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Quality Control Analysis at a Screen Printing Workshop Using the FMEA and Fuzzy FMEA Methods at UD. MKKG Gresik

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ABSTRACT

UD. MKKG is a screen printing company facing product defect issues, such as ink not adhering, cracked prints, and imprecise results. This study aims to identify the primary causes of these defects and establish priorities for improving production quality in the screen printing unit. The research method used is the integration of Failure Mode and Effect Analysis (FMEA) with a Fuzzy approach to address subjectivity in risk assessment. Conventional RPN calculations showed the highest values for cracked prints (240), imprecision (150), and ink not adhering (75). The application of Fuzzy FMEA yielded more accurate and continuous FRPN values, namely cracked prints (249.5), imprecision (158), and ink not adhering (81.5). Proposed improvements include strict supplier selection, the use of periodic temperature thermometers, fabric pre-press techniques, and scheduling routine machine maintenance. The implementation of these steps is expected to minimize defective products and maintain customer confidence in product quality.

INTRODUCTION

The garment industry in Indonesia continues to experience significant growth in line with the increasing demand for clothing products from various segments of society. The garment industry involves screen printing, which is the process of printing images or designs onto fabric surfaces, commonly applied to T-shirts, uniforms, or promotional clothing (Hakim & Al-Faritsy, 2024). This process has high added value because it can enhance the aesthetic appeal of a product, thereby influencing consumer purchasing interest. However, in practice, the screen printing process is highly susceptible to various types of defects that can reduce the quality of the final product (Prasmoro & Aryansyah, 2026).

UD. MKKG, located in Gresik, is a micro-medium enterprise engaged in clothing production, including screen printing services. As a garment manufacturer that serves orders from various regions, UD. MKKG faces the challenge of maintaining product quality consistency in order to maintain customer satisfaction and business competitiveness. Unfortunately, in recent months, there has been an increase in the number of defective products in the screen printing process, resulting in product returns by consumers, waste of raw materials, increased rework time, and ultimately reduced production efficiency and business profits.

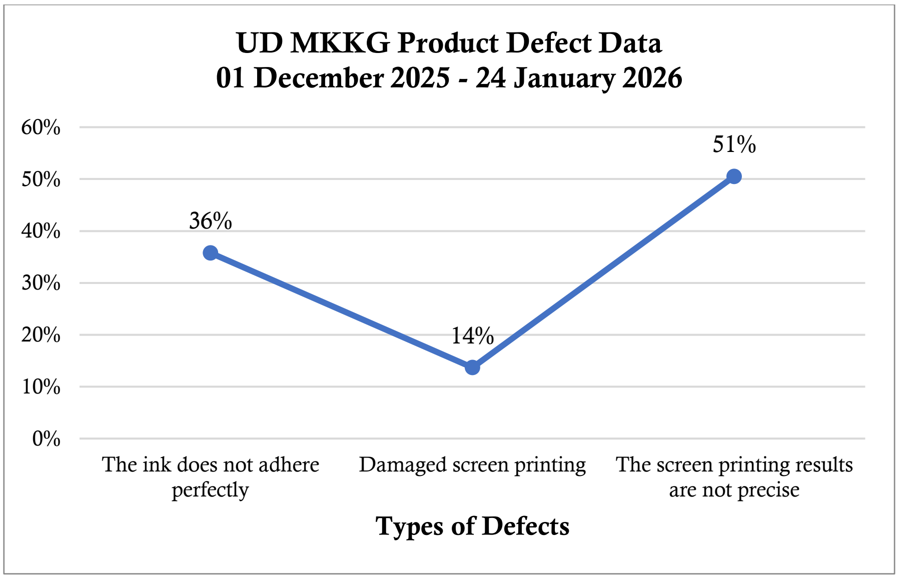

Figure 1. UD MKKG Product Defect Data

Figure 1 shows that defects in the screen printing process consist of three types: ink not adhering properly (36%), damaged screens (14%), and imprecise printing results (51%). The results of this graph indicate that improvements must be made to reduce product waste at UD. MKKG.

Although previous studies have discussed quality control in the garment industry using conventional methods such as FMEA or Fishbone diagrams, the identification of failure risks is often subjective and ambiguous because it relies solely on rigid discrete numerical assessments. In MSME environments such as UD. MKKG, risk assessment is often constrained by information uncertainty and differences in perception among assessors. There is a research gap in which failure risk analysis in the screen printing process requires a more precise approach to address this uncertainty so that the determination of improvement priorities is not biased.

Therefore, to reduce the number of defects during the production process, an analysis was conducted using the Failure Mode and Effect Analysis (FMEA) and Fuzzy Failure Mode and Effect Analysis (Fuzzy FMEA) methods. FMEA is an analysis technique that aims to identify potential defects in a process, assess the impact of these defects on output, and determine priorities (Safitri & Nelfiyanti, 2025). Fuzzy FMEA integration was carried out due to the need for more structured identification and prioritization that could accommodate human subjectivity in critical failure modes in the screen printing process. Although the problem was known, there had been no systematic analysis at UD. MKKG that mathematically determined the root causes and impacts of these failures. The objective is to determine the FMEA from December 2025 to January 2026, identify critical failure modes using Fuzzy FMEA, and provide structured corrective actions based on the Fuzzy Risk Priority Number (FRPN) to improve system reliability and production performance.

RESEARCH METHODS

Flowchart Diagram

The following is a flowchart diagram used during research at UD. MKKG.

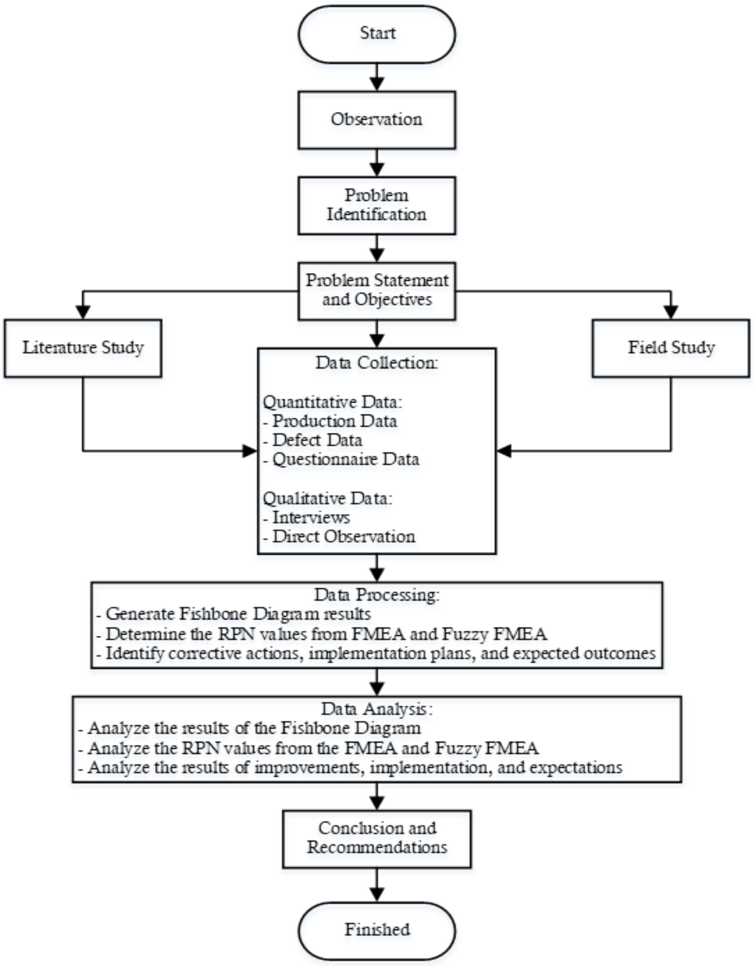

Figure 2. Flowchart UD. MKKG

Failure Mode and Effect Analysis (FMEA)

A systematic method for identifying, analyzing, and minimizing potential errors and problems in the production process, whether known or potentially emerging in the system (Aiman & Nuruddin, 2023). Risk Priority Number (RPN) is calculated using three main components, namely Severity (S), Occurrence (O), and Detection (D), with the formula RPN = SxOxD (Romadhoni et al., 2022). The stages for determining the three main components are as follows :

1. **Severity** initial action in the evaluation to assess the extent of the impact or influence of the event on the process and results of the assessment on a scale of one to ten (Wardana & Widiasih, 2023).
2. **Occurrence** the potential for process and result defects is defined as an occurrence measured on a scale of one to ten (Nurdiansyah & Dahda, 2026).
3. **Detection** evaluation of control capabilities to identify errors in process implementation, on a scale of one to ten (Rafi, 2023).

Fuzzy Failure Mode and Effect Analysis (Fuzzy FMEA)

To overcome uncertainty and subjectivity in researching Severity (S), Occurrence (O), and Detection (D) scores in conventional FMEA. In Fuzzy FMEA, these scores are represented by Fuzzy Numbers, usually Triangular Fuzzy Numbers (TFN) (Islam et al., 2020). The crisp values from the 1-10 scale on inputs S, O, D are converted into five categories of linguistic variables. The following is table 4 of the conversion of the crisp scale into linguistic variables and tables 5, 6, 7 of the membership function parameters Severity, Occurrence, and Detection (Puspitaloka, 2022).

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Table 1. Convert Crisp Scale to Linguistic

Crisp Scale	Linguistic Scale
1-2	Very Low
3-4	Low
5-6	Moderate
7-8	High
9-10	Very High

Table 2. Membership Parameters Input Variables Severity

Category	Curve Type	Parameters
Very Low (VL)	Triangle	[1 1 3]
Low (L)	Triangle	[1 3 5]
Moderate (M)	Trapezoid	[3 5 6 8]
High (H)	Triangle	[6 8 10]
Very High (VH)	Triangle	[8 10 10]

Table 3. Membership Parameters Input Variables Occurrence

Category	Curve Type	Parameters
Very Low (VL)	Triangle	[1 1 3]
Low (L)	Triangle	[1 3 7]
Moderate (M)	Trapezoid	[2 5 6 9]
High (H)	Triangle	[4 8 10]
Very High (VH)	Triangle	[8 10 10]

Table 4. Membership Parameters Input Variables Detection

Category	Curve Type	Parameters
Very Low (VL)	Triangle	[1 1 3]
Low (L)	Triangle	[1 3 6]
Moderate (M)	Trapezoid	[3 5 6 8]
High (H)	Triangle	[5 8 10]
Very High (VH)	Triangle	[8 10 10]

The following is the Fuzzy FMEA calculation formula (Arnanda et al., 2026):

1. In Fuzzy FMEA, the Fuzzy Risk Priority Number ($\tilde{R}$/FRPN) value is often calculated using fuzzy number multiplication operations :
$$\tilde{R} = \tilde{S} \otimes \tilde{O} \otimes \tilde{D} \quad (1)$$
Description :
   - $\tilde{R}$ or FRPN : Fuzzy Risk Priority Number.
   - $\tilde{S}, \tilde{O}, \tilde{D}$: Fuzzy Numbers for Severity, Occurrence, and Detection.
   - $\otimes$: Fuzzy number multiplication operation.

   If $\tilde{A} = (a_1, a_2, a_3)$ and $\tilde{B} = (b_1, b_2, b_3)$ are TFNs, then their product is $\tilde{A} \otimes \tilde{B} = (a_1 x\, b_1, a_2 x\, b_2, a_3 x\, b_3)$.
2. Calculate the Crisp FRPN value after obtaining the FRPN in the form of a fuzzy number $\tilde{R} = (r_1, r_2, r_3)$, to obtain a single (crisp) value that can be used for risk ranking, the Center of Gravity (COG) method is used :
$$FRPN_{crisp} = \frac{r_1 + 2(r_2) + r_3}{4} \quad (2)$$
Description :
   - r_1 : Lower limit (lowest value) of Fuzzy RPN numbers.
   - r_2 : Peak value (average value or mode) of Fuzzy RPN numbers.
   - r_3 : Upper limit (highest value) of Fuzzy RPN numbers.

Differences Between Conventional FMEA and Fuzzy FMEA

The difference in risk priority order between conventional FMEA and Fuzzy FMEA methods is not merely a statistical anomaly, but rather a reflection of how the two methods handle uncertainty. In conventional FMEA, the Risk Priority Number (RPN) value is calculated by multiplying Severity (S), Occurrence (O), and Detection (D) discretely (Milah & Suseno, 2022). The fundamental weakness of this method is the assumption that the weights of the three parameters are equal and that each combination of multiplication produces a unique risk meaning (Wardana & Widiasih, 2023). Fuzzy FMEA solves this problem by using continuous membership functions, thereby providing more precise defuzzification values and distinguishing between the urgency levels of the two scenarios (Febriyana & Hartini, 2023).

RESULTS AND DISCUSSION

Data Collection

Data was collected through interviews and observations at UD. MKKG, focusing on the production volume and number of defective screen-printed T-shirts from December 1, 2025, to January 24, 2026, as follows :

Table 5. Defect and Production Data

Week	Types of Defects (Pcs)			Total Defects	Total Production	Percentage of Defects (%)
	The ink does not adhere perfectly	Damaged screen printing	The screen printing results are not precise			
Week 1	6	0	0	6	60	6%
Week 2	7	4	17	28	210	29%
Week 3	9	5	28	42	200	44%
Week 4	3	1	2	6	85	6%
Week 5	3	0	1	4	75	4%
Week 1	2	0	0	2	45	2%
Week 2	3	3	0	6	60	6%
Week 3	1	0	0	1	80	1%
Total	**34**	**13**	**48**	**95**	**815**	**100%**

Sumber : UD. MKKG

Tables 8 show that the total number of product defects at UD. MKKG from December 1, 2025 to January 24, 2026 was 95 pieces. These defects consist of several types, with the largest number of defects originating from imprecise screen printing, totaling 48 pieces with a percentage of 51%. This type of defect indicates uncertainty in the screen printing process, resulting in prints that do not match the expected design. In addition, there were also 34 pieces with imperfect ink adhesion, with a percentage of 36%. This is most likely caused by the condition of the ink, drying temperature, or suboptimal screen printing machine pressure. The next type of defect is cracked screen printing, amounting to 13 pieces with a percentage of 14%. Cracked screen printing can occur due to the use of unsuitable materials or improper heating during drying. This data shows that most defects occur at the screen printing stage, so a comprehensive evaluation of the screen printing process is necessary.

Data Processing

Fishbone Diagram

A visual tool used to identify, explore, and graphically organize all potential causes of a specific problem. The following are the sources and root causes of ink not adhering perfectly, cracked screen printing, and imprecise screen printing results on UD. MKKG.

- **The Ink Does Not Adhere Perfectly**

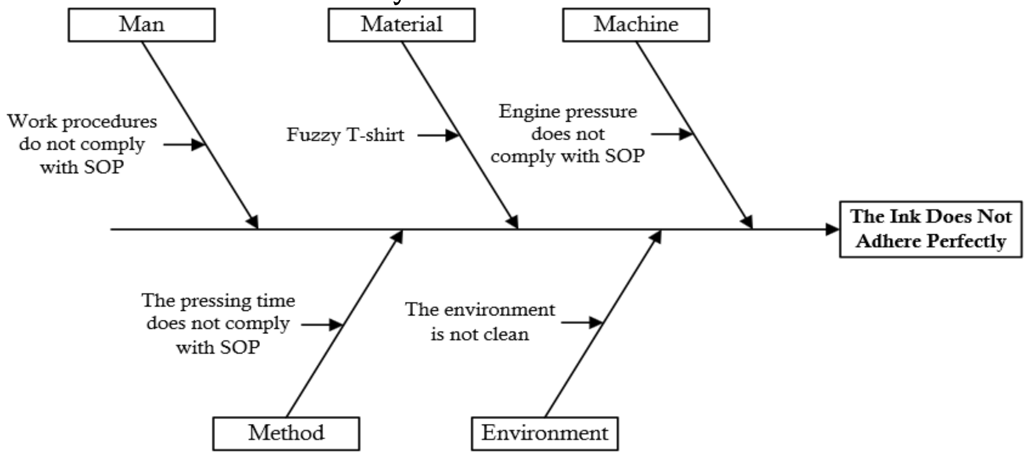

Figure 3. The Ink Does Not Adhere Perfectly

- **Damaged Screen Printing**

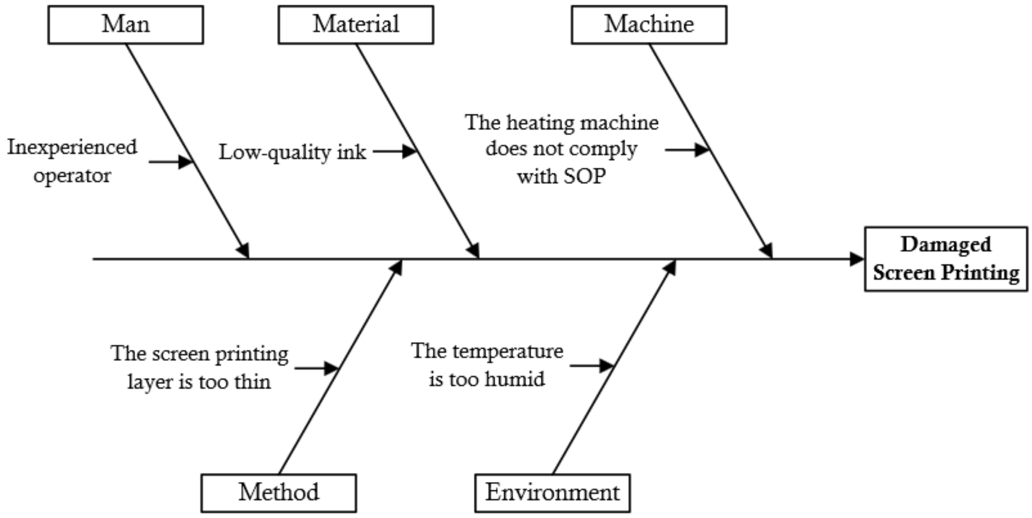

Figure 4. Damaged Screen Printing

- **The Screen Printing Results Are Not Precise**

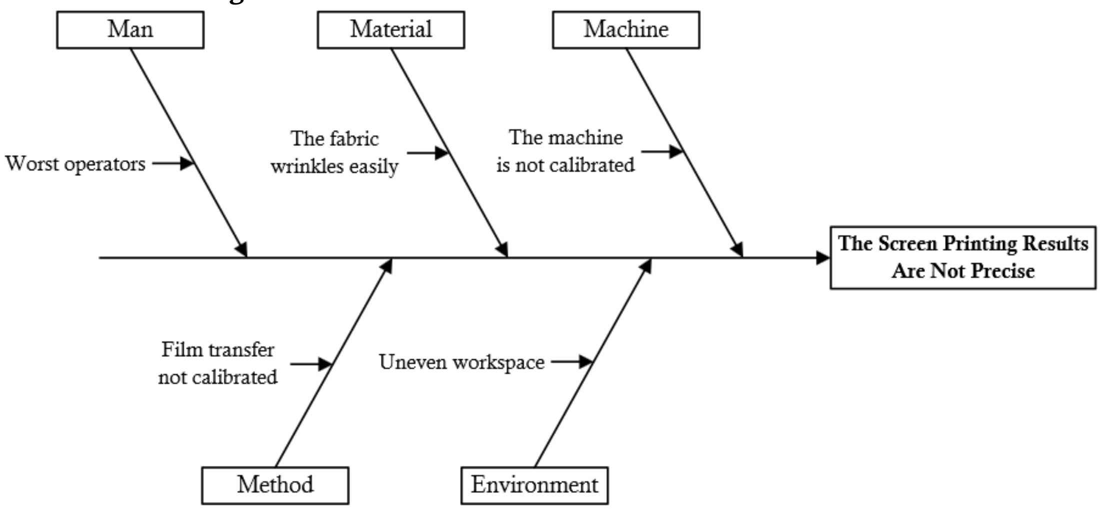

Figure 5. The Screen Printing Results Are Not Precise

After identifying the root causes of the problems that occurred during the screen printing stage, namely ink not adhering properly, damaged screens, and the screen printing results are not precise, consisting of five factors, namely human, material, machine, method, and environment. Next, these will be identified using the FMEA method.

Failure Mode and Effect Analysis (FMEA)

At this stage, questionnaires will be given to the owner, production task leader, and equipment task leader, using the FMEA method for analysis to identify the types of failures that may occur, detect potential errors in each process, and understand the impact of each failure mode.

Table 9. The Ink Does Not Adhere Perfectly FMEA

The Ink Does Not Adhere Perfectly				
Impact	**Causal Factors**		**RPN**	**Rank**
The screen printing peels off easily	Man	Work procedures do not comply with SOP	40	4
	Material	Fuzzy T-shirt	75	1
	Machine	Engine pressure does not comply with SOP	40	4
	Method	The pressing time does not comply with SOP	70	2
	Environment	The environment is not clean	60	3

Table 9 shows that the greatest defect with the highest RPN value was caused by materials, at 75, while the lowest RPN values were caused by humans, at 40, and machines, at 40.

Table 10. Damaged Screen Printing FMEA

Damaged Screen Printing				
Impact	**Causal Factors**		**RPN**	**Rank**
The damaged screen printing does not comply with the SOP	Man	Inexperienced operator	162	3
	Material	Low-quality ink	168	2
	Machine	The heating machine does not comply with SOP	240	1
	Method	The screen printing layer is too thin	144	4
	Environment	The temperature is too humid	120	5

Table 10 shows that the greatest defect with the highest RPN value was caused by the machine at 240, while the lowest RPN value was caused by the environment at 120.

Table 11. The Screen Printing Results Are Not Precise FMEA

The Screen Printing Results Are Not Precise				
Impact	**Causal Factors**		**RPN**	**Rank**
The screen printing placement is not what the customer wanted	Man	Worst operators	135	2
	Material	The fabric wrinkles easily	150	1
	Machine	The machine is not calibrated	150	1
	Method	Film transfer not calibrated	60	3
	Environment	Uneven workspace	45	4

Table 11 shows that the greatest defect with the highest RPN value was caused by materials and machinery at 150, while the lowest RPN value was caused by the environment at 45.

Fuzzy Failure Mode and Effect Analysis (Fuzzy FMEA)

At this stage, a transition is made from conventional FMEA to the determination stage using the Fuzzy FMEA method. Where subjective continuous processes require Fuzzy, this is done due to the lack of structured identification and prioritization of critical failure modes in the screen printing process.

Table 12. The Ink Does Not Adhere Perfectly Fuzzy FMEA

The Ink Does Not Adhere Perfectly														
Causes	**FMEA**			**Fuzzy**						**FRPN**			**FRPN$_{crisp}$ (COG)**	**Rank (FRPN)**
	S	**O**	**D**	**S**	**Category**	**O**	**Category**	**D**	**Category**	**S**	**O**	**D**		
Man	5	4	2	4 5 6	M	3 4 5	L	1 2 3	VL	12	40	90	45,5	4

Material		5	3	4 5 6	M	4 5 6	M	2 3 4	L	32	75	144	81,5	1
Machine		4	2	4 5 6	M	3 4 5	L	1 2 3	VL	12	40	90	45,5	4
Method		7	2	4 5 6	M	6 7 8	H	1 2 3	VL	24	70	144	77,0	2
Environment		3	4	4 5 6	M	2 3 4	L	3 4 5	L	24	60	120	66,0	3

Table 13. Damaged Screen Printing Fuzzy FMEA

Damaged Screen Printing														
Causes	FMEA			Fuzzy						FRPN			$FRPN_{crisp}$ (COG)	Rank (FRPN)
	S	O	D	S	Category	O	Category	D	Category	S	O	D		
Man		9	3	5 6 7	M	8 9 10	VH	2 3 4	L	80	162	280	171,0	3
Material		7	4	5 6 7	M	6 7 8	H	3 4 5	L	90	168	280	176,5	2
Machine	6	8	5	5 6 7	M	7 8 9	H	4 5 6	M	140	240	378	249,5	1
Method		8	3	5 6 7	M	7 8 9	H	2 3 4	L	70	144	252	152,5	4
Environment		5	4	5 6 7	M	4 5 6	M	3 4 5	L	60	120	210	127,5	5

Table 14. The Screen Printing Results Are Not Precise Fuzzy FMEA

The Screen Printing Results Are Not Precise														
Causes	FMEA			Fuzzy						FRPN			$FRPN_{crisp}$ (COG)	Rank (FRPN)
	S	O	D	S	Category	O	Category	D	Category	S	O	D		
Man		9	3	4 5 6	M	8 9 10	VH	2 3 4	L	64	135	240	143,5	2
Material		6	5	4 5 6	M	5 6 7	M	4 5 6	M	80	150	252	158,0	1
Machine	5	5	6	4 5 6	M	4 5 6	M	5 6 7	M	80	150	252	158,0	1
Method		4	3	4 5 6	M	3 4 5	L	2 3 4	L	24	60	120	66,0	3
Environment		3	3	4 5 6	M	2 3 4	L	2 3 4	L	16	45	96	50,5	4

From the results of tables 12, 13, and 14, it is known that ink defects that do not adhere perfectly are obtained from the highest FRPN value, namely from the material factor of 81.5 and the smallest from the human and machine factors of 45.5. Cracked screens are obtained from the highest FRPN value, namely from the machine factor of 249.5 and the smallest from the environmental factor of 127.5. The imprecise screen printing results obtained the highest FRPN value from the material and machine factors at 158, and the lowest from the environmental factor at 50.5.

Proposed Improvements

These improvement proposals will focus on failure modes with the highest FRPN values, with the aim of minimizing potential risk errors, improving system reliability, and achieving the expected improvement results after implementation.

Table 15. Proposed Improvements

Types of Defects	Causes	Proposed Improvements	Implementation	Hope
The Ink Does Not Adhere Perfectly	Material	Use a lint roller or premium quality (combed) cotton fabric	Providing lint rollers on work desks and conducting strict selection of T-shirt material suppliers	The surface of the shirt is free of fibers/dust so that the ink absorbs strongly and does not come off easily
Damaged Screen Printing	Machine	Periodic temperature checks using a thermometer	Purchase a laser thermometer/gun to measure the heat press temperature in real time every 10-20 operations	The heating temperature is stable according to standards, so the ink cures perfectly without becoming brittle or cracking
The Screen Printing Results Are Not Precise	Material	Pre-press ironing before screen printing	Press briefly (3-5 seconds) on plain T-shirts to remove wrinkles and moisture before applying ink	The fabric surface is flat and stable, preventing the image from shifting during the screen printing process
	Machine	Scheduling routine maintenance and machine	Create a monthly service schedule to check bolt tightness, rail lubrication, and machine position sensor calibration	The machine works accurately and consistently in placing designs at the same spot on each shirt

From the results in table 15, UD. MKKG can reduce the impact that occurs during the screen printing process, such as losses due to wasted or replaced products, decreased customer trust, risky distribution due to product defects, and negative perceptions of product quality.

CONCLUSION

Based on research at UD. MKKG, there are three defects, namely ink that does not adhere perfectly, cracked screen printing, and imprecise screen printing results. After that, an FMEA questionnaire was distributed and the highest RPN was obtained, namely ink not adhering perfectly in terms of material at 75, cracked screen printing in terms of machinery at 240, and imprecise screen printing results in terms of material at 150 and machinery at 150. To determine the subjective continuous process, Fuzzy FMEA was needed, which yielded the highest FRPN results, namely ink not adhering perfectly in terms of material at 81.5, cracked screen printing in terms of machinery at 249.5, and imprecise screen printing results in terms of material at 158 and machinery at 158. After the results are known, improvement proposals are needed, namely high-quality materials by strictly selecting suppliers, using a temperature thermometer every 10-20 times of work, short pressing on plain shirts to remove wrinkles and moisture, and scheduling service on machine components. That way, it is hoped that losses due to defective products, decreased customer trust, and negative perceptions of product quality will be reduced. Future research could explore the integration of advanced methods to assign more objective weights to each criterion.

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