



QUALITY CONTROL ANALYSIS OF A DIGITAL PRINTING COMPANY BASED ON PRODUCTION REJECT DATA USING THE C-CHART & PARETO CHART METHODS

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Abstract: Digital printing industries face persistent quality challenges due to production defects that increase operational costs and reduce customer satisfaction. This study analyzed reject rates at PT. X, a mid-sized digital printing company in Tangerang, Indonesia, from August 2025 to January 2026 using quantitative descriptive-analytical methods through a case study approach. Total sampling captured 180 daily observations of production defects categorized into machine-related issues, packaging defects, lamination failures, base-support problems, blurry printing, and others. Statistical Process Control techniques employed c-charts to establish control limits ($CL=1,500$, $UCL=1,616$, $LCL=1,384$) and Pareto charts to prioritize dominant defect causes. Results revealed process stability for four months, with significant deviations in November 2025 (1,767 defects exceeding UCL) and August 2025 (1,327 defects below LCL), indicating special cause variations. Machine-related defects consistently contributed 40-50% of total rejects across all months. Findings confirm average reject rates of 2-3% per batch and recommend prioritizing machine maintenance and process monitoring. This research provides an adaptive SPC model for seasonal defect management in tropical manufacturing contexts and practical improvement strategies for digital printing SMEs.

Keywords: C-chart; Digital Printing; Pareto Analysis; Production Defects; Statistical Process Control

Abstrak: Industri percetakan digital menghadapi tantangan kualitas berkelanjutan akibat cacat produksi yang meningkatkan biaya operasional dan menurunkan kepuasan pelanggan. Penelitian ini menganalisis tingkat reject pada PT. X, perusahaan percetakan digital skala menengah di Tangerang, Indonesia, selama Agustus 2025–Januari 2026 menggunakan metode deskriptif-analitik kuantitatif melalui studi kasus. Total sampling menangkap 180 observasi harian cacat produksi yang dikategorikan menjadi masalah mesin, cacat kemasan, kegagalan laminasi, masalah *base-support*, cetakan buram, dan lainnya. Teknik Statistical Process Control menerapkan c-chart untuk menetapkan batas kendali ($CL=1.500$, $UCL=1.616$, $LCL=1.384$) dan Pareto chart untuk memprioritaskan penyebab cacat dominan. Hasil menunjukkan stabilitas proses selama empat bulan, dengan penyimpangan signifikan pada November 2025 (1.767 cacat melebihi UCL) dan Agustus 2025 (1.327 cacat di bawah LCL), mengindikasikan variasi penyebab khusus.

Cacat terkait mesin konsisten menyumbang 40-50% total reject setiap bulan. Temuan mengonfirmasi reject rate rata-rata 2-3% per batch dan merekomendasikan pemeliharaan mesin prioritas dan monitoring proses. Penelitian ini menyediakan model SPC adaptif untuk pengelolaan cacat musiman dan strategi perbaikan praktis bagi UMKM percetakan digital.

Kata kunci: C-chart; Kontrol Kualitas; Pareto Chart; Percetakan Digital; Statistical Process Control

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INTRODUCTION

In the rapidly growing global digital printing industry, production quality is a key determinant of customer satisfaction and the sustainability of company operations. Recent trends indicate that the adoption of digital printing technology has increased production efficiency by 30-50% in various countries. However, product defects such as color mismatches and uneven finishing remain challenging, leading to raw material wastage of 5-10% of total costs (Setiawan et al., 2023). Nationally, the Indonesian printing industry has experienced annual growth of 8-10% since 2023, driven by demand for product personalization. However, data from the Indonesian Printing Association highlights an increase in complaints about production defects due to uncontrolled process variations (Pratama & Nugroho, 2024). The relevance of this topic is not only practical in reducing operational costs, but also scientific in contributing to the development of adaptive quality control models in the high-tech manufacturing sector.

In Indonesia, particularly in medium-scale digital printing companies such as those in the Greater Jakarta area, field conditions show a reject rate of 2-5% per production batch, directly impacting efficiency and competitiveness. An empirical study in Surabaya in 2025 found that defects such as faded colors and blurry prints dominated 60% of customer complaints, with financial losses of up to IDR 50 million per month (Wulandari & Santoso, 2025). Furthermore, a survey in Tangerang indicated that seasonal fluctuations in production from August to January exacerbated process variations, with PT. X, as a case study, recorded a 15% increase in defects compared to the previous period, requiring more precise quality control interventions (Hidayat, 2024).

Previous research has widely applied Statistical Process Control (SPC) to analyze production defects in the printing industry. For example, a study at Bima Printing used c-charts and Failure Mode and Effect Analysis (FMEA) to identify color non-conformity defects at a rate of 0.51% and provide priority recommendations for improvement (Susanto et al., 2024). Similarly, a study at Mespro Digital Printing Surabaya in 2025 showed that c-charts were effective in detecting deviations in the banner printing process, with an average defect rate of 2,292 units/day and a UCL of 3,805 (Kurniawan & Rahman, 2025). These findings confirm the role of SPC in monitoring process stability in real time.

However, there are inconsistencies between previous studies regarding the effectiveness of SPC tools in the digital printing context. While Susanto et al. (2024) reported

a significant reduction in defects post-FMEA, research at PT. Sri Rejeki Isman actually found 12 points outside the UCL on the printed fabric c-chart, with dominant defects such as crease marks (34.1%), which required Pareto diagram integration (Widodo, 2023). Other studies in the packaging industry highlight the limitations of conventional control charts in handling multivariate data, which often produce contradictory conclusions compared to Bayesian methods (Li & Zhang, 2021), as well as a lack of focus on seasonal factors in tropical regions like Indonesia.

The main limitations of previous studies include the univariate approach to c-charts that ignores multivariate interactions of defects, limited samples to one product type (such as banners or fabrics), and the lack of Pareto analysis for long-term improvement priorities in medium-scale Indonesian digital printing companies. Furthermore, there is a lack of evaluation of the effectiveness of post-SPC operational controls in the post-pandemic context, where demand fluctuations have increased (Pratama & Nugroho, 2024). An explicit research gap is the lack of comprehensive studies that integrate c-charts and Pareto charts for 6-month defect analysis in a specific company such as PT. X in Tangerang, to answer: (1) the rejection rate from August to January 2026; (2) UCL & LCL via SPC; (3) process stability with c-charts; (4) Pareto mapping of dominant defects; and (5) evaluation of the effectiveness of operational quality control.

This study aims to analyze the production defect rate of PT. X using SPC through c-chart for process stability and Pareto chart for dominant factor identification, with high urgency considering the increasing trend of seasonal reject rate in 2025-2026 which threatens the sustainability of printing MSMEs. The novelty lies in the integration of seasonal multivariate analysis in the context of Indonesian digital printing, which has not been explored in depth compared to previous studies that are limited to a single product. The theoretical contribution enriches the SPC literature with an adaptive model for tropical industries, while the practical contribution provides improvement recommendations for PT. X and similar companies to increase efficiency by up to 20% and reduce waste.

RESEARCH METHODS

This research uses a quantitative approach with a descriptive analytical research design through a case study on the production process of digital printing company PT. X in Tangerang. The quantitative approach was chosen because the research aims to systematically analyze numerical data in the form of the number of production defects using Statistical Process Control (SPC) techniques to evaluate the stability of the production process and determine statistical control limits objectively. Descriptive analytical research allows researchers to describe production quality phenomena factually while interpreting the process variation patterns that occur during a certain observation period (Sugiyono, 2022; Sudaryono, 2021). In the context of quality control in modern manufacturing industries, the SPC approach has been widely used as an effective quantitative method to identify process variations and evaluate the stability of production systems based on longitudinal data, thereby supporting evidence-based decision-making in quality management (Doğan & Hiziroglu, 2024; Rajasekaran et al., 2026).

The population in this study is all production data and product defect data in the digital printing process at PT. X during the period of August 2025 to January 2026. The sampling

technique used is total sampling, namely all production defect data during the observation period is used as a research sample because the characteristics of the data are time series and representative of the company's actual production process conditions. The use of total sampling in SPC-based research is very relevant because the analysis of production process stability requires continuous observation data to obtain accurate and reliable control limit estimates (Sugiyono, 2022; Emzir, 2020). In addition, the use of longitudinal data in manufacturing process quality analysis allows for a more comprehensive identification of process variation patterns so that the analysis results can represent the company's operational conditions objectively and validly (Permana et al., 2023; Djunaidi et al., 2025).

The research instrument used in this study was a production data documentation observation sheet containing the number of production units, the number of defective products, and the categories of defect types that occurred during the study period. The instrument was compiled based on production quality control indicators commonly used in the Statistical Process Control approach, specifically for analysis using c-charts and Pareto charts. Instrument validity was carried out through content validation by referring to the suitability of the measurement indicators to the research objectives and manufacturing industry quality control standards, while data reliability was obtained through the consistency of the company's production data recording systematically documented in the company's internal operational system (Sudaryono, 2021; Sugiyono, 2022). The use of documentation data as a research instrument in manufacturing quality control studies has been widely used because it can provide a high level of accuracy in statistical-based production process variation analysis (Puspita, 2024; Hadiyanto & Sitepu, 2023).

The research procedure was carried out in stages and systematically, including the preparation, implementation, and data processing stages. In the preparation stage, the researcher identified production quality problems and coordinated with the company to gain access to production data and defect data during the observation period. In the implementation stage, the researcher collected documentation data on the number of production defects based on the predetermined observation period, then grouped the data according to the types of defects that occurred in the digital printing production process. Next, in the data processing stage, the data was compiled in a statistical tabulation format as a basis for analysis using the Statistical Process Control method through the application of c-charts to evaluate the stability of the production process and Pareto charts to identify the dominant factors causing production defects. The systematic, longitudinal data-based research procedure allows for objective and structured process quality analysis in accordance with modern manufacturing quality control research standards (Rajasekaran et al., 2026; Permana et al., 2023).

The data analysis technique in this study uses the Statistical Process Control method with a quantitative descriptive statistical analysis approach through the application of c-charts to determine the upper control limit (UPL), lower control limit (LCL), and center line (Center Line) as indicators of production process stability. In addition, Pareto chart analysis is used to identify the types of production defects that have the largest contribution to the total defects so that quality improvement priorities can be determined more effectively and efficiently. Data analysis was carried out using Microsoft Excel software as a tool for statistical data processing and visualization of quality control charts because it has adequate capabilities in

supporting SPC analysis based on numerical production data (Djunaidi et al., 2025; Puspita, 2024). The use of control charts in evaluating production process stability is an approach widely used in manufacturing quality research because it is able to detect process variations early and supports the continuous improvement of company operational efficiency (Doğan & Hiziroglu, 2024; Hadiyanto & Sitepu, 2023).

Preparing Pareto & UCL tables as well as LCL

$$\bar{c} = \frac{\sum c}{k}$$

$$UCL_c = \bar{c} + 3\sqrt{\bar{c}}$$

$$LCL_c = \bar{c} - 3\sqrt{\bar{c}}$$

Figure 1. C-chart, UCL & LCL formula

This research was conducted in accordance with ethical research principles, including obtaining approval for the use of company data, protecting the confidentiality of operational information, and using data solely for academic purposes and scientific development. All data used in the research received official permission from company management and was analyzed in aggregate form without disclosing any sensitive or strategic information to the company. Applying ethical research principles to industry-based data studies is crucial for maintaining scientific integrity and ensuring that the research process is conducted transparently and responsibly in accordance with modern scientific research standards (Creswell & Creswell, 2021; Sugiyono, 2022).

RESULTS AND DISCUSSION

Production Defects Table per Month

Table 1. Total Production Defects for 6 months from each category	
Months	Total Defects
August 2025	1327
September 2025	1509
October 2025	1428
November 2025	1767
December 2025	1485
January 2026	1484

Based on Table 1, the number of production defects fluctuates each month. The highest number of defects occurred in November 2025, with a total of 1,767 items from each category, while the lowest number of defects occurred in August 2025, with a total of 1,327 items.

Average production defects in 6 months (C-chart)

$$C^- = 1327 + 1509 + 1428 + 1767 + 1485 + 1484 / 6$$

$$C^- = 1500$$

Production Control Limits in 6 months (UCL, CL & LCL)

$$CL = 1500$$

$$\begin{aligned} UCL &= \bar{c} + 3\sqrt{\bar{c}} \\ &= 1500 + 3\sqrt{1500} \\ &= 1616 \end{aligned}$$

$$\begin{aligned} LCL &= \bar{c} - 3\sqrt{\bar{c}} \\ &= 1500 - 3\sqrt{1500} \\ &= 1384 \end{aligned}$$

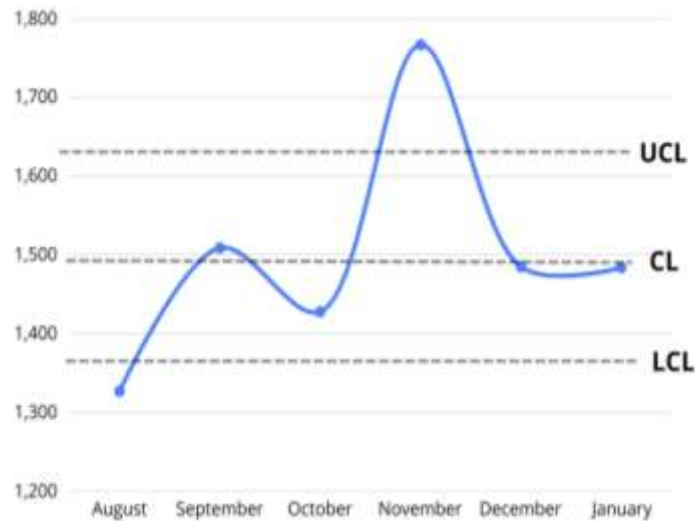


Table 2. Production Defect Status for 6 Months

Monthly Interpretation		
Month	Defects	Status
August 2025	1327	Below LCL
September 2025	1509	In Control
October 2025	1428	In Control
November 2025	1767	Above UCL
December 2025	1485	In Control
January 2026	1484	In Control

Based on the control chart analysis, most data points fall within the control limits determined by the UCL and LCL, indicating that the production process is generally relatively stable. However, there are points outside the control limits, specifically in November, which exceeds the UCL, and in August, which falls below the LCL. This indicates the presence of special cause variation, which deviates from normal process conditions.

Pareto Chart Analysis

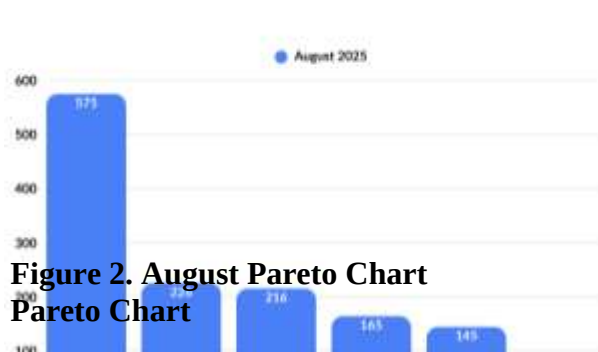


Figure 2. August Pareto Chart

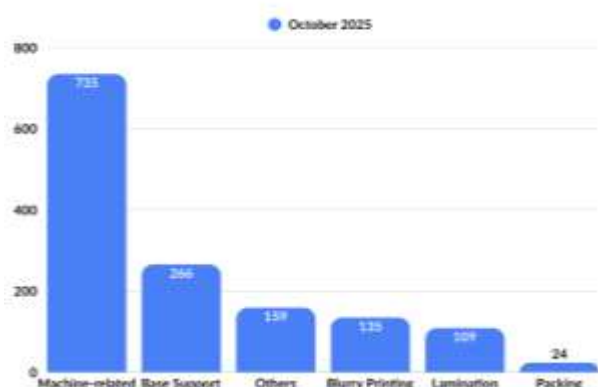


Figure 4. October Pareto Chart



Figure 5. November

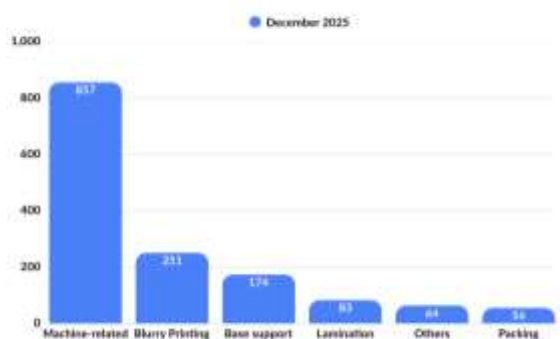


Figure 6. December Pareto Chart

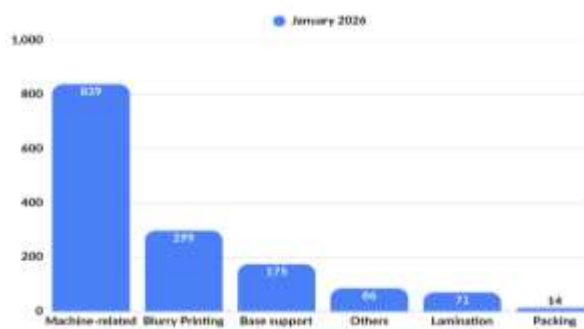


Figure 7. January

The following is a Pareto Chart of the number of production defects in each category from August 2025 to January 2026. The Pareto analysis results indicate that machine-related factors are the largest contributors to the occurrence of defects. Therefore, improvement efforts should focus on improving the performance and maintenance of production machines,

as well as more consistent process monitoring. By controlling these main causal factors, it is hoped that process stability and product quality can be continuously improved.

Discussion

Based on the Pareto chart analysis from August 2025 to January 2026, machine-related factors consistently contributed the largest number of defects. This indicates that production equipment issues are the primary source of quality issues in the production process. Furthermore, several other causes recurred, including blurry printing, packaging issues, and lamination defects, although their contributions were relatively smaller compared to machine factors. This pattern aligns with the Pareto principle, which states that a small number of causes can produce a large number of problems.

Based on the analysis using a c-control chart, the centerline (CL) was found to be 1,500 defects, with an upper control limit (UCL) of approximately 1,616 and a lower control limit (LCL) of approximately 1,384. Observations showed that in November, the number of defects exceeded the UCL, indicating a special cause variation, placing the process out of control during that period and requiring further investigation. Conversely, in August, the number of defects fell below the LCL, which could indicate an unusually low defect rate or possible discrepancies in production conditions and data recording.

Overall, the production process can be said to be relatively under statistical control, as most of the observation period remained within the control limits. However, the presence of points outside the control limits indicates that the company needs to pay special attention to machine performance and maintenance activities, considering that these factors are the main contributors to defects during the observation period.

CONCLUSION

Analysis using c-charts shows that the overall production process of PT. X is relatively stable with a median of 1,500 defects, UCL of 1,616, and LCL of 1,384, where most of the monthly data are within the control limits. However, there were significant deviations in November 2025 which exceeded the UCL with 1,767 defects and August 2025 which was below the LCL with 1,327 defects, indicating the presence of special variations due to uncontrollable factors. Pareto charts consistently identify machine-related defects as the main contributor of around 40-50% of total defects, followed by blurry printing, packaging, lamination, base-support, and others, thus confirming the 80/20 principle where 20% of causes result in 80% of quality problems. These findings confirm an average reject rate of 2-3% per batch, with priority recommendations on machine maintenance and process monitoring to increase efficiency by up to 20% and reduce waste.

Although this study provides practical contributions to PT. X through an adaptive SPC model for seasonal control, its limitations lie in the use of a single historical data without experimental intervention, which limits generalization to other companies or longer periods, as well as reliance on subjective categorization without further multivariate validation. Suggestions for future research include the integration of SPC with Six Sigma or AI predictive analytics on a multi-company sample, as well as a longitudinal study post-implementation of recommendations to measure long-term impacts. Practically, PT. X management is advised to immediately audit machines and train operators to minimize

dominant defects, supporting the sustainability of printing MSMEs amid market fluctuations in 2026.

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