Product Quality Analysis in a Printing MSME: Problem Identification and Quality Control Recommendations

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Abstract
This study analyzes product quality in a printing micro, small, and medium enterprise (MSME) using defect records collected over the most recent five-month period. Employing a descriptive quantitative approach, the research classifies defects, evaluates their frequency distribution, and establishes improvement priorities to support practical quality control actions. The dataset contains 106 defect occurrences comprising five defect types: Color Mismatch (37 cases), Blurred Print Output (28 cases), Print Misalignment/Shifted Position (17 cases), Uneven Screen-Printing Result (13 cases), and Ink Smearing/Overflow (11 cases). The results show that Color Mismatch, Blurred Print Output, and Print Misalignment/Shifted Position constitute the dominant defects, jointly accounting for 77.36% of total defects, indicating that stabilization of color reproduction, print clarity, and registration should be the primary focus of improvement. Root-cause exploration suggests that these defects are driven by interacting factors related to operator consistency and competence, machine calibration and cleanliness, non-standardized setup and proofing procedures, variability in ink and substrate characteristics, the absence of objective inspection criteria, and environmental conditions such as humidity and lighting. The study recommends standardizing process parameters and proofing practices, implementing first-off inspection and pre-production checklists, strengthening ink/material control, and adopting preventive maintenance to reduce defect recurrence and improve output consistency.

Keywords: Printing MSME, Product Quality, Defect Analysis, Quality Control, Continuous Improvement

1. Introduction

Printing MSMEs play a critical role in supporting local economic activity by providing diverse printed products such as brochures, banners, packaging, business cards, and screen-printed items [1]. However, the operational environment of printing services is characterized by high product variety, frequent job changes, and tight delivery deadlines, which increase the likelihood of process variation and inconsistent quality outcomes.

In the printing industry, product quality is primarily assessed through conformance to customer specifications, including color accuracy, sharpness/clarity, print position accuracy (registration), and ink neatness [2, 3]. Any deviation from these specifications can cause customer dissatisfaction, rework, material waste, and delays in delivery, ultimately reducing profitability and increasing operational risk for MSMEs with limited resources [4, 5].

Quality issues in MSMEs are often compounded by limited documentation practices, non-standardized operating procedures, and insufficient preventive maintenance [6, 7, 8, 9]. When defects recur without systematic measurement and analysis, corrective actions tend to be reactive and localized, addressing symptoms rather than underlying process drivers [10].

A practical quality improvement initiative should begin with a structured, data-driven diagnosis that identifies dominant defects, ranks their contribution to total quality loss, and explores plausible root causes. In this context, basic quality tools offer a pragmatic pathway because they are relatively simple to apply, rely on observable production evidence, and can be integrated into routine shop-floor management [11, 12, 13, 14, 15,16].

Accordingly, this study aims to (1) classify and quantify production defects over a five-month period, (2) prioritize the most critical defects that contribute disproportionately to total defects, and (3) articulate root-cause hypotheses to inform implementable quality control recommendations for a printing MSME.

The contribution of this paper lies in translating defect records into an operational improvement roadmap for MSME settings. By focusing on dominant defects and their likely drivers, the study provides targeted recommendations that can be implemented incrementally, supporting continuous improvement without requiring substantial capital investment.

2. Method

This research employs a descriptive quantitative design using historical defect records collected over the last five months from a printing MSME. The unit of analysis is the defect occurrence (frequency of nonconformities) observed in completed or in-process printed products during the study period.

The object of analysis is a printing MSME that produces a variety of printed and screen-printed items. Defects are categorized into five types based on the enterprise's quality records: (1) Color Mismatch, (2) Blurred Print Output, (3) Print Misalignment/Shifted Position, (4) Ink Smearing/Overflow, and (5) Uneven Screen-Printing Result. The dataset represents aggregated counts across the five-month window.

Data collection is based on internal defect summaries maintained by the enterprise. To support interpretation, the study assumes a typical printing workflow comprising file preparation, substrate setup, ink preparation, machine setup, test printing, full production printing, drying/curing (where applicable), and final inspection. Informal shop-floor observation and practitioner input are used to contextualize possible sources of variation.

The analytical procedure consists of three steps. First, the defect data are organized into a structured summary to represent the frequency distribution of defect types. Second, defects are ranked by frequency, and proportional contribution and cumulative contribution are computed to identify priority defects. Third, a cause-and-effect (root-cause) analysis is carried out for the priority defects using a structured 6M classification: Man, Machine, Method, Material, Measurement, and Environment.

The outputs of the methodology include: (1) a defect distribution profile, (2) a prioritized defect list with cumulative contribution, and (3) a set of root-cause hypotheses and actionable recommendations. These outputs are intended to support decision-making by MSME managers in selecting high-impact improvement actions under resource constraints.

Because the available data are aggregated rather than time-stamped by day, machine, operator, or product family, the analysis focuses on prioritization and plausible cause mapping rather than statistical inference. Nevertheless, the approach is adequate for initiating structured quality improvement and for guiding more granular data collection in subsequent cycles.

3. Results and Discussion

3.1. Defect Profile

Across the five-month observation period, a total of 106 defects were recorded. Table 1 summarizes the frequency and proportional contribution of each defect type.

Table 1: Results of the Eligibility Score and Student Responses to the Development of *Virtual Reality* (VR) Based Learning Media

Defect Type	Frequency (cases)	Share (%)
Color Mismatch	37	34.91
Blurred Print Output	28	26.42
Print Misalignment / Shifted Position	17	16.04
Uneven Screen-Printing Result	13	12.26
Ink Smearing / Overflow	11	10.38
Total	106	100.00

The defect distribution indicates that quality issues are concentrated in appearance-related attributes that are highly visible to customers. Color mismatch and blurred output dominate the defect profile, suggesting that the enterprise's primary quality risk is inconsistency in print reproduction (color and sharpness), which is sensitive to both setup parameters and process stability.

Print misalignment represents the third-largest defect category and is commonly associated with registration control, substrate feeding stability, and setup accuracy. Although its contribution is lower than the top two defects, misalignment can significantly reduce product acceptability, especially for multi-color prints or jobs requiring precise placement.

The remaining defect types such as uneven screen-printing and ink smearing/overflow also present material and method control challenges, typically linked to ink viscosity, application pressure, drying conditions, and cleanliness. Collectively, these defects imply a need for more consistent control over ink handling and process parameters.

3.2. Priority Defects and Improvement Focus

To establish improvement priorities, defect types were ranked by frequency and their proportional and cumulative contributions were calculated (Table 2).

Table 2:

Rank	Defect Type	Frequency	Share (%)	Cumulative (%)
1	Color Mismatch	37	34.91	34.91
2	Blurred Print Output	28	26.42	61.32
3	Print Misalignment / Shifted Position	17	16.04	77.36
4	Uneven Screen-Printing Result	13	12.26	89.62
5	Ink Smearing / Overflow	11	10.38	100.00

The results indicate that the three most frequent defects, Color Mismatch, Blurred Print Output, and Print Misalignment/Shifted Position, account for 77.36% of all recorded defects. This cumulative share demonstrates that quality losses are concentrated in a limited set of defect modes, and that focusing corrective actions on these vital few defects is likely to yield the greatest overall reduction in defect occurrence.

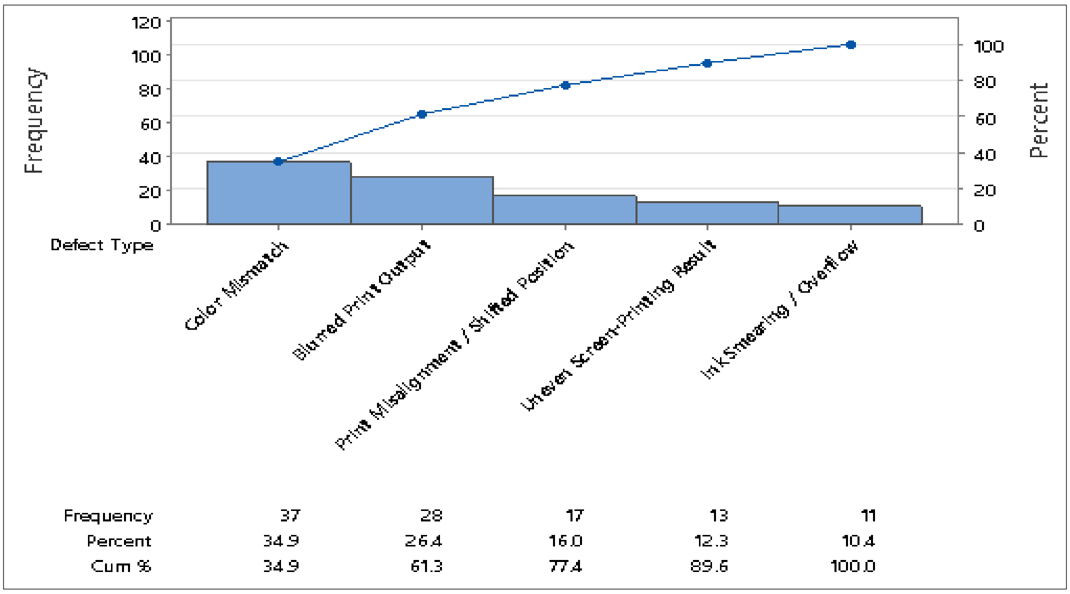

Fig 1: Pareto Chart of Detect Type

From an operational perspective, the prioritization suggests a Pareto-aligned improvement focus on (i) stabilizing color reproduction (Color Mismatch), (ii) improving print clarity (Blurred Print Output), and (iii) strengthening registration/positioning control (Print Misalignment). The first two defects are strongly associated with ink-substrate interaction, machine condition, and setup discipline, while misalignment reflects additional sensitivity to substrate feeding stability, mechanical registration, and fixture accuracy. In an MSME environment with limited resources, concentrating improvement efforts on these three defect categories provides an efficient pathway to measurable quality gains.

Moreover, addressing Print Misalignment alongside the top two defects is strategically justified because misalignment frequently results in immediate product rejection and rework, particularly for multi-color prints and jobs requiring tight tolerances. Therefore, a three-priority improvement program is expected to produce a more substantial and faster impact on overall quality performance than limiting the intervention to only two defect types.

3.3. Root-Cause Analysis for Dominant Defects

1) Color Mismatch (Priority 1)

❖ **Man (Human factors):**
- Inconsistent Color-Matching Practices;
- Limited Competence in Interpreting Color References;
- Inadequate Attention to Detail During Setup;
- VariabilityBetween Operators During Changeovers;
- Fatigue and Time Pressure Leading to Rushed Adjustments

❖ **Machine (Equipment):**
- Lack of Calibration and Profiling;
- Instability in Ink Delivery/Printing System
- Worn Components Affecting Consistency;
- Inconsistent Print Pressure or Speed;
- Limited Machine Capability to Maintain Repeatability Across Runs

❖ **Method (Procedures):**
- Absence of Standardized Proofing and Color Approval Workflow;
- Lack of Documented Parameter Settings;
- Inconsistent Pre-Production Checks;
- No Structured Process for Job Setup and Changeover;
- Limited Control of Drying/Curing Procedures

❖ **Material (Ink and substrate):**
- Batch-To-Batch Ink Variation;
- Incomplete Ink Mixing/Homogenization;
- Inconsistent Ink Viscosity Due to Unstandardized Dilution;
- Substrate Variability (Absorbency, Coating, Texture, Thickness);
- Incompatibility Between Ink Type and Substrate Leading to Color Shift

❖ **Measurement (Inspection and standards):**
- No Objective Color Standard (
- Inconsistent Viewing Conditions and Acceptance

Criteria;
- Reliance on Subjective Judgment;
- Lack of Basic Measurement Aids
- Insufficient Documentation of Acceptable Color Range/Tolerance

❖ **Environment (Work conditions)**:
- Humidity and Temperature Fluctuations Affecting Drying and Ink Behavior;
- Inconsistent Lighting (Color Temperature Differences) Influencing Perceived Color;
- Airborne Dust/Contaminants Affecting Surface Appearance;
- Workspace Conditions that Vary Between Day and Night Shifts

2) Blurred Print Output (Priority 2)

❖ **Man (Human factors):**
- Inconsistent Setup of Resolution/Print Quality Settings;
- Inadequate Cleaning Discipline
- Rushed Production Under Tight Deadlines;
- Limited Skill in Adjusting Print Parameters to Substrate and Ink Conditions;
- Inconsistent Monitoring During Production

❖ **Machine (Equipment):**
- Dirty/Misaligned Print Heads or Clogged Nozzles;
- Unstable Pressure/Contact Between Printing Components (Roller, Head, Plate/Screen);
- Vibration or Mechanical Looseness Reducing Sharpness; Worn Plates/Screens or Rollers Causing Loss of Definition;
- Inconsistent Substrate Feed Leading to Slight Motion During Printing

❖ **Method (Procedures)**:
- Absence of Preventive Cleaning and Maintenance Schedule;
- Lack of Standardized First-Off Inspection Focused on Clarity;
- Inconsistent Parameter Setup (Speed, Pressure, Pass);
- No Formal Control of Ink Viscosity Before Printing; Inadequate Drying/Curing Method That Can Cause Smearing and Reduce Apparent Sharpness

❖ Material (Ink and Substrate):
- Ink Viscosity Too Low/High Resulting in Bleeding or Poor Definition;
- Excessive or Inconsistent Use of Thinner/Solvent;
- Substrate That Absorbs Ink Excessively or Has Uneven Surface Texture;
- Contamination (Dust/Oil) On Substrate Surface;
- Variability Across Material Batches

❖ Measurement (Inspection and Standards):
- Unclear Acceptance Criteria for Sharpness (No Master Sample or Specification);
- Limited In-Process Inspection Frequency; Absence of Simple Checks for Ink Condition (Viscosity/Density);
- Subjective Evaluation by Different inspectors/Operators;
- Incomplete Documentation of Defect Occurrence Conditions

❖ Environment (Work Conditions):
- High Humidity Slowing Drying and Increasing Smearing Risk;
- Temperature Instability Affecting Ink Flow;
- Dusty Environment Contaminating Print Surfaces;
- Airflow Patterns (Fans) that May Unevenly Affect Drying and Cause Smudge If Handled Prematurely

3) Print Misalignment / Shifted Position (Priority 3)

❖ Man (Human Factors):
- Insufficient Attention During Setup;
- Inconsistent Alignment Practices;
- Inadequate Skill in Setting Registration Marks;
- Rushed Operation Under Tight Deadlines

❖ Machine:
- Unstable Substrate Feed Mechanism;
- Worn Rollers/Belts; Mechanical Play (Backlash) in Guides;
- Poor Clamping/Locking of Fixtures;
- Vibration Affecting Positional Stability

❖ Method:
- Lack of Standardized Registration Procedure;
- Absence of First-Off Approval Specifically for Alignment;
- Limited Use of Guides/Jigs;
- Inconsistent Job Setup Sequence Between Operators

❖ Material:
- Substrate Curling/Warping;
- Variable Thickness Leading to Feed Inconsistency;
- Slippery Surfaces;
- Adhesive/Tape Slippage on Jigs

❖ Measurement:
- No Clear Tolerance Limits for Positional Deviation;
- Lack of Reference Marks and Documented Setup Parameters;
- Inconsistent Inspection Points and Acceptance Decisions

❖ Environment:
- Humidity Affecting Substrate Dimensional Stability;
- Dust Affecting Friction and Feed;
- Workspace Layout Causing Handling Disturbances During Loading/Unloading

3.3.1. Synthesis: Linking Root Causes to Priority Improvement Actions

Overall, the root-cause patterns across the three priority defects indicate that quality losses are driven less by a single isolated factor and more by process variability arising from weak standardization and control. Recurring issues in operator-dependent setup, machine condition (calibration/cleanliness), ink-substrate variability, and subjective inspection criteria suggest that the enterprise's quality system requires tighter control at the front end of production (setup and approval) and stronger stabilization mechanisms during execution (maintenance and in-process checks). Therefore, the most effective improvement approach is to implement simple, repeatable controls that reduce between-job and between-operator variation while strengthening equipment readiness and material consistency. For Color Mismatch, the dominant drivers cluster around non-standardized proofing and parameter setting (Method), ink/substrate variation (Material), and lack of objective color acceptance standards (Measurement), with supporting influences from machine calibration and environmental viewing conditions. Accordingly, the most direct corrective pathway is to formalize a proofing-and-approval workflow (e.g., a signed first-off color sample), document critical setup parameters by substrate and job type, and stabilize inspection through controlled lighting and reference standards. Complementary actions such as routine calibration/profiling and standardized ink mixing/dilution practices further reduce systematic color shifts and improve repeatability across production runs.

For Blurred Print Output, the analysis highlights the interaction between equipment cleanliness and mechanical stability (Machine), absence of preventive routines and first-off clarity checks (Method), and ink condition and substrate behavior (Material). These findings imply that quality improvement should prioritize scheduled cleaning and preventive maintenance, followed by the introduction of a clarity-focused first-off inspection at each changeover and a simple checklist verifying resolution settings, ink readiness, and substrate cleanliness.

Finally, for Print Misalignment, the primary leverage points are registration standardization and fixture control (Method/Machine) combined with tolerance-based inspection (Measurement). Practical measures include using registration marks, jigs/guides, and a defined positional tolerance with mandatory first-off alignment approval, which collectively reduce setup-related misalignment and prevent defect propagation into full production.

3.4 Quality Control Recommendations

Based on the priority structure and root-cause mapping, the highest-impact recommendations should target the three priority defects (77.36% cumulative contribution):

1. **Color Mismatch:** Standardize proofing and approval (color reference and sign-off), document key process parameters per substrate and job type, and ensure calibration routines are performed consistently.
2. **Blurred Print Output:** Implement scheduled cleaning and preventive maintenance, define minimum clarity/resolution standards, and enforce first-off inspection to verify sharpness before full production.
3. **Print Misalignment:** Introduce a standardized registration procedure, utilize simple jigs/guides and registration marks, define allowable positional tolerances, and perform alignment-focused first-off checks for every job changeover.

Across all three priorities, supporting actions include operator micro-training on setup discipline, improving ink/substrate handling (mixing and batch traceability), and standardizing inspection conditions (lighting and viewing practices). To strengthen future analysis and sustain improvements, the enterprise should enhance defect recording by adding identifiers such as date, machine, operator, substrate type, and product family, enabling more precise diagnosis and targeted corrective action in subsequent improvement cycles.

4. Conclusion

This study analyzed product quality in a printing MSME using defect records over a five-month period, totaling 106 defect occurrences across five categories. The results demonstrate that Color Mismatch (37 cases), Blurred Print Output (28 cases), and Print Misalignment/Shifted Position (17 cases) are the dominant defects, jointly contributing 77.36% of total defects, and therefore represent the most critical improvement targets. Root-cause analysis indicates that these defects are driven by multiple interacting factors, including operator consistency, machine calibration and cleanliness, lack of standardized proofing, setup and registration procedures, ink and substrate variability, subjective inspection practices, and environmental conditions. To reduce defect recurrence and improve quality consistency, the study recommends standardizing process parameters and proofing, implementing first-off inspection and pre-production checklists, strengthening ink/material control, and adopting preventive maintenance and cleaning routines, supported by more granular defect recording to sustain continuous improvement.

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