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Identification of the Causes of Product Defects in the Screen-Printing Production Process Using Fault Tree Analysis (FTA) at PT. XYZ

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A B S T R A C T

The screen-printing industry faces a high rate of product defects. PT. XYZ recorded a defect rate of 9,4% during January–May 2026 (2.532 defective units out of 26.940 units produced). This study aims to identify the dominant defect types and their root causes using a Pareto Diagram and Fault Tree Analysis (FTA), and to formulate improvement proposals. Data were collected through observation, interviews, and production documentation. The Pareto results show three dominant defects: uneven ink (35%), ink fading (25%), and print position error (18%), with a cumulative contribution of 78%. The FTA analysis produced top event probabilities of 0,81, 0,63, and 0,79, with the human factor as the most dominant cause. Improvement proposals include operator training, preventive maintenance, process standardization, and the application of check sheets at every production stage.

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INTRODUCTION

Manufacturing is one of the strategic sectors in the Indonesian economy that plays a role in producing various products to meet market needs while driving economic growth and employment absorption (Harahap et al., 2026). One of the rapidly growing industries is printing and screen printing, particularly sponsor banner products, which are widely used in promotional activities and visual communication media. Screen printing is a printing method that transfers ink onto a medium through a screen intermediary with a specific pattern, and is capable of producing prints with sharp, long-lasting colors on various types of media (Prahadi et al., 2024). The screen-printing production process requires precision and operator skill at every stage, from design creation, screen exposure, ink mixing, and printing, to drying and finishing, so it must be managed systematically to produce consistent products.

PT. XYZ is a manufacturing company engaged in screen printing that is required to maintain product quality according to established standards. Based on production data for the period January–May 2026, production reached 26.940 units with 2.532 defective units, resulting in a defect rate of 9,4%. Five types of defects were identified: uneven ink, ink fading, print position error, faded color, and stains/wrinkles on the printed result. The initial analysis using a Pareto Diagram shows that three main defect types contribute a cumulative 78% of all defective products, indicating that most quality issues stem from these three defect types (Siallagan and Manik, 2024).

An analysis capable of identifying the root causes of product defects is needed so that corrective actions can be more precisely targeted. The Fault Tree Analysis (FTA) method was chosen because it can systematically describe the logical relationship between a failure event (top event) and its various contributing factors (intermediate events and basic events) through a deductive logic approach. The use of FTA in the screen-printing industry is still relatively limited compared to its application in other industrial sectors, which more commonly use Seven Tools or Failure Mode and Effect Analysis/FMEA (Arifin et al., 2023; Wicaksono et al., 2023). Several studies have shown the effectiveness of combining FTA with other methods in structurally identifying the root causes of production failures (Andrian et al., 2023; Muchsinin and Sulistiyowati, 2022; Zakaria et al., 2023). Based on this, the present study aims to identify the factors causing product defects in the screen-printing production process at PT. XYZ, analyze their root causes using the FTA method, and formulate improvement proposals to minimize product defects.

LITERATURE REVIEW

Quality Control and Defective Products

Quality control is an activity to ensure that the products produced conform to established standards, thereby minimizing defective products and company losses (Diansari et al., 2024). A defective product is one that does not meet the established quality specifications, whether in terms of function, appearance, or safety, and can cause losses in the form of wasted raw materials, production time, rework costs, and product liability toward consumers (Eleanora and Ahmad, 2023). In the screen-printing industry, product defects are generally influenced by a combination of human, machine, material, method, and work-environment factors (Laksono et al., 2022).

Fault Tree Analysis (FTA)

Fault Tree Analysis (FTA) is a failure analysis method used to systematically identify the cause-and-effect relationship between a main failure event (top event) and its various contributing factors, depicted as a logic tree diagram using OR and AND logic gates. An OR gate is used when any one of several causes is sufficient to produce the event above it, with probability calculated by addition, whereas an AND gate is used when all causes must occur simultaneously, with probability calculated by multiplication. The probability value of each basic event is obtained by dividing the frequency of occurrence by the total frequency of all basic events under the relevant top event. FTA analysis allows the basic event with the highest probability to be identified as the priority for corrective action (Andrian et al., 2023; Zakaria et al., 2023).

The conceptual framework of this study begins with the collection of production data and defective-product data, followed by a Pareto Diagram analysis to determine the dominant defect type as the top event. Each top event is then broken down into intermediate events and basic events using the FTA method, its probability values are calculated, and the basic event with the highest probability is used as the basis for formulating improvement proposals.

METHODOLOGY

This research was conducted at PT. XYZ, located at Sawah, Kadokan, Grogol District, Sukoharjo Regency, Central Java. The object of the research is the screen-printing production process, with a focus on the defective products generated during production. The data used are quantitative data on production quantity and the number of defective products for the period January–May 2026, sourced from primary data (field observation and interviews with operators and the quality control department) and secondary data (company production documents and reports). Data collection was carried out through interviews, direct observation, and a literature study of books, scientific journals, and relevant prior research.

Data analysis was carried out in two stages. First, a descriptive analysis was used to calculate the number and percentage of each defect type, followed by the construction of a Pareto Diagram to identify the dominant defect type based on the 80/20 principle. Second, the dominant defect type was analyzed using the Fault Tree Analysis (FTA) method with the following steps: (a) determining the top event based on the dominant defect type; (b) identifying the intermediate events based on the (Man, Machine, Material, Method, Environment) approach; (c) constructing the Fault Tree diagram with OR and AND logic gates; (d) calculating the probability of each basic event, intermediate event, and top event using the equation P = frequency of occurrence / total frequency; and (e) analyzing the basic event with the highest probability as the basis for formulating improvement proposals.

RESEARCH RESULTS

Production Data and Product Defect Rate

Recapitulation of PT. XYZ's production data for the period January–May 2026 is shown in Table 1. Total production during this period reached 26.940 units, with the highest production in April at 8.505 units and the lowest in March at 480 units. Of this total production, 2.532 units were recorded as defective, resulting in an average defect rate of 9,4% during the study period.

Table 1. Production Data for the Period January–May 2026

Month	Production Quantity (pcs)
January	6.626
February	8.416
March	480
April	8.505
May	2.913
Total	26.940

Source: Internal Data of PT. XYZ, Processed By the Author (2026)

Identification of Dominant Defect Types (Pareto Diagram)

Based on observations of products that did not meet quality standards, five types of defects were identified during the screen-printing production process, as presented in Table 2.

Table 2. Identification of Defect Types and Cumulative Contribution

Defect Type	Quantity (pcs)	Percentage (%)	Cumulative %
Uneven ink	886	35	35
Ink fading	633	25	60
Print position error	456	18	78
Faded color	304	12	90
Stains/wrinkles	253	10	100
Total	2.532	100	-

Source: Primary Data Processed By The Author (2026).

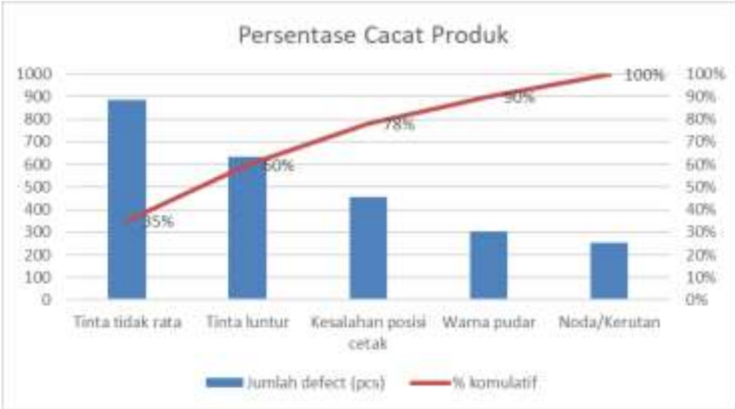

Figure 1. Pareto Diagram of Screen-Printing Product Defect Types at PT. XYZ

The Pareto Diagram in Figure 1 shows that the three most dominant defect types are uneven ink (35%), ink fading (25%), and print position error (18%), with a cumulative contribution of 78%. In accordance with the 80/20 Pareto principle, these three defect types were set as priorities and used as top events in the subsequent Fault Tree Analysis (FTA).

Fault Tree Analysis (FTA) Analysis

The three dominant defect types were then analyzed using the FTA method to identify the cause-and-effect relationship between the top event and the intermediate events and basic events. Probability values were calculated using the equation P = frequency of occurrence / total frequency, then summed (OR gate) or multiplied (AND gate) according to the fault tree structure of each top event.

Top Event 1: Uneven Ink Defect

The uneven ink defect is the most dominant defect type, contributing 35% of all defective products. Its causes stem from human factors (insufficient training, operator carelessness, insufficient understanding of the screen-printing process, fatigue due to long working hours), machine factors (clogged screen, dirty screen), and environmental factors (excessive dust, uneven table surface). The Fault Tree diagram for this top event is shown in Figure 2.

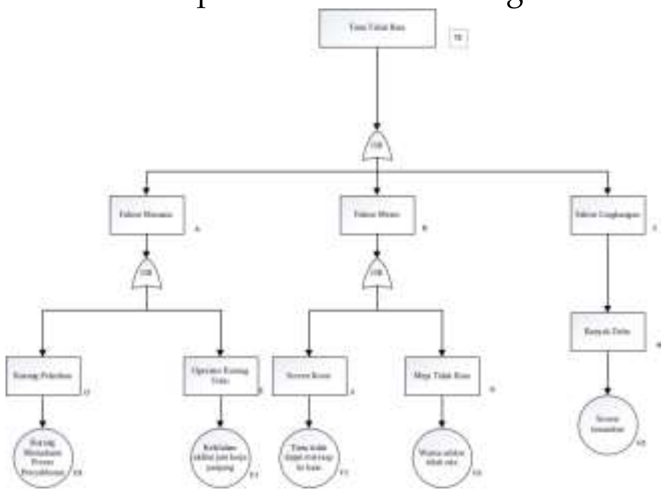

Figure 2. Fault Tree Analysis Diagram for the Uneven Ink Defect Top Event

Table 3. Occurrence Frequency and Basic Event Probability – Uneven Ink

Code	Basic Event	Frequency	Probability
D1	Insufficient training	6	0,06
E1	Operator carelessness	18	0,18
F1	Insufficient understanding of the screen-printing process	12	0,12
G1	Fatigue due to long working hours	5	0,05
B1	Clogged screen	15	0,15
B2	Dirty screen	10	0,10
C1	Excessive dust	8	0,08
C2	Uneven table surface	7	0,07
Total	-	81	0,81

Source: Data Processed By The Author (2026).

The OR-gate calculation for the intermediate events produced a human factor (A) probability of 0,41 (D1+E1+F1+G1), a machine factor (B) probability of 0,25 (B1+B2), and an environmental factor (C) probability of 0,15 (C1+C2). The top event probability was calculated as TE = A+B+C = 0,41+0,25+0,15 = 0,81 (81%). The human factor particularly operator carelessness (0,18) and clogged screen (0,15) was the largest contributor.

Top Event 2: Ink Fading Defect

The ink-fading defect contributes 25% of all defective products, with causes stemming from material factors (incorrect ink composition, hardened press rubber), human factors (operator carelessness, incomplete inspection), and curing-process factors (curing temperature and time, air circulation, heater machine distance). The Fault Tree diagram for this top event is shown in Figure 3.

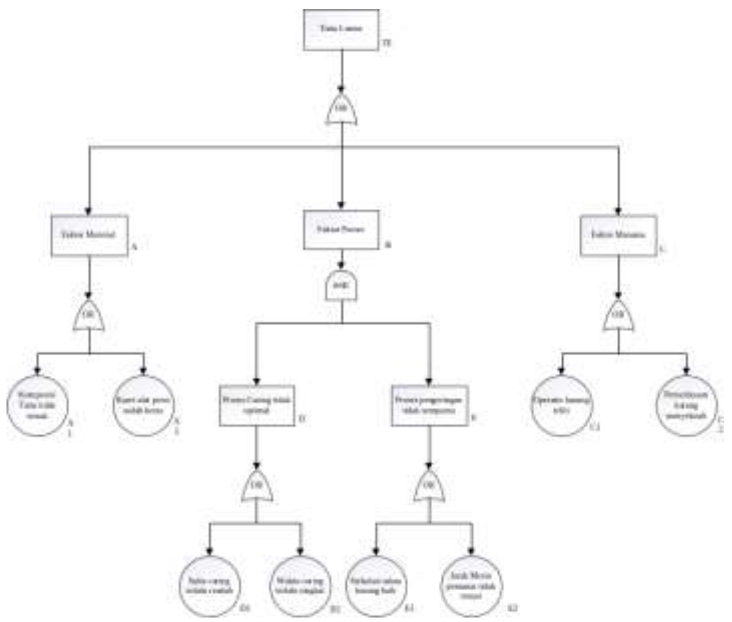

Figure 3. Fault Tree Analysis Diagram for the Ink Fading Defect Top Event

Table 4. Occurrence Frequency and Basic Event Probability – Ink Fading

Code	Basic Event	Frequency	Probability
A1	Incorrect ink composition	12	0,12
A2	Hardened press rubber	8	0,08
B1	Operator carelessness	15	0,15
B2	Incomplete inspection	9	0,09
D1	Curing temperature too low	10	0,10
D2	Curing time too short	8	0,08
E1	Poor air circulation	11	0,11
E2	Improper heater machine distance	7	0,07

Source: Data Processed By The Author (2026).

The intermediate event calculation produced a material factor probability of A = A1+A2 = 0,20; human factor B = B1+B2 = 0,24; sub-factor D (AND gate, temperature×curing time) = D1×D2 = 0,008; sub-factor E (OR gate) = E1+E2 = 0,18; and process factor C = D+E = 0,19. The top event probability was calculated as TE = A+B+C = 0,20+0,24+0,19 = 0,63 (63%). The human factor was again the largest contributor, followed by the material factor and the curing process, which are interrelated in determining ink adhesion.

Top Event 3: Print Position Error Defect

The print-position-error defect contributes 18% of all defective products, with causes stemming from setting errors (imprecise screen position, improper vise adjustment), operator errors (operator carelessness, fabric shifting during printing, material placement not aligned with markings), and equipment conditions (loose clamping vise, unstable printing table). The Fault Tree diagram for this top event is shown in Figure 4.

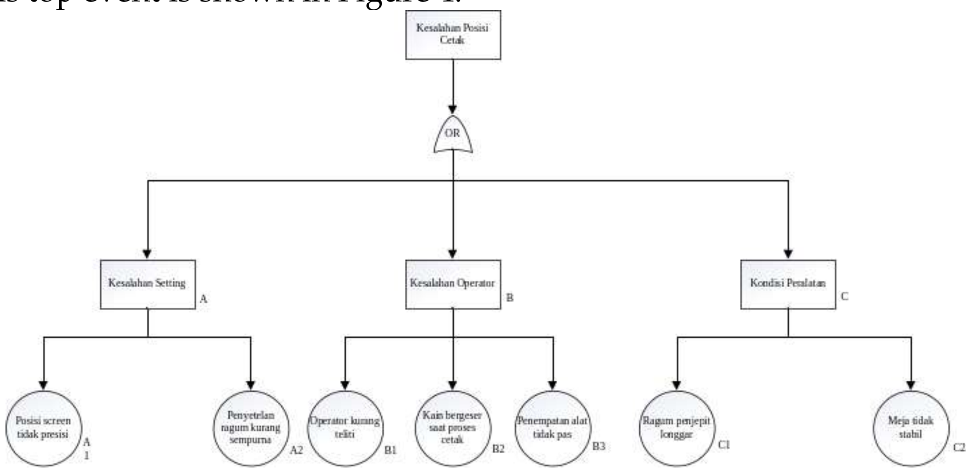

Figure 4. Fault Tree Analysis Diagram for the Print Position Error Top Event

Table 5. Occurrence Frequency and Basic Event Probability – Print Position Error

Code	Basic Event	Frequency	Probability
A1	Imprecise screen position	13	0,13
A2	Improper vise adjustment	9	0,09
B1	Operator carelessness	16	0,16
B2	Fabric shifting during printing	12	0,12
B3	Material placement not aligned with markings	10	0,10
C1	Loose clamping vise	11	0,11
C2	Unstable printing table	8	0,08

Source: Data Processed By The Author (2026).

The OR-gate calculation for the intermediate events produced a setting-error probability of A = A1+A2 = 0,22; an operator-error probability of B = B1+B2+B3 = 0,38; and an equipment-condition probability of C = C1+C2 = 0,19. The top event probability was calculated as TE = A+B+C = 0,22+0,38+0,19 = 0,79 (79%). Operator error was the most dominant factor, indicating that operator precision in screen adjustment, material placement, and machine operation strongly determines the accuracy of the print position.

Table 6. Summary of Top Event Probabilities from the FTA Analysis

Top Event	Pareto Contribution (%)	Dominant Factor	Top Event Probability
Uneven ink	35	Human (0,41)	0,81 (81%)
Ink fading	25	Human (0,24)	0,63 (63%)
Print position error	18	Operator error (0,38)	0,79 (79%)

Source: Data processed by the author (2026).

DISCUSSION

Improvement proposals were formulated based on the basic event with the highest probability value for each top event, following the 5M approach (Man, Machine, Material, Method, Environment). Improvement priorities based on probability values are shown in Table 7.

Table 7. Improvement Proposal Priorities Based on Basic Event Probability Values

Priority	Basic Event	Probability	Improvement Proposal
1	Operator carelessness (uneven ink)	0,18	Pre-production briefing, supervision, operator work checklist
2	Operator carelessness (print position)	0,16	Development of SOP for material placement/mounting
3	Clogged screen	0,15	Preventive maintenance and regular screen cleaning
4	Operator carelessness (ink fading)	0,15	Enhanced process supervision
5	Imprecise screen position	0,13	Calibration and SOP for screen adjustment
6	Incorrect ink composition	0,12	Standardization of ink mixing using calibrated measuring instruments

Source: Data Processed By The Author (2026).

Based on the analysis results, the human factor proved to be the most dominant cause across all top events, as shown by the high probability of the basic event ‘operator carelessness,’ which consistently appeared as the main cause. This is in line with the view that workforce competence is an important component of quality control in small and medium-sized manufacturing industries (Jumawati et al., 2025; Wicaksono et al., 2023). Besides the human factor, machine, material, method, and environmental factors also contributed, albeit with lower probabilities. The comprehensive improvement proposals formulated include: (1) improving operator competence through regular training and pre-production briefings; (2) implementing preventive maintenance on screens, vises, and printing tables; (3) standardizing the ink-mixing process and curing parameters; (4) applying markings for material position on the printing table; (5) implementing a 5R work culture to maintain the cleanliness of the production area; and (6) developing inspection check sheets for the pre-production stage, during the production process, and for final-result inspection as a documented quality-control tool.

The results of this study reinforce previous research findings that the FTA method can systematically break down a top event into intermediate events and basic events, allowing the root causes of production failure to be identified more precisely than through descriptive analysis alone (Andrian et al., 2023; Zakaria et al., 2023). By identifying the basic event with the highest probability, the company can determine improvement priorities more effectively and efficiently, so that the application of FTA can serve as a relevant quality-control approach for small and medium-sized screen-printing industries such as PT. XYZ.

CONCLUSION AND RECOMMENDATIONS

The Pareto Diagram analysis identified three dominant defect types in PT. XYZ's screen-printing production process, namely uneven ink (35%), ink fading (25%), and print position error (18%), with a cumulative contribution of 78% of total defective products. The FTA analysis showed top event probability values of 0,81; 0,63; and 0,79 respectively, with the human factor—particularly operator precision—as the most dominant cause across all top events, followed by machine, material, method, and environmental factors.

The company is advised to promptly implement the priority improvement proposals, namely enhanced operator supervision and training, preventive maintenance of production equipment, standardization of the ink-mixing and curing processes, implementation of a 5R work culture, and the development of inspection check sheets for the pre-production stage, during production, and for final-result inspection as a documented and sustainable quality-control tool.

ADVANCED RESEARCH

This study is limited to the analysis of three dominant defect types based on five months of production data at a single company, so generalization of the results should be made with caution. Future research is recommended to combine FTA with other methods such as Failure Mode and Effect Analysis (FMEA) to determine risk priorities (Risk Priority Number) while more comprehensively evaluating the effectiveness of improvement proposals, as well as to extend the observation period to obtain a more representative picture of defects.

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