JNEST EISSN: 2961-8738 ● PISSN: 2961-8916 ● DOI: 10.56741/jnest.v5i02.1197
Article Received 04 July 2025, Revised 07 July 2026

Cosmetic Packaging Quality Analysis Using the Six Sigma and House of Quality Methods at PT XYZ

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***Abstract*—Product quality is a critical factor in the success of manufacturing industries, particularly in the cosmetic packaging sector, where packaging serves both protective and marketing functions. PT XYZ experienced a defect rate of 4.09% in cosmetic packaging products, resulting in increased production costs and reduced customer satisfaction. This study aims to reduce product defects by applying the Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) methodology integrated with Failure Mode and Effects Analysis (FMEA) and the House of Quality (HoQ). DMAIC was employed to identify defect sources, measure process performance, analyze root causes, implement improvements, and establish process control. FMEA was used to evaluate potential failure modes and prioritize corrective actions based on Risk Priority Numbers, while HoQ translated improvement priorities into practical technical actions. Data were collected through direct observation and interviews with relevant personnel at PT XYZ. The implementation of the proposed improvements reduced overall defects by 2,321.43 defects per million opportunities (DPMO), equivalent to 2.32%, and increased the process sigma level by 0.21. Specifically, the "Dirty Glass/Grepes" defect decreased by 11,616.07 DPMO (1.16%) with a sigma improvement of 0.58, whereas the "Scratch" defect declined by 5,660.71 DPMO (0.57%) with a sigma improvement of 0.25. Root cause analysis revealed that Dirty Glass/Grepes defects were primarily associated with human and method factors, while Scratch defects were related to human, equipment, and method factors. Seven improvement alternatives were identified, with two successfully implemented: adding a blower stage during final assembly and inspecting the cover pull-force testing instrument.**

***Index Terms*—Cosmetic Packaging, Defect Products, FMEA, HoQ, Product Quality, Six Sigma DMAIC**

I. Introduction

In a competitive manufacturing industry, product quality is a key factor determining a company's success. Product quality is defined as the ability to satisfy and exceed customer needs [1]. High-quality products not only ensure customer satisfaction but also strengthen a company's image and market competitiveness [2]–[4]. On the other hand, poor quality can lead to waste, increased operational costs, and reduced customer loyalty.

In the cosmetics industry, packaging plays a crucial role. It not only protects the product from damage and contamination but also attracts consumer attention and shapes brand perception. Therefore, packaging quality significantly affects a product's market success.

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PT XYZ is a plastic cosmetic packaging manufacturing company using injection, decoration, and assembly processes. Over the past two months (January–February 2025), the company experienced a 4.09% increase in defective products, from 1,611 to 6,550 defective units. This situation highlights the need for a comprehensive evaluation and improvement of the production process.

Several previous studies have successfully implemented quality control using the Six Sigma and FMEA methods. In PT ABC, a powdered beverage industry, the implementation of Six Sigma reduced defect levels to a sigma value of 4.165 and led to improvements in operator training and machine maintenance [5]. In a tempeh SME, FMEA helped identify high-risk areas related to machines and manpower, resulting in suggestions for machine replacement and stricter worker supervision [6]. Meanwhile, in a garment convection business, the combination of Six Sigma and FMEA successfully reduced the daily average number of defects by 24.8 units, with a defect proportion of 11.6%, a DPMO value of 13,709.57, and a sigma level of 3.715 [7]. Furthermore, a study conducted in a regional public hospital (RSUD X) applied the House of Quality (HoQ) method to improve service quality, which successfully identified technical response priorities for improvement [8].

Various quality control methods have been applied in these studies, such as Six Sigma with the DMAIC approach [9]–[11] for process improvement, FMEA to identify potential failures [12]–[14], and HoQ to align customer needs with technical product characteristics [15]–[16]. However, each method has limitations when applied individually.

Therefore, this study integrates the Six Sigma DMAIC method, FMEA, and HoQ to analyze defect causes, prioritize risks, and design improvements based on customer needs. The combination of these three methods is expected to reduce the number of defective products, improve production efficiency, and enhance PT XYZ's competitiveness in the cosmetic packaging industry.

The purpose of this study is to identify the factors causing the high level of defects in cosmetic packaging products at PT XYZ and to provide suggestions for continuous improvement. The improvements are made through the application of the Six Sigma method with the DMAIC, FMEA, and House of Quality (HoQ) approaches, in order to increase the efficiency of the production process, reduce the number of defective products, and ensure that product quality remains in accordance with the established standards.

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II. METHOD

Data analysis was conducted using a quantitative method. The data collection process included the following steps:

1. Data Collection: Data was collected in February 2025. The data obtained included production quantity, number of defective products, and types of defects, sourced from the Non-Conformance Notice (NCN) sheets.
2. Observation: Observations were carried out on the production floor in the injection, decoration, and assembly departments, with a primary focus on the assembly department.
3. Interviews: Interviews were conducted with relevant parties such as the production head section and the quality head section to obtain more detailed information.
4. Literature Study: A literature review was conducted on the Six Sigma, FMEA, and HoQ methods to support and complete the report with relevant data.

III. RESULT AND DISCUSSION

A. Define

In the Define phase, the focus of the research is directed at the CM-216 Red Infallible L'OREAL cosmetic packaging model from PT XYZ, as it has the highest defect rate based on Pareto analysis. There was an increase in the defect percentage from 1.22% in January 2025 to 5.31% in February 2025. The types of defects identified include cracked platforms, cracked covers, dirty glass, spots/stains, dull surfaces, and non-standard weights. The production process for this model involves injection molding machines, stamping for decoration, and assembly, with quality control conducted at each stage. The main material used is SAN Resin, which is known for its strength and resistance to chemicals. These defects lead to increased rework and product waste, impacting production efficiency and posing potential losses for the company.

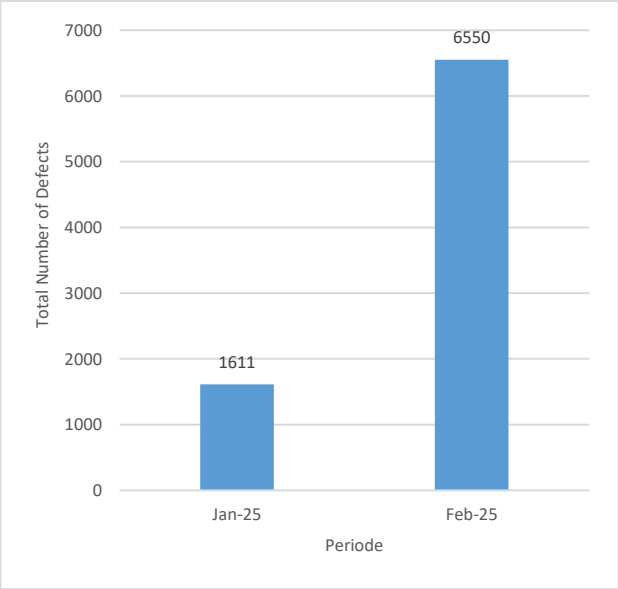


Fig. 1. Defects Increase Graph

B. Measure

In cosmetic packaging, Critical to Quality (CTQ) emphasizes aesthetic aspects and alignment with the brand's design specifications, including texture, finishing, and freedom from visual defects such as scratches or stains. In the CM-216 Red Infallible L'OREAL model, various types of defects were identified, including fiber contamination, hair contamination, dirty/smudged glass, dust contamination, cracked covers, cracked platforms, scratches, uneven decoration results, spots/stains, and loosely attached glass. All these defects have a direct impact on the visual quality of the packaging and are unacceptable to customers. This study focuses on two main types of defects—dirty/smudged glass and scratches—as they are considered the most influential on product quality and customer satisfaction.

The P control chart is one of the tools used in Statistical Process Control (SPC) to monitor the proportion of occurrences or nonconformities in a process [17]. If the defect proportion is above the upper control limit or below the lower control limit, the process is considered to be out of control [18]–[20]. On the other hand, if the defect proportion falls within the upper and lower control limits, the process can be considered under control. Below is the calculation of the P control chart using the first data sample as an example.

a. Defect Proportion

$$\hat{P}\imath = \frac{Di}{ni} = \frac{total\ of\ defects}{total\ of\ inspection\ product}$$

$$\hat{P}\imath = \frac{13}{200} = 0{,}065$$

b. Central Limit (CL)

$$\bar{p} = \frac{\sum_{i=1}^{m} Di}{\sum_{i=1}^{m} ni} = \frac{total\ of\ defects}{total\ of\ production}$$

$$\bar{p} = \frac{355}{7000} = 0{,}05071$$

c. Upper Central Limit (UCL)

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$UCL = 0{,}05071 + 3\sqrt{\frac{0{,}05071\ (1-0{,}05071)}{200}}$$

$$UCL = 0{,}09726$$

d. Lower Central Limit (LCL)

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$LCL = 0{,}05071 - 3\sqrt{\frac{0{,}05071\ (1-0{,}05071)}{200}}$$

$$LCL = 0{,}00417$$

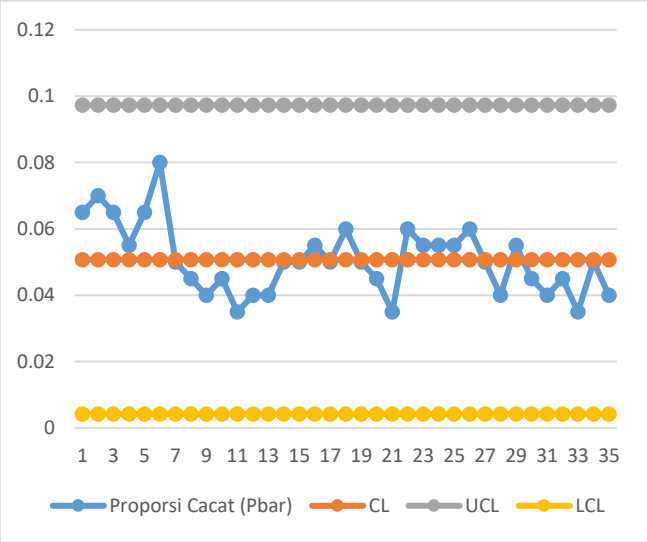


Fig. 2. Product Defect Control Chart

Based on the above calculations, all data points fall within the control limits. This indicates that the process in February was in a normal or controlled condition. The average defect rate was 0.0507 or 5.07%.

The calculation of Defect Per Million Opportunity (DPMO) and sigma level is used as an initial reference to evaluate process quality before and after improvement [21]–[23]. A lower DPMO value reflects a better process, while a lower sigma level indicates a decline in process quality. The analysis is conducted for the overall product as well as focused specifically on the two main types of defects: dirty/smudged glass and scratches.

e. Defect Per Million Opportunities (DPMO)

$$DPMO = \frac{total\ defect}{total\ produksi\ x\ jumlah\ CTQ} x\ 1.000.000$$

Overall, in one million units of production, there are 5,071.43 defective products or 0.507%, with a sigma level of 4.071. For the dirty/smudged glass defect, there are 14,428.6 defective products per million or 0.014%, with a sigma level of 3.685. For the scratch defect, there are 11,285.7 defective products per million or 0.011%, with a sigma level of 3.781. These results indicate that the production process is fairly good, but there is still room for improvement to approach the Six Sigma level with fewer defects. With these sigma levels, the process capability is above the industry average, yet it can still be improved by implementing targeted improvement strategies.

C. Analyze

The root cause analysis for dirty/grepes glass was conducted using a fishbone diagram. This tool categorizes potential causes into six main groups: man, machine, method, material, environment, and measurement [7]. This approach enables a comprehensive identification of possible causes, allowing the company to implement appropriate corrective actions and prevent similar defects from occurring in the future.

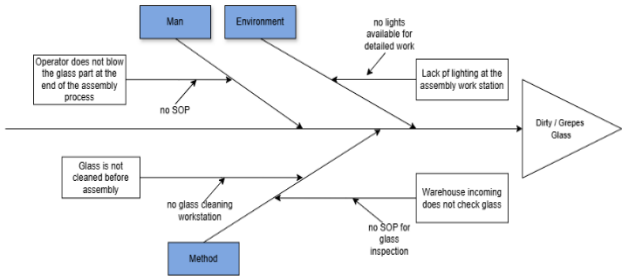


Fig. 3. Fishbone Diagram for Types of Dirty / Grepes Glass

The root cause analysis for dirty/smudged glass and scratch defects was conducted using a fishbone diagram. This tool categorizes potential causes into six main groups: man, machine, method, material, environment, and measurement. This approach enables a comprehensive identification of possible causes, allowing the company to implement appropriate corrective actions and prevent similar defects from occurring in the future.

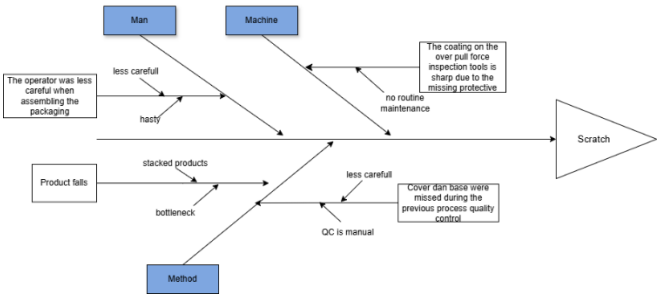


Fig. 4. Fishbone Diagram for Types of Scratch

Scratch defects are caused by three main factors: human, equipment, and method. The human factor includes a lack of attentiveness and hurried behavior by operators during the assembly process. The equipment factor involves damaged protective layers on inspection tools and the absence of regular maintenance, which increases the risk of scratches. From the method perspective, defects occur due to products falling during bottlenecks in the assembly process and missed quality inspections in previous stages. The combination of these factors highlights the need for comprehensive improvements to prevent similar defects in the future.

The primary failure modes in the cosmetic packaging production process at PT XYZ occur mainly during the decoration stage and are analyzed using the Failure Mode and Effect Analysis (FMEA) method [12]. Failure Mode and Effects Analysis (FMEA) is a methodology designed to identify and analyze potential failure modes within a system, design, process, or service [13]–[14], [24]. Failure factors are prioritized based on their level of risk to the quality of the CM-216 Red Infallible L'OREAL product [25]. The assessment of severity, occurrence, and detection was carried out through discussions with the quality division's section head, who has direct insight into the process and potential failure points.

TABLE I
DISTRIBUTION FAILURE MODE AND EFFECT ANALYSIS (FMEA)

No.	Potential Failure Mode	Potential Effect(s) of Failure	Potential Cause(s) of Failure	S	O	D
1	Operator does not blow the glass part at the end of the assembly process	Dirt on the glass remains stuck	There is no blower process step for the glass section at the end of the assembly process in the SOP	8	7	7
2	Glass is not cleaned before assembly	Glass on the finished product is dirty and smudged	There is no workstation for cleaning the glass	9	6	7
3	Product was stratched during the cover pull force inspection process	Product is scratched by metal on the inspection tool	The cover pull force inspection tool is not regularly maintained	7	6	7
4	Warehouse incoming does not check glass	Some smudged glass passed through to the production process	There is no SOP for glass inspection by the incoming warehouse.*incoming*	9	4	6
5	Cover dan base were missed during the previous process quality control	Scratched covers and bases entered the assembly process	Quality control lacks accuracy, inspections are done manually	8	4	4
6	Product falls	Product is scratched	A bottleneck occurs, causing product pile-up	7	3	5
7	Operator was less careful when assembling the packaging	Product was hit by assembly tools, causing scratches	Lack of attentiveness, working in a hurry	5	4	4

From the seven calculated RPN values, the four highest 392, 378, 294, and 216 account for approximately 80.35% of the total overall risk. This indicates that these four failure modes are the top priorities for process improvement in order to significantly reduce the associated risks.

D. Improve

In the Improve phase, solutions were proposed to address the defects of dirty/smudged glass and scratches on the product. The House of Quality (HoQ) method was used to map critical quality attributes valued by customers and to determine the technical priorities that need improvement. The results of the HoQ analysis served as the basis for designing more targeted solutions to enhance product quality and customer satisfaction at PT XYZ.

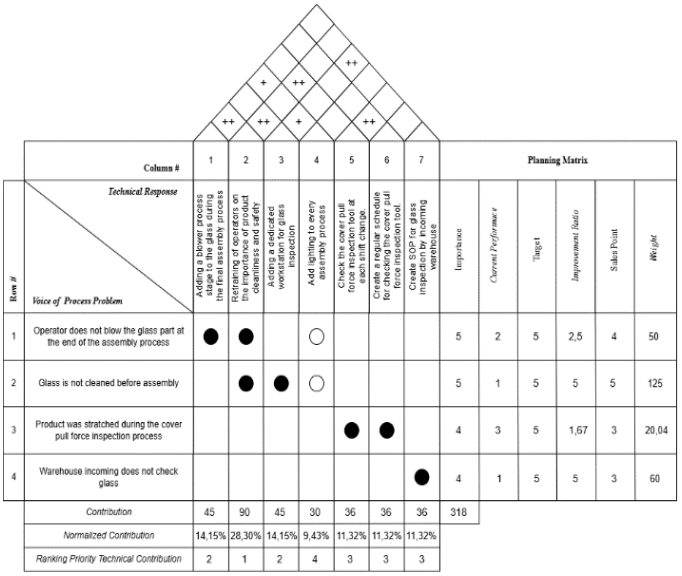


Fig. 1. House of Quality

The HoQ analysis was conducted to design solutions for the dirty/smudged glass and scratch defects found in the cosmetic packaging products of PT XYZ. The voice of process problems was derived from four main causes that contributed to 80.35% of the highest risk according to FMEA:

1. Operator does not blow the glass part at the end of the assembly process
2. Glass is not cleaned before assembly
3. Product was scratched during the cover pull force inspection process
4. Warehouse incoming does not check glass

As technical responses, seven improvement proposals were established: adding a blower process, retraining operators, adding a glass inspection workstation, improving lighting, performing regular inspection tool checks, scheduling equipment maintenance, and developing a standard operating procedure (SOP) for glass inspection.

Through the relationship matrix, the connection between problems and proposed improvements was evaluated with strong (score of 9) and moderate (score of 3) relationships. A planning matrix was used to determine priorities based on importance, current performance, target, improvement ratio, sales point, and weight. The highest priority was given to the issue of uncleaned and uninspected glass.

The technical correlation showed strong positive relationships between several improvements, such as operator retraining with the addition of an inspection workstation and tool checks. Meanwhile, the technical matrix was used to assess the relative contribution of each solution, where the highest normalized contribution indicated the urgency of implementation.

Based on the calculations, the prioritized technical improvements are as follows:

1. Retraining of operators on the importance of product cleanliness and safety (28.30%)
2. Adding a blower process stage to the glass during the final assembly process and adding a dedicated workstation for glass inspection (14.15%)
3. Check the cover pull force inspection tool at each shift change, create a regular schedule for checking the

cover pull force inspection tool and Create SOP for glass inspection by incoming warehouse (11.32%)
4. Add lighting to every assembly process (9.43%)

This analysis provides a data-driven foundation for decision-making to enhance product quality and customer satisfaction. The effectiveness of the improvements was evaluated by comparing the DPMO and sigma values before and after the implementation of solutions. After the improvements, the overall DPMO decreased from 5,071.43 to 2,750 (a 2.32% reduction), and the sigma level increased from 4.071 to 4.276. For dirty/smudged glass defects, the DPMO dropped from 14,428.57 to 2,812.5, with a sigma improvement of 0.58. Meanwhile, for scratch defects, the DPMO decreased from 11,285.71 to 5,625, with a sigma increase of 0.25.

These results indicate that the implemented improvements were effective in reducing the number of defects and enhancing the quality of the cosmetic packaging production process at PT XYZ.

E. Control

The Control phase aims to ensure that the proposed improvements are implemented consistently to prevent the recurrence of product defects. Although implementation has not yet been carried out on the production floor, a control plan has been prepared, which includes:

1. Statistical Process Control (SPC) to monitor process stability using control charts,
2. Monthly internal audits by the quality control team to ensure compliance with SOPs and the effectiveness of improvements,
3. Periodic retraining every six months for operators on cleanliness and product damage prevention techniques,
4. Lighting condition reports submitted by operators to supervisors, with mandatory follow-up actions within 24 hours.

These efforts are designed to maintain sustainable quality and enhance consistency in the production process.

The findings demonstrate that integrating Six Sigma with the DMAIC framework, supported by FMEA and House of Quality (HoQ), provides an effective strategy for improving manufacturing quality in the cosmetic packaging industry. The reduction of defects and improvement in sigma level observed in this study confirm that the structured DMAIC cycle enables organizations to systematically identify, analyze, and eliminate process variations, consistent with previous studies reporting significant quality improvements across manufacturing environments [1], [9], [11]. Similar results were also reported in food and textile industries, where the combination of Six Sigma and FMEA effectively reduced defect rates through data-driven corrective actions [5], [7], [23].

The root cause analysis revealed that product defects primarily originated from human, environmental, methodological, and equipment-related factors. These findings reinforce the principle that product quality is influenced by multiple interconnected process elements rather than a single operational issue. FMEA successfully prioritized failure modes based on risk severity, allowing improvement efforts to focus on the most critical defects. This supports previous studies highlighting the effectiveness of FMEA as a proactive risk management tool for identifying potential failures before they result in quality losses [12], [24]. Likewise, the proposed corrective actions—including operator retraining, establishment of standard operating procedures, routine equipment inspection, improved lighting, and additional inspection processes—reflect continuous improvement practices recommended in Lean Six Sigma implementations [9]–[10].

Furthermore, incorporating the House of Quality strengthened the improvement strategy by translating production problems into technical responses that directly support customer quality expectations. Previous studies emphasize that HoQ enables organizations to align operational improvements with customer requirements, thereby increasing product competitiveness and customer satisfaction [15]–[16]. Although customer perception was not directly measured in this study, improved packaging quality is expected to positively influence customer satisfaction and long-term loyalty because product quality remains one of the primary determinants of consumer evaluation [2]–[4].

The decrease in defect rate by 2.32%, equivalent to a DPMO reduction of 2,321.43 and a sigma level increase of 0.21, indicates measurable enhancement in process capability. While the numerical improvement appears moderate, it represents meaningful progress toward continuous quality improvement, particularly in high-volume cosmetic manufacturing where even small reductions in defects generate substantial cost savings and operational efficiency. Continuous monitoring through statistical process control and periodic DMAIC evaluation is therefore recommended to sustain these improvements and further approach zero-defect manufacturing [17], [20].

IV. CONCLUSION

This study concludes that the implementation of Six Sigma using the DMAIC approach, combined with FMEA and House of Quality (HoQ), was effectively applied at PT XYZ. The integrated analysis significantly contributed to reducing product defects, improving production process quality, and enabling sustainable quality control, thereby enhancing operational efficiency.

The main factors causing defects in cosmetic packaging were identified as human, environmental, method, and equipment-related. For "dirty glass/grepes" defects, the causes included the absence of the blower process, inadequate lighting, and lack of glass cleaning and inspection procedures. For "scratched" defects, the causes were operator negligence, sharp inspection tool surfaces, and product stacking issues during assembly. To address these problems, seven improvement actions were proposed, including operator retraining, adding a blower step and inspection station, routine inspection of equipment, SOP development for incoming inspections, and improved lighting.

As a result of these improvements, the defect rate decreased by 2.32% (DPMO reduction of 2,321.43), accompanied by a sigma level improvement of 0.21,

indicating enhanced product quality and process performance.

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