PotentialFailure Mode	***Potential Effect of Failure***	***Potential Cause of Failure***	***S***	***O***	***D***	***RPN***	***Ranking***
Color out motif	The color results on the batik cloth do not match the motif	**Man**					
		Operator in a hurry	6	8	3	144	5

	desired by the consumer.	Lack of control and monitoring of work	8	7	4	224	1
		Less skilled operator	7	7	4	196	3
		Machine					
		Inappropriate use of brushes	6	7	5	210	2
		Brush fibers stretch	7	6	4	168	4
		Method					
		Inappropriate work movements	7	6	3	126	6
		Environment					
		Weather factors that affect the drying process	6	6	3	108	7

According to the results of the FMEA questionnaire calculation, which can be found in Table 3 above, it is evident that the RPN value that is the highest is associated with the absence of monitoring and controlling of work, which accounts for 224, the inappropriate use of brushes, which accounts for 210, and unskilled operators, which accounts for 196. It is necessary to make improvements at this time because the Risk Value Priority Value (RPN) that falls between 192 and 1,000 is considered high. Researchers use it as a foundation for determining the prioritized areas for improvement.

Table 4. Results of FMEA (Failure Mode and Effect Analysis) of broken candles. Motifs do not appear.

PotentialFailure Mode	***Potential Effect of Failure***	***Potential Cause of Failure***	***S***	***O***	***D***	***RPN***	***Ranking***
Broken Candle (Pattern Not Raised)	The color results on the batik cloth do not match the motif desired by the consumer.	**Man**					
		Lack of training in wax application	5	6	4	120	6
		The operator needs help understanding the correct wax application technique.	6	7	4	168	4
		Material					
		The quality of the wax is not good	7	6	5	210	1
		Machine					
		Poor-quality stamp printing	7	7	4	196	2

		Wax application pressure is inconsistent	6	6	5	180	3
		Method					
		Incorrect wax drying technique	5	5	5	125	5

- **Improve Stage**

This fourth stage is an action or proposed improvement that PT. Batik Banten Mukarnas to reduce defects in the stamping process for Batik Cap Cloth products., to concentrate on making improvements to batik flaws that develop, specifically through the utilization of 5W + 1H (What), (Why), (Where), (When), (Who), and (How in the process.

The enhancements implemented concentrate on identifying the root cause through a fishbone diagram. In instances of potential failure attributed to the operator's lack of skill resulting in color discrepancies in the motif, the suggested improvement is for the division leader to provide training to enhance the operator's proficiency. For operators working hastily, the proposed solution is to enforce controls, ensuring adherence to standard operating procedures (SOP). Additionally, to address insufficient work control and oversight, it is recommended that the division leader conducts regular inspections or evaluations within the production area.

The improvements made are focused on the results of identifying the root cause with a fishbone diagram, where in the case of potential failure that occurs due to the color coming out of the motif due to the operator being less skilled, the proposed improvement is that the division leader provides training to the operator to work skillfully. The proposed improvement for the operator in a hurry is to control so that the operator can work well. Based on the SOP and lack of work control and monitoring, the proposed improvement is that the division leader routinely conducts inspections or checks in the production section. Two examples of possible failure cases are improper brush use and stretched brush fibers. One solution is to increase the number of brush types according to the details of the batik motif. For potential failure cases, such as inappropriate work movements, the proposed improvement is to provide socialization and training on the SOP for periodic swabbing for workers in the production section. For potential failure cases, such as weather factors affecting drying time, the proposed improvement is for the operational manager to exercise control in the production section.

Figure 5. The brush for the stroking process is made of bamboo and replaced with a standard brush.

For potential failure cases that occur Broken Wax (Motif Does Not Raise) due to lack of training in wax application, the proposed improvement is that the division leader provides training to operators to work skillfully; operators do not understand the correct wax application technique, the proposed improvement is to carry out control so that operators can work well and by SOP. If a potential failure occurs, explicitly concerning the wax's quality, the proposed improvement is for the division leader to control the raw materials routinely. The proposed improvement is to perform maintenance and repairs on stamped batik cloth prints. It is even though potential failure cases include poor stamp print quality.

The operational manager should exercise control in the production section to ensure operators adhere to standard operating procedures (SOPs). It will help handle potential failure cases, such as inconsistent wax application pressure. However, the operational manager should exercise control in the production section in the event of possible failure cases, such as using the wrong wax drying techniques.

(a) (b)

Figure 5 (a) Night Candle; (b) Canting Cap

- **Control Stage**

This stage, namely the fifth stage, is where control results from corrective actions carried out by researchers with assistance from PT. Batik Banten Mukarnas. At this stage, data that has been corrected is collected; due to time constraints in research activities, data collection after repairs was carried out from June 1 to June 29, 2024, with the number of products examined as many as 2,254 pcs.

(1) Comparison Analysis of P Control Chart Before and After Improvement

The research shows that the proportion of defects in the Batik Cap Fabric product before the repair was carried out was six (6), and the data was out of control. It shows that the process still has deviations; the repairs carried out no longer have out-of-control data, indicating that the repairs carried out have produced good results and the problems can be resolved.

(2) Analysis of Defect Percentage Before and After Repair

The percentage of defects before and after repairs can be seen in Table 5 as follows:

Table 5. Recapitulation of the Average Percentage of Defects Before and After Repair

Before Repair	**After Repair**
6.3%	2.13%

Table 5 demonstrates that the percentage after repairs decreased, with the average defect percentage falling from 6.3% to 2.13%. Additionally, there was a decrease of 4.17% between the percentages before and after the repairs, which indicates that the repairs that were carried out were successful.

(3) Analysis of DPMO Value and Sigma Level Before and After Improvement

The recapitulation of DPMO values and Sigma Values on three CTQs and one CTQ before and after improvement is presented in Tables 6 and 7 below.

Table 6. DPMO Values and Sigma Levels Before and After Improvement in Three CTQs

Before Repair		**After Repair**	
DPMO Value	**Sigma Value**	**DPMO Value**	**Sigma Value**
21,143.1	3.54	9,401.2	3.86

Table 7. DPMO Values and Sigma Levels Before and After Improvement on One CTQ

Before Repair		**After Repair**	
DPMO Value	**Sigma Value**	**DPMO Value**	**Sigma Value**
63,429.3	3.04	28,203.7	3.42

The table shows the DPMO value and Sigma Value before and after improvement against 3 (CTQ) with the DPMO value before improvement of 21,143.1 with a sigma value of 3.54, and after the repair, the DPMO value decreased to 63,429.3 and the sigma value increased to 3.04. It proves that the corrective actions taken effectively reduce DPMO and increase the sigma level in all 3 (three) CTQs. Table 6 shows the DPMO value and sigma value before and after repair of 1 (one) CTQ with a DPMO value before repair of 63,429.3 with a sigma value of 3.04, and after repair, the DPMO value decreased to 28,203.7 and the sigma value increased to 3.42. It proves that the corrective actions taken are effective in reducing that the corrective actions taken are effective in lowering DPMO and increasing the sigma value in all 1 (one) CTQs. Therefore, the improvements made are entirely satisfactory, although the target sigma level of six has yet to be reached. On account of this, PT. Batik Banten Mukarnas or subsequent researchers should continuously improve the quality of their products.

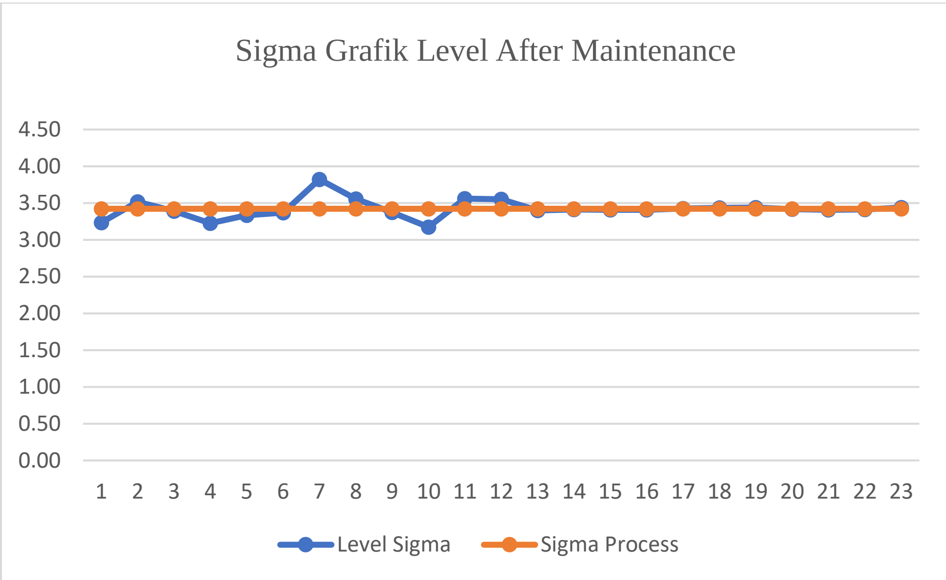

Figure 6. Sigma Level Graph After Improvement

Source: Processed Data, 2024

Based on the data presented in Figure 6, it is evident that the sigma level has increased following the implementation of the improvement. The process sigma level now stands at a value of 3.86, higher than the previous value of 3.54. It demonstrates that the improvements have achieved the highest possible results per the anticipated target and that the production defects can be reduced further.

5. REFERENCES]

Abdullah, GG, & Mardiani, GT (2019). Project Risk Management Information System Using Failure Mode and Effect Analysis Method at PT. Hilal Mitra Perkasa. 2–3.

Abdullah, MA (2018). Application of Statistical Control Charts in Controlling a Company's Production Results. Saintifik, 1(1), 5–13. https://doi.org/10.31605/saintifik.v1i1.71

Astuti, RD, & Lathifurahman, L. (2020). Lean Six-Sigma Application to Reduce Waste in Cement Packaging Section. JISI: Journal of Industrial System Integration, 7(2), 143. https://doi.org/10.24853/jisi.7.2.143-153

Hanifah, PSK, & Iftadi, I. (2022). Application of Six Sigma Method and Failure Mode Effect Analysis to Improve Sugar Production Quality Control. *INTECH Journal of Industrial Engineering, Serang Raya University*, 8(2), 90–98. https://doi.org/10.30656/intech.v8i2.4655

Kartikasari, V., & Romadhon, H. (2019). Analysis of Control and Improvement of Tuna Canning Process Quality Using Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) Methods Case study at PT XXX East Java. *Journal of Industrial View*, 1(1), 1–10. https://doi.org/10.26905/jiv.v1i1.2999

Nurcahyanie, YD, Nizar., Kurnia., & Fadli. (2019). Making Tie-Dye Batik in Kalikatir Village. *Penamas Adi Buana Journal*, 2(2), 3(1) 34.

Ratnadi, R., & Suprianto, E. (2016). Production Quality Control Using Statistical Tools (Seven Tools) to Reduce Product Damage Rates. *Indept Journal*, 6(2), 11.

Riadi, S., & Haryadi, H. (2020). Controlling the Number of Product Defects in the Cutting Process Using the Quality Control Circle (Qcc) Method at PT. Toyota Boshoku Indonesia (Tbina). *Journal Industrial Manufacturing*, 5(1), 57. https://doi.org/10.31000/jim.v5i1.2433

Saori, S., Anjelia, S., Melati, R., Nuralamsyah, M., Djorghi, ERS, & Ulhaq, A. (2021). Analysis of Quality Control in the Candle Industry (Case Study at PD Ikram Nusa Persada, Sukabumi City). *Journal of Research Innovation*, Vol. 1(No. 10), 2133–2138.

Saputri, R., Vitasari, P., & Adriantantri, E. (2022). Identification of Defective Products Using CTQ and DPMO Methods in the Sari Rasa Tempe Chips Home Industry. *Valtech Journal*, 5(1), 94–100. https://ejournal.itn.ac.id/index.php/valtech/article/view/4518

Sari, IP, Wulandari, S., & Maya, S. (2019). The Urgency of Batik Mark in Answering Indonesian Batik Problems (Case Study at Tanjung Bumi Batik Center). Socio E-Cons, 11(1), 16. https://doi.org/10.30998/sosioekons.v11i1.2932

Siregar, AP, Raya, AB, Nugroho, AD, Indana, F., Prasada, IMY, Andiani, R., Simbolon, TGY, & Kinasih, AT (2020). Efforts to Develop the Batik Industry in Indonesia. Dynamics of Crafts and Batik: Scientific Magazine, 37(1). https://doi.org/10.22322/dkb.v37i1.5945

Sukirno, E., Prasetiyo, J., Rosma, R., & Sari, MHRSR (2021). Implementing the Six Sigma Dmaic Method to Reduce Defects in Exhaust Pipe XE 611. *Journal of Industrial Engineering Applications (JAPTI)*, 2(2), 75-83.

Suharyanto, S., Herlina, RL, & Mulyana, A. (2022). Analysis of Waring Product Quality Control Using the Seven Tools Method at CV. Kas Sumedang. *Tedc Journal*, 16(1), 37-49.

Tambunan, DG, Sumartono, B., & Moektiwibowo, DH (2020). Analysis of Quality Control Using the Six Sigma Method to Reduce Defects in the Suitcase Production Process at PT SRG. *Journal of Industrial Engineering*, 9(1), 58–77.

Wicaksono, A., Priyana, ED, & Nugroho, YP (2023). Quality Control Analysis Using Failure Mode and Effects Analysis (FMEA) Method on Centrifugal Pumps at PT. X. Journal of Industrial Engineering: *Journal of Research Results and Scientific Works in the Field of Industrial Engineering*, 9(1), 177-185. https://doi.org/10.24014/jti.v9i1.22233