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APPLICATION OF STATISTICAL QUALITY CONTROL (SQC) TO ENHANCE PRODUCT QUALITY IN THE PRINTING INDUSTRY OF MAKASSAR

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Abstract (English)

The printing industry in Makassar faces significant challenges related to product quality, often characterized by a high defect rate. This study aims to enhance product quality by applying Statistical Quality Control (SQC) methods to identify and analyze the root causes of defects, as well as to provide effective improvement recommendations. The methodologies employed include various quality analysis tools such as histograms, Pareto charts, scatter diagrams, control charts, and fishbone diagrams. The findings indicate that the application of SQC successfully identified key defects, including torn materials and unclear prints, along with contributing factors related to human, material, machine, and method aspects. These insights provide a solid foundation for formulating effective corrective actions to improve overall product quality. The impact of this research is a significant enhancement in quality control practices within the printing industry, along with the implementation of best practices that can be adopted by other companies. The conclusions emphasize that the application of SQC is effective in identifying and addressing product defects, enabling companies to develop targeted improvement measures, such as enhancing employee training and selecting higher-quality materials. This research is expected to contribute meaningfully to the advancement of quality control practices in the printing industry and serve as a valuable reference for other companies seeking to improve product quality and production efficiency.

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Key Words

Statistical Quality Control (SQC), Product Quality, Defect Analysis, Printing Industry, Quality Improvement.

1. INTRODUCTION

The printing industry is one of the important sectors in the economy, especially in major cities like Makassar (Mostajabdaveh et al., 2022). With the increasing demand for high-quality printed products, printing companies are required to enhance their product quality standards (Kusrini et al., 2022; Mail et al., 2019). However, many companies in this industry face significant challenges related to high defect rates, which can negatively impact customer satisfaction and profitability (Iffah et al., 2024). Therefore, it is crucial for printing companies to implement effective quality control methods to ensure that the products produced meet consumer expectations (Iftekar et al., 2023).

One proven method for improving product quality is Statistical Quality Control (SQC) (Skrzypczak, 2023). SQC is a statistical-based approach used to measure and control quality in the production process (Murjana & Handayani, 2022). By utilizing statistical analysis tools, companies can identify and analyze the root causes of defects and take necessary corrective actions (Rauf et al., 2023). The application of SQC not only helps reduce product defects but also enhances operational efficiency and lowers production costs (Oktavia & Herwanto, 2021).

In Makassar, the printing industry is experiencing rapid growth; however, many companies still rely on traditional methods for quality control. This often results in an inability to identify problems in a timely manner and take the necessary actions (Fole, 2023; Fole & Kulsaputro, 2023). By implementing SQC, companies can shift from a reactive to a proactive

approach in uality control (Rucitra & Amna, 2021). This will enable them to anticipate issues before they escalate and become detrimental.

This research aims to explore the application of SQC in the printing industry in Makassar, focusing on the identification and analysis of the root causes of product defects (Ben Khedher et al., 2023). Through the use of analytical tools such as histograms, Pareto diagrams, and fishbone diagrams, this study will provide in-depth insights into the factors affecting product quality (Mulyono & Apriyani, 2021). Consequently, companies can formulate effective corrective actions to improve their product quality.

The results of this research are expected to make a significant contribution to quality control practices in the printing industry in Makassar. Additionally, this study aims to provide recommendations that can be adopted by other companies in their efforts to enhance product quality and production process efficiency. Thus, this research is not only relevant for academics but also for practitioners in the field who wish to elevate quality standards in their companies (Andayu & Rahmayanti, 2021).

Overall, the implementation of SQC in the printing industry in Makassar has the potential to bring about significant positive changes (Nazia et al., 2023). By improving product quality, companies can not only meet customer expectations but also enhance their competitiveness in the market. This research is expected to serve as a reference for other printing companies in adopting best practices in quality control and to encourage sustainable growth in the printing industry in Makassar.

2. RESEARCH METHOD

This study employs a quantitative approach with a case study design to analyze the application of Statistical Quality Control (SQC) in improving product quality in the printing industry in Makassar. The data used includes historical data on product defects obtained from the company's production records, as well as primary data collected through semi-structured interviews with managers and employees. Direct observations were also conducted to understand the production process and the challenges in quality control (Absa & Suseno, 2022).

Data analysis was performed using statistical tools such as histograms to illustrate the distribution of defects, Pareto diagrams to identify the most frequently occurring types of defects, and control charts to monitor the production process. Additionally, fishbone diagrams were utilized to identify the root causes of product defects. Based on the findings from the analysis, corrective actions were formulated to reduce the defect rate and enhance overall product quality. This research is expected to make a significant contribution to quality control practices in the printing industry in Makassar.

3. RESULTS AND DISCUSSION

3.1 Analysis Using Statistical Quality Control (SQC)

The application of SQC analysis was carried out by identifying defective products in the production process of the printing industry in Makassar using histograms, Pareto diagrams, scatter diagrams, control charts, and fishbone diagrams (Wilda et al., 2023). The types of defects in the production process can be seen below.

Table 1. Types of Product Defect Activities in the Printing Industry in Makassar

No	Type of Defect	Description	Code
1	Misregistration	Misalignment between colors or layers of print, resulting in blurry or duplicated images or text.	C1
2	Color Variation	Differences in color between printed outputs due to inconsistencies in ink, pressure, or machine temperature.	C2

3	Smudging	The presence of smears or ink overflow caused by ink not drying completely before proceeding to the next process.	C3
4	Streaks and Banding	The appearance of horizontal or vertical lines due to issues with the print head, ink rollers, or uneven ink distribution.	C4
5	Ghosting	Faint images or text appearing elsewhere on the paper due to incomplete ink transfer.	C5
6	Paper Wrinkling	Creases or folds in the paper caused by excessive moisture, unbalanced roller pressure, or poor paper quality.	C6
7	Pinholes	Small dots that are not printed due to dust particles or an uneven paper surface.	C7
8	Overinking/ Underinking	Prints that are either too thick or too thin due to suboptimal ink settings.	C8
9	Blurry or Unsharp Text	Letters or images that lack sharpness due to low resolution or errors in plate adjustment.	C9
10	Trapping Defects	Imperfections at the junction of two adjacent colors, leading to gaps or inappropriate blending.	C10

The table outlines ten distinct types of product defects commonly encountered in the printing industry, each with specific characteristics and implications for quality. Misregistration, for instance, results in misalignment between colors or layers, leading to blurry or duplicated images, which can significantly detract from the visual appeal of printed materials (Mulyana et al., 2022). Color variation, on the other hand, arises from inconsistencies in ink or machine settings, potentially causing customer dissatisfaction, especially when brand colors are involved. Other defects such as smudging and streaks are often linked to issues with ink drying and uneven distribution, respectively, highlighting the importance of maintaining optimal production conditions to ensure high-quality outputs (Farhan Khan et al., 2021).

Additionally, defects like ghosting, paper wrinkling, and pinholes can further compromise the integrity of printed products. Ghosting occurs due to incomplete ink transfer, while paper wrinkling is often a result of environmental factors or improper handling. Pinholes, caused by dust or uneven surfaces, can lead to unsightly blemishes on the final product. Overinking and underinking affect the print density, resulting in either excessively thick or thin prints, while blurry text can stem from low resolution or misadjusted plates. Lastly, trapping defects at the junction of adjacent colors can lead to visual inconsistencies. Addressing these defects through effective quality control measures and equipment maintenance is essential for enhancing product quality and ensuring customer satisfaction in the competitive printing market (Fauzi et al., 2023).

a. Analysis Using Histogram Method

Based on defect data from the production process in the Makassar printing industry, histograms are used to describe the frequency distribution (Fole, Herdianzah, et al., 2024; Hijra et al., 2024). The frequency distribution shows how often each different value appears in a data set. The results of this determination are as follows.

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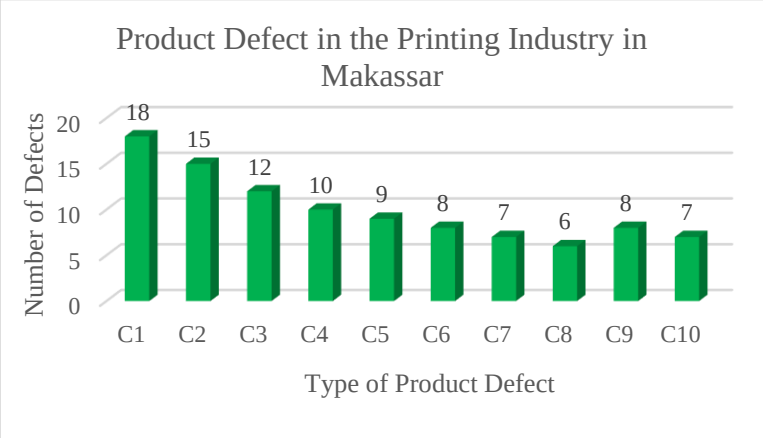

Figure 1. Histogram of Product Defects

The table above shows ten types of product defects commonly encountered in the printing industry, along with the number of defects detected. Misregistration, with 18 defects, is the most prevalent issue, where misalignment between colors or layers can result in blurry or duplicated images. This defect is often caused by errors in machine settings or a lack of attention during the production process. Furthermore, color variation (15 defects) and smudging (12 defects) are also significant problems that can affect customer satisfaction, especially when printing products that require high color consistency. Research by (Mohammed Ali et al., 2022), indicates that defects such as misregistration and color variation can directly impact consumers' perceptions of product quality, which in turn can affect brand loyalty.

Other defects, such as streaks and banding (10 defects) and ghosting (9 defects), highlight the importance of equipment maintenance and proper settings in the production process. Paper wrinkling (8 defects) and pinholes (7 defects) also underscore the challenges faced in maintaining the quality of raw materials and the production environment. Research by (Singh et al., 2021), emphasizes that effective quality control, including monitoring environmental conditions and routine equipment maintenance, can significantly reduce defect rates. With a total of 100 defects detected, it is crucial for printing companies to implement better quality control methods, such as Statistical Quality Control (SQC), to enhance product quality and meet customer expectations.

b. Analysis Using Pareto Chart

The Pareto chart is used to identify the dominant causes of product defects and their respective percentages.

Table 2. Pareto Chart

Code	Type of Product Defect	Number of Defects	Percentage	Cumulative Percentage
C1	Misregistration	18	18%	18%
C2	Color Variation	15	15%	33%
C3	Smudging	12	12%	45%
C4	Streaks and Banding	10	10%	55%
C5	Ghosting	9	9%	64%
C6	Paper Wrinkling	8	8%	72%
C7	Pinholes	7	7%	79%
C8	Overinking/ Underinking	6	6%	85%

Code	Type of Product Defect	Number of Defects	Percentage	Cumulative Percentage
C9	Blurry or Unsharp Text	8	8%	93%
C10	Trapping Defects	7	7%	100%

Based on the results from the Pareto chart, the percentage of defective products for each activity was determined, resulting in the figure below (Astutik et al., 2024).

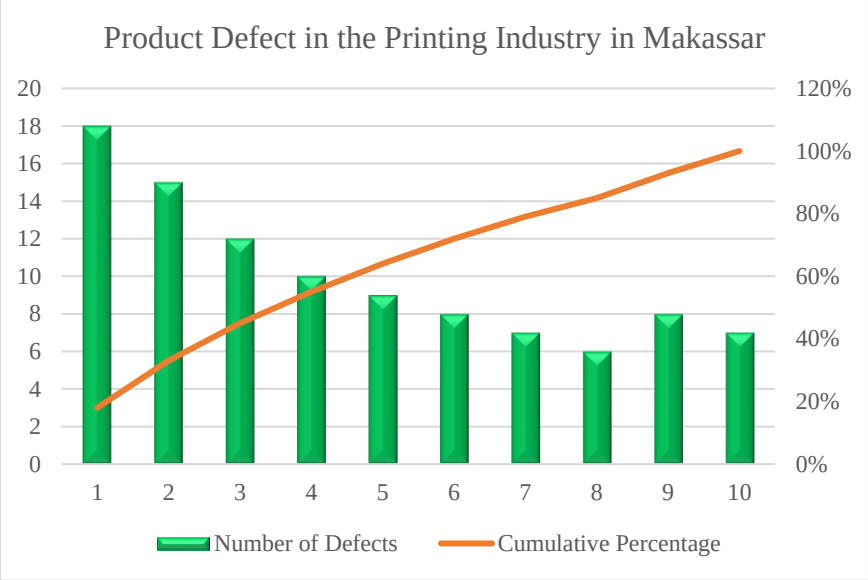

Figure 2. Pareto Chart of Product Defects

The table above presents data on various types of product defects commonly occurring in the printing industry, along with the number of defects, percentages, and cumulative percentages for each defect. From the data, misregistration emerges as the most common defect with 18 occurrences, accounting for 18% of the total defects detected. This defect can lead to misalignment between colors or layers, directly impacting the visual quality of printed products. It is followed by color variation (15 defects or 15%) and smudging (12 defects or 12%), which also indicate that inaccuracies in the printing process can diminish customer satisfaction. These defects highlight the importance of stringent quality control in the production process to ensure consistent results that meet consumer expectations.

Previous research by (Harriet et al., 2024), shows that defects such as misregistration and color variation can significantly affect consumers' perceptions of product quality, which in turn can impact brand loyalty. Additionally, research by (Budzik et al., 2021) emphasizes that implementing effective quality control methods, such as Statistical Quality Control (SQC), can help identify and reduce product defects. By applying corrective measures based on defect data analysis, printing companies can enhance their overall product quality. With a total of 100 defects detected, it is crucial for the printing industry to continue investing in technology and training to reduce defects and improve customer satisfaction.

c. Analysis Using Scatter Diagram

The scatter diagram is used to test the strength of the relationship between two variables and to determine the nature of that relationship, whether it is positive, negative, or nonexistent (Fole et al., 2025). The results of this determination are as follows.

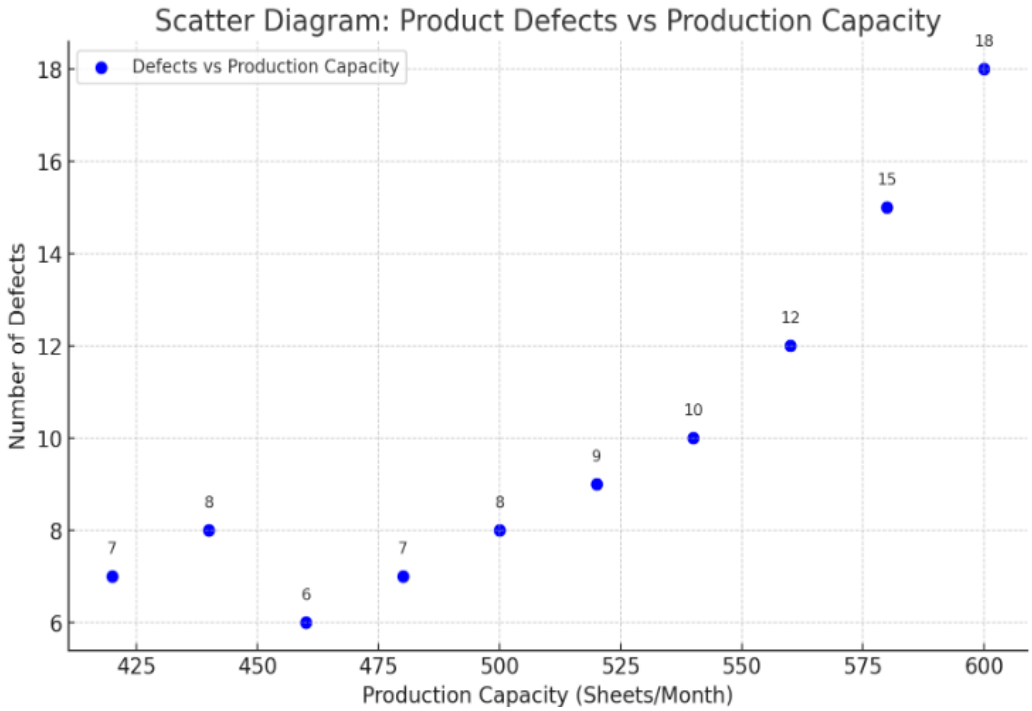

Figure 3. Scatter Diagram of Product Defects

The scatter diagram above illustrates the relationship between production capacity (sheets/month) and number of defects in the printing industry. From the graph, we can observe a trend where higher production capacity tends to be associated with a higher number of defects. At 600 sheets/month, the number of defects reaches 18, whereas at lower production capacities, the defect numbers tend to be lower.

This result aligns with previous research, such as (Saihi et al., 2023), who stated that increasing production without proper quality control measures can lead to a rise in defect rates. Additionally, emphasized the correlation between workload and product quality, where increasing capacity without quality control measures may increase the risk of defects. Furthermore, introduced the *Cause-and-Effect Diagram* methodology, which helps in identifying the root causes of frequent defects (Carvalho & Lima, 2022).

d. Analysis Using Control Chart

To find out whether the production defects are within the control limits, an analysis was conducted on each type of production defect in the Makassar printing industry using the p control chart. The calculation results are as follows.

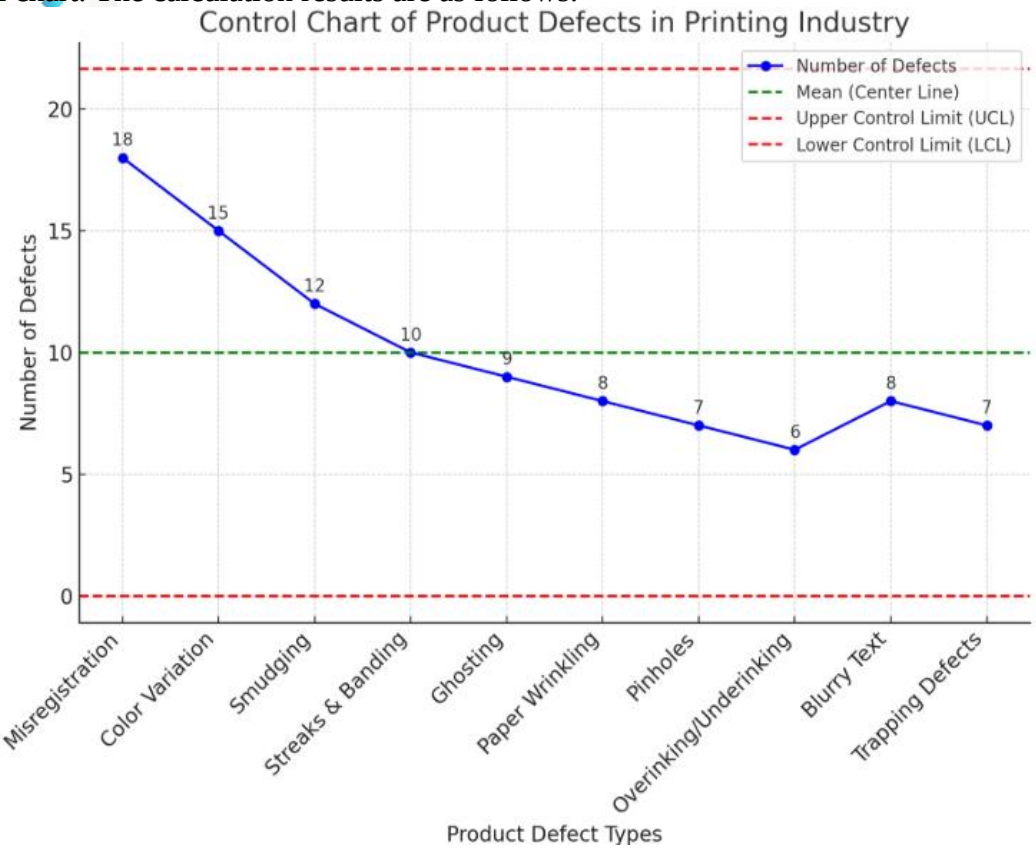

Figure 4. Control Chart of Product Defects in Printing Industry

The control chart displayed shows the distribution of defects across various types in the printing industry. From the graph, it is evident that all data points fall within the control limits, with an average number of defects of 10, an upper control limit (UCL) of 21.66, and a lower control limit (LCL) of 0. This indicates that statistically, the production process is still under control, although there are several types of defects approaching the upper limit, such as Misregistration (18 defects) and Color Variation (15 defects). Meanwhile, other defects like Blurry Text and Paper Wrinkling (8 defects) and Pinholes (7 defects) have lower counts but still need to be monitored to prevent any increase. Therefore, the primary focus in quality control should be on reducing the number of high-frequency defects to enhance production efficiency.

These findings align with research in his book "Introduction to Statistical Quality Control," which explains that control charts can help detect variations in a production process before significant deviations occur (Budzik et al., 2021). Additionally, emphasizes that in manufacturing industries, quality improvement can be achieved by identifying and reducing the most frequently occurring defects (Saihi et al., 2023). Another study by supports this approach with the concept of the Cause-and-Effect Diagram, which can be used to identify the root causes of the most common defects (Carvalho & Lima, 2022). Therefore, based on this analysis, the printing industry in Makassar can implement Statistical Quality Control (SQC) methods to control variations in production and improve the quality of printed outputs.

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e. Analysis Using Fishbone Diagram

To analyze product defects in the printing industry in Makassar, an analysis was conducted using a fishbone diagram for all types of defects. Before implementing corrective actions, the causes of defects were analyzed using the fishbone diagram, resulting in the following findings. The results of this analysis are as follows.

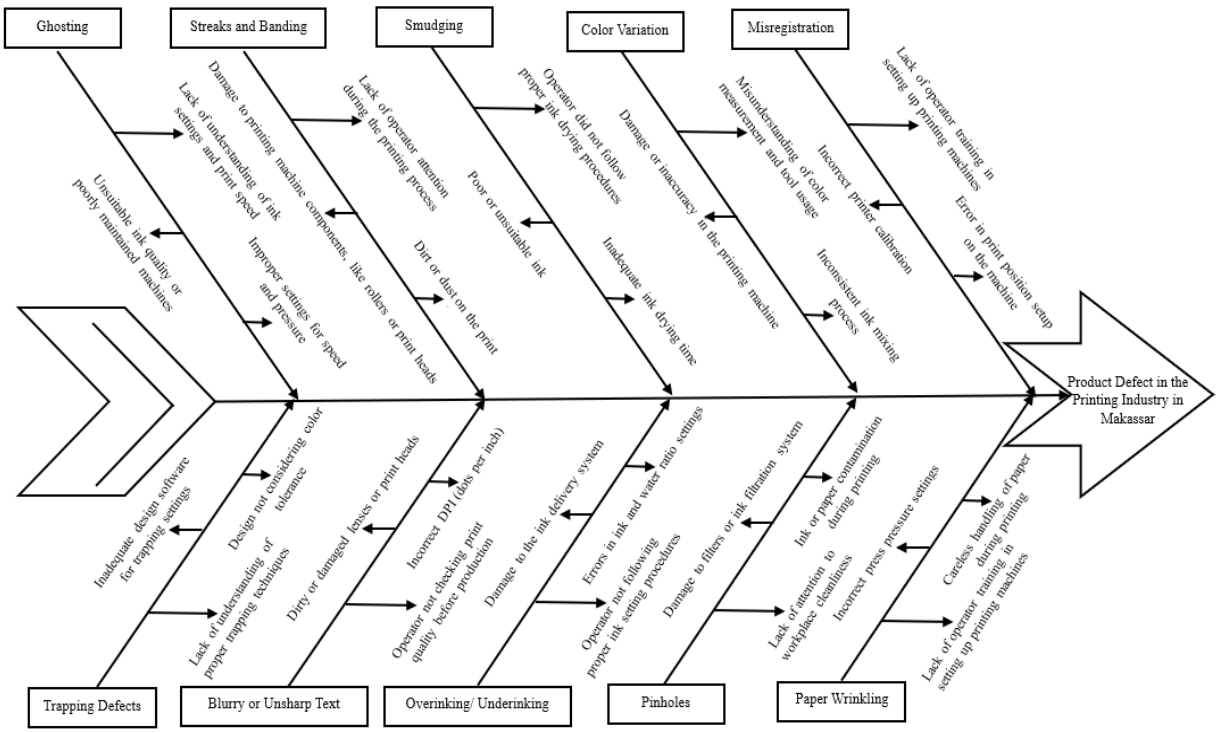

Figure 5. Fishbone Chart Product Defect in the Printing

The analysis conducted using the fishbone diagram demonstrates its effectiveness as a tool for identifying and analyzing the root causes of product defects in the production process. In the context of defects such as misregistration, color variation, and smudging, previous research has indicated that improved operator training and the use of appropriate measuring tools can significantly reduce these errors . For instance, research by (Haruna et al., 2024) emphasized the importance of operator training in machine settings to minimize misregistration, while also highlighting that a thorough understanding of color measurement can enhance color consistency. Additionally, it was demonstrated that an efficient drying system is crucial for preventing smudging, underscoring the necessity of attention to detail in the printing process (Abusaq et al., 2023).

Moreover, defects such as streaks and banding, ghosting, and pinholes can also be effectively addressed with the right strategies (Raj & Kaur, 2025). Research has highlighted the importance of maintaining cleanliness in the printing process to avoid streaks, while other studies have shown that proper speed and pressure settings can reduce ghosting. Furthermore, it has been emphasized that maintaining cleanliness in the workspace and equipment can significantly decrease the occurrence of pinholes. Therefore, regular maintenance, enhanced operator training, and the adoption of the latest technology in ink settings and print resolution are critical steps that can be taken to improve product quality and overall production efficiency (Masod & Zakaria, 2024). Implementing the recommendations derived from this research will contribute to reducing product defects and enhancing customer satisfaction.

3.2 Recommendations for Improving Product Quality

To improve product quality in the printing industry using fishbone analysis, focus on enhancing operator training, implementing effective measuring tools, and maintaining cleanliness in the workspace. Research supports that these measures can significantly reduce defects like misregistration, color variation, and smudging, ultimately boosting customer satisfaction.

a. Enhancing Operator Training

One of the most critical recommendations for improving product quality is to enhance operator training. Research by (Safie & Khairil, 2025) highlights that well-trained operators are better equipped to handle machine settings, which can significantly minimize issues such as misregistration. By investing in comprehensive training programs that cover not only the technical aspects of machine operation but also the nuances of quality control, companies can ensure that their workforce is capable of producing high-quality outputs consistently. This approach not only reduces defects but also fosters a culture of quality awareness among employees.

b. Implementing Effective Measuring Tools

In addition to training, the implementation of effective measuring tools is essential for maintaining product quality. Found that a thorough understanding of color measurement techniques can lead to improved color consistency in printed materials (Xiang & Feng, 2021). By equipping operators with advanced measuring instruments and providing training on their proper use, organizations can better monitor and control the quality of their products. This proactive approach allows for early detection of potential issues, enabling timely interventions that can prevent defects from reaching the final product.

c. Maintaining Cleanliness in the Workspace

Lastly, maintaining cleanliness in the workspace is a fundamental practice that can significantly impact product quality. Emphasizes the importance of cleanliness in the printing process to avoid defects such as streaks and banding. Regular cleaning schedules and protocols should be established to ensure that all equipment and work areas are kept free of contaminants (Bălan et al., 2021). Furthermore, (Haruna et al., 2024) suggest that a clean working environment not only reduces the occurrence of pinholes but also enhances overall operational efficiency. By prioritizing cleanliness, companies can create a conducive environment for high-quality production, ultimately leading to increased customer satisfaction.

3.3 Discussion

The findings from the analysis of product defects in the printing industry underscore the critical need for effective quality control measures to enhance product quality. The prevalence of defects such as misregistration, color variation, and smudging highlights the challenges faced by printing companies in maintaining high standards. Research by (Carvalho & Lima, 2022)indicates that these defects not only diminish the visual appeal of printed materials but also negatively impact customer satisfaction and brand loyalty. Therefore, addressing these issues through targeted interventions is essential for improving overall product quality and meeting consumer expectations.

One of the primary recommendations emerging from this analysis is the enhancement of operator training. As noted by (Silva et al., 2022), well-trained operators are better equipped to manage machine settings and understand the intricacies of the printing process. This investment in training not only reduces the likelihood of defects but also fosters a culture of quality awareness among employees. By prioritizing operator education, printing companies can create a workforce that is more adept at identifying and mitigating potential issues before they escalate into significant defects.

In addition to training, the implementation of effective measuring tools is crucial for maintaining product quality (Fole, 2022). Emphasize that a thorough understanding of color

measurement techniques can lead to improved consistency in printed materials (Xiang & Feng, 2021). By equipping operators with advanced measuring instruments and providing training on their proper use, organizations can enhance their ability to monitor and control product quality (Fole & Kulsaputro, 2023). This proactive approach allows for early detection of potential issues, enabling timely interventions that can prevent defects from reaching the final product.

Moreover, maintaining cleanliness in the workspace is a fundamental practice that significantly impacts product quality (Fole et al., 2025). Highlights the importance of cleanliness in the printing process to avoid defects such as streaks and banding (Abusaq et al., 2023). Establishing regular cleaning schedules and protocols ensures that all equipment and work areas remain free of contaminants (Kusrini et al., 2022). Further support this notion by suggesting that a clean working environment not only reduces the occurrence of pinholes but also enhances overall operational efficiency (Fole & Mujaddid, 2023; Haruna et al., 2024). By prioritizing cleanliness, companies can create a conducive environment for high-quality production, ultimately leading to increased customer satisfaction.

In conclusion, the analysis of product defects in the printing industry reveals that a multifaceted approach is necessary to enhance product quality. By focusing on operator training, implementing effective measuring tools (Fole, Mail, et al., 2024; Malik et al., 2024), and maintaining cleanliness in the workspace, printing companies can significantly reduce defect rates and improve customer satisfaction. The recommendations supported by research highlight the importance of continuous improvement in quality control practices, which is essential for sustaining competitiveness in the dynamic printing market. Future research should explore the long-term impacts of these interventions on product quality and customer loyalty, providing further insights into best practices for the industry.

4. CONCLUSION

Based on the results and discussions conducted, this study highlights the importance of implementing Statistical Quality Control (SQC) methods in the printing industry to enhance product quality by systematically identifying and analyzing the root causes of defects. The analysis results indicate that defects such as misregistration, color variation, and smudging are common issues that significantly impact customer satisfaction and brand loyalty. By focusing on improving operator training, implementing effective measuring tools, and maintaining cleanliness in the workplace, printing companies can address these defects more effectively. Research supports that well-trained operators are better equipped to manage machine settings and understand the nuances of quality control, which can lead to a reduction in defect rates. Additionally, the use of advanced measuring instruments allows for better monitoring of product quality, enabling timely interventions to prevent defects from reaching the final product. Furthermore, maintaining a clean working environment is crucial for minimizing defects such as streaks and pinholes, thereby enhancing overall operational efficiency. These findings emphasize the need for continuous improvement in quality control practices to sustain competitiveness in the dynamic printing market. By adopting the recommendations derived from this study, printing companies can significantly improve their product quality, ultimately leading to increased customer satisfaction and loyalty. Future research should focus on the long-term effects of these interventions on product quality and explore additional strategies for further enhancing quality control in the printing industry. Overall, this study provides a comprehensive framework for addressing product defects and improving quality through effective SQC methodologies.

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