

# Implementation of the DMAIC (Define, Measure, Analyze, Improve, Control), FTA (Fault Tree Analysis), and Poka-Yoke (Error-Proofing) Methods to Reduce Codification Defects in Gift Box Packaging at PT ASD

Rakay Edhiargo Toyosito<sup>1</sup>, Mochamad Eko Nugroho<sup>2</sup>, Refo Aditya<sup>3</sup>

Industrial Engineering Study Program, Industrial Engineering Study Program, Faculty of Engineering, Universitas Tangerang Raya  
Email: rakaytoyosito@untara.ac.id

The Gift Box packaging line at PT ASD experienced recurring codification defects, particularly Missing Code defects, which affected product traceability and process reliability. Historical quality control data showed that Missing Code was the dominant defect, accounting for 426,096 units or 92.7% of the recorded codification defects. This study aims to reduce codification defects on the Gift Box packaging line through the integrated implementation of DMAIC (Define, Measure, Analyze, Improve, Control), Fault Tree Analysis (FTA), and Poka-Yoke. The research followed the DMAIC framework, with the Measure phase evaluating process capability using DPMO and Sigma Level, the Analyze phase identifying root causes through Fishbone Diagram and FTA, and the Improve phase implementing Poka-Yoke-based corrective actions. The identified root causes included product accumulation at the guide rail, improper WIP input, uniform conveyor speed settings, and photoelectric sensor misalignment. The improvement actions consisted of installing a Guide Roll, applying a transparent acrylic cover, adjusting the conveyor speed ratio from 1:1:1 to 1:1.5:2, relocating the sensor, and implementing a timer-based automatic rejector. The results showed that the initial process capability was 77,296.44 DPMO with a Sigma Level of 2.93. Following the implementation of the improvements, the DPMO decreased to 257.20 and the Sigma Level increased to 4.98 based on post-improvement data collected from March to May 2026. The findings indicate that the integration of DMAIC, FTA, and Poka-Yoke improved the stability of the Gift Box coding process by addressing root causes and reducing reliance on manual error detection.

**Keywords:** DMAIC; Fault Tree Analysis; Poka-Yoke; Codification Defects; Gift Box; Quality Improvement.

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## Corresponding Author:

Rakay Edhiargo Toyosito  
Industrial Engineering Study Program, Industrial Engineering Study Program,  
Faculty of Engineering, Universitas Tangerang Raya  
rakaytoyosito@untara.ac.id

## 1. Introduction

The food and beverage (F&B) industry is one of the most dynamic and competitive manufacturing sectors in the world, and is even the largest contributor to Indonesia's processing GDP. Fierce competition demands that every company continuously develop and identify and address potential failures in the production process, particularly those related to product quality [1]. To maintain its reputation and business continuity as a high-quality F&B producer, emphasizing product quality, food safety, and customer satisfaction is a top priority. Therefore, the quality control process is an integral and crucial part of a company's production system [2]. PT ASD, one of Indonesia's largest multinational food and beverage (F&B) companies, exports products to more than 100 countries and prioritizes product quality, food safety, and traceability through comprehensive *Quality Control* processes [3]. However, the *Gift Box* packaging line experienced recurring codification defects involving expiration dates, batch numbers, and production codes, which pose risks to product traceability and food safety [4]. Production data from July 2025 to January 2026 recorded 607,337

defective units out of 1,982,232 units produced, with codification defects accounting for 75.7% of all defects, making them the most critical quality issue. Based on the Pareto principle, reducing codification defects is expected to significantly decrease overall production failures, improve cost efficiency, and enhance product quality at PT ASD.

To address this issue, a structured continuous improvement approach is required. Modern quality management emphasizes systematic methods to identify, analyze, and eliminate the root causes of process variation while ensuring consistent product quality and food safety ([5]. Among the most effective approaches are DMAIC, Fault Tree Analysis (FTA), and Poka-Yoke. DMAIC provides a systematic framework for quality improvement, FTA identifies root causes through logical and hierarchical analysis, and Poka-Yoke prevents recurring human and process errors [6]. Previous studies have demonstrated the effectiveness of DMAIC in reducing manufacturing defects [7], FTA in identifying packaging failure causes [8], and Poka-Yoke in minimizing product rejects [9].

Therefore, the writing of this report aims to close the research gap by developing and implementing the DMAIC-FTA-Poka-Yoke Integrative Model in the manufacturing industry, especially packaging. This model is believed to create the most effective and comprehensive improvement approach, because it combines DMAIC as a systematic project management framework, FTA as a logical root cause analysis tool, and Poka Yoke as a permanent error prevention solution. Based on the theoretical foundation, the application of DMAIC, FTA, and Poka-yoke methods is an effective and integrated solution in reducing case codification on *gift box* packaging. Therefore, this study is focused on implementing these three methods to improve packaging quality and significantly reduce error rates.

## 2. Methods

### Research Location and Schedule

This research was conducted at PT ASD Plant Jayanti 3, located at Jl. Raya Serang Km 31, Sumur Bandung Village, Jayanti District, Tangerang Regency, Banten. Data collection and field observations were conducted twice a week during the research period.

### Research Instruments

Research instruments were used to collect valid and reliable primary and secondary data related to the Gift Box (GB) coding process at PT ASD. The instruments included:

- a. Check Sheet  
Used to record coding defects before and after improvement implementation based on monthly internal QC reports.
- b. Direct Observation Sheet  
Conducted twice a week (one shift) to observe factors causing GB coding defects.
- c. Visual Documentation  
Used to compare conditions before and after improvements as visual evidence for DMAIC evaluation.
- d. Improvement Evaluation Form  
Used to summarize post-implementation results and evaluate the effectiveness of corrective actions.

The research procedure systematically followed the DMAIC cycle. The study began by identifying coding problems through direct observation on the Gift Box packaging line at PT ASD. During the Define phase, the coding defect problem and reduction targets were established. The Analyze phase employed Fault Tree

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Analysis (FTA) to identify the root causes of coding failures, including conveyor speed mismatch and guide design issues. Based on these findings, the Improve phase developed Poka-Yoke solutions by modifying the production system to prevent errors automatically without relying on operator intervention. Finally, the Control phase evaluated the effectiveness of the improvements. If successful, a new Standard Operating Procedure (SOP) was drafted to standardize the improved process; otherwise, remaining limitations were documented. The study concluded with a report presenting the findings and strategic recommendations for PT ASD management. The integration of FTA and Poka-Yoke enabled theoretical root-cause analysis to be translated into practical production-floor solutions. FTA identified causal relationships among sensor failures, conveyor speed, and guide geometry, providing the basis for effective error-proofing. To ensure sustainability, the Control phase standardized synchronized conveyor settings and roll-guide usage through the new SOP, preventing quality regression caused by human error.

### 3. Result and Discussion

#### Field Observation Data

Direct observations were conducted on the Gift Box packaging line in the BC packing area of PT ASD, focusing on the coding station, conveyor system, photoelectric sensors, WIP handling, and package alignment. The main findings were:

1. Packaging flaps often remained open, causing packages to jam against the guide rail.
2. Operators manually pushed jammed packages, resulting in tightly packed products entering the coding area.
3. Repeated impacts caused sensor misalignment, reducing detection accuracy.

#### Interview Data

Interviews with operators, helpers, production supervisors, technical supervisors, and QC supervisors identified the main causes of coding defects:

1. Open packaging flaps caused product jams.
2. Manual handling of jams created packages with no spacing before coding.
3. Incorrect WIP loading overloaded the conveyor.
4. Conveyor speeds were set at a 1:1:1 ratio, preventing proper package spacing.
5. Closely packed products caused sensors to detect multiple packages as a single object, resulting in incomplete coding.
6. Repeated package impacts loosened sensor mounts, causing sensor misalignment and detection failures.

#### Historical Production and Coding Defect Data

Secondary data from PT ASD Quality Control (QC) reports covering July 2025–January 2026 showed a significant number of coding defects on the Gift Box packaging line, indicating the need for process improvement.

**Table 1.** Case of BC Line Codification Defect of PT ASD

| Month     | Missing GB Code | GB Coding Cases (pcs)            |                   | Production Output (pcs) |
|-----------|-----------------|----------------------------------|-------------------|-------------------------|
|           |                 | Unclear/Incomplete Gift Box Code | Duplicate GB Code |                         |
| September | 151.200         | 12.096                           | -                 | 707.616                 |
| October   | 254.016         | -                                | 18.144            | 555.660                 |
| November  | 6048            | -                                | -                 | 283,500                 |

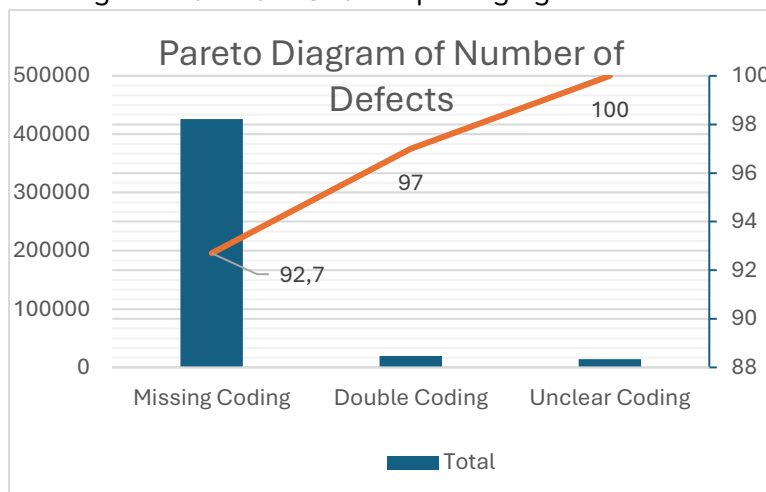
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| Month   | GB Coding Cases (pcs) |                                  |                   | Production Output (pcs) |
|---------|-----------------------|----------------------------------|-------------------|-------------------------|
|         | Missing GB Code       | Unclear/Incomplete Gift Box Code | Duplicate GB Code |                         |
| January | 14.832                | 1.872                            | 1.440             | 435.456                 |
| Total   | 426.096               | 13.968                           | 19.584            | 1.982.232               |

Source: PT ASD BC Line QC Report (2025)

## Data Processing

Data processing was carried out following the steps in the DMAIC (Define, Measure, Analyze, Improve, Control) cycle to resolve coding defects in the Gift Box packaging line.



**Figure 1.** Results of Pareto Analysis of the Number of Defects  
Source: Data Processing Results (2026)

The Pareto analysis identified Missing Code as the dominant defect, accounting for 426,096 units (92.7%) of all defects. Based on the Pareto Principle (80/20), reducing this defect is expected to significantly improve production quality.

## Define Phase (Critical Quality Definition)

### 1. Process Mapping (SIPOC)

The SIPOC diagram was developed to map the overall Gift Box coding process, from suppliers to internal customers, and identify system boundaries. The analysis showed that the photoelectric sensor and print head are the most critical process points. Poor synchronization between material flow and the control system leads to Missing Code defects. From the SIPOC perspective, the Quality Control (QC) department depends on consistent outputs; therefore, improvement efforts should focus on synchronizing conveyor movement with accurate sensor detection before printing.

### 2. Voice of Customer (VOC) and Critical to Quality (CTQ)

Internal Voice of Customer (VOC) data were translated into measurable Critical to Quality (CTQ) attributes. Based on production supervisors' feedback, Missing Code was identified as the highest priority because it directly affects product traceability and batch records. In addition to print quality, package stability on the conveyor was established as a key CTQ. These CTQs provide a clear technical basis for designing effective Poka-Yoke solutions to minimize quality deviations on the Gift Box packaging line.

### Measure Phase (Current Process Capability Measurement)

The Measure phase evaluated the current process capability using Defects Per Million Opportunities (DPMO) and Sigma Level based on historical production data from July 2025 to January 2026. Process capability was calculated using 502,308 defects, 918,542 production units, and three defect opportunities (CTQs) per unit to establish the baseline performance and prioritize improvement efforts.

#### 1. Calculating DPMO (Defects Per Million Opportunities)

$$DPMO = \frac{Total\ Defects}{Total\ Production \times Opportunities} \times 1.000.000$$

$$DPMO = \frac{459.648}{1.982.232 \times 3} \times 1.000.000$$

$$DPMO = 77.296,44$$

#### 2. Finding the Sigma Value

$$\text{Sigma} = \text{NORMSINV} (1 - DPMO / 1.000.000) + 1,5$$

$$\text{Sigma} = \text{NORMSINV} (1 - 77.296,44 / 1.000.000) + 1,5$$

$$\text{Sigma} = 2.93$$

The Sigma Level was determined by converting the DPMO value using the standard normal distribution table. A 1.5 Sigma Shift was applied, following the Six Sigma methodology to account for long-term process variation. The results indicate that PT ASD's coding process operates at 2.93 Sigma, which is well below the Six Sigma (6.0) target and reflects high process variability.

### Analyze Phase (Root Cause Analysis)

The Analyze phase identified the root causes of the problem based on the Measure results (2.93 Sigma). Using field observations and interviews, the study systematically analyzed the causes of Missing Code defects through the following tools:

#### 1. Fishbone Diagram

A Fishbone (Ishikawa) Diagram based on the 5M approach was used to identify relationships among machine, method, material, manpower, and environmental factors contributing to Missing Code defects.

#### 2. Fault Tree Analysis (FTA)

FTA was applied using a hierarchical deductive logic approach to trace the Top Event Missing Code defects on Gift Box packaging to its Basic Events through AND and OR logic gates. Based on observations and production-line analysis, four main root causes were identified: guide rail jams, helper operational errors, mismatched conveyor speeds, and sensor misalignment caused by repeated physical impacts.

**Table 2.** Summary of Codes and Terms in Fault Tree Analysis (FTA)

| Code | Event Type         | Description                                                        | Logic Gate |
|------|--------------------|--------------------------------------------------------------------|------------|
| TE   | Top Event          | Occurrence of <b>Missing Code</b> Defects on Gift Box Packaging    | –          |
| G1   | Intermediate Event | Path A: Product Accumulation on the Guide Rail Conveyor            | OR to TE   |
| G2   | Intermediate Event | Path B: Product Accumulation Due to WIP Helper Input               | OR to TE   |
| G3   | Intermediate Event | Path C: Product Accumulation Due to Conveyor Speed Synchronization | OR to TE   |

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| Code | Event Type         | Description                                                                                           | Logic Gate |
|------|--------------------|-------------------------------------------------------------------------------------------------------|------------|
| G4   | Intermediate Event | Path D: Sensor Misalignment Caused by Physical Impact                                                 | OR to TE   |
| A1   | Basic Event        | Gift Box (GB) flap opens and becomes stuck on the guide rail, then is forcibly pushed by the operator | AND to G1  |
| A2   | Basic Event        | Sensor detects only one product because the products are positioned too closely together              | AND to G1  |
| B1   | Basic Event        | Helper feeds WIP products directly before the coding machine, causing an overload                     | AND to G2  |
| B2   | Basic Event        | Sensor detects only one product following the WIP overload condition                                  | AND to G2  |
| C1   | Basic Event        | All conveyor speeds are set to the same ratio (1:1:1), resulting in no spacing between products       | AND to G3  |
| C2   | Basic Event        | Sensor detects only one product due to the absence of gap time between products                       | AND to G3  |
| D1   | Basic Event        | Sensor mounting is struck by a misaligned row of Gift Boxes, causing sensor misalignment              | OR to G4   |

Source: Research Results (2026)

### Fault Tree Analysis (FTA) Interpretation

Based on the event mapping, the causal relationships among the basic events were analyzed to explain how they lead to the Top Event (Missing Code).

#### 1. Failure Path A: Guide Rail Jam and Product Accumulation

This failure path uses an AND logic gate, indicating that Missing Code occurs only when package jamming, manual operator intervention, and sensor limitations happen simultaneously.

##### 1) Basic Event A1 – Package Flap Jammed on the Guide Rail

An unlocked Gift Box flap protrudes and becomes stuck on the guide rail, stopping product flow. Operators manually push the accumulated packages, causing them to enter the coding station with little or no spacing.

##### 2) Basic Event A2 – Sensor Detects Multiple Packages as One

Because no physical gap exists between packages, the photoelectric sensor identifies the entire group as a single object. Consequently, the printer marks only the first package, while the remaining packages pass without coding (Missing Code).

#### 2. Failure Path B: Incorrect WIP Input by Helper

This path also follows an AND logic gate, where human error and sensor limitations must occur together to produce Missing Code.

##### 1) Basic Event B1 – Incorrect WIP Loading

Helpers load Work in Process (WIP) products directly onto the active conveyor before the coding station, creating an overload and causing tightly packed packages.

##### 2) Basic Event B2 – Sensor Detects Only One Unit After Overload

The overloaded packages eliminate spacing between products, preventing the sensor from distinguishing individual units. As a result, the printer codes only the leading package, while the remaining packages pass uncoded, producing Missing Code defects.

#### 3. Failure Path C: Product Accumulation Due to Equal Conveyor Speed Synchronization

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This technical failure path was analyzed using an AND logic gate, indicating that missing code occurs when identical conveyor speeds eliminate the gap between products, preventing the sensor from detecting individual units.

1) Basic Event C1: Identical Conveyor Speeds Before, During, and After Coding

The root cause is the uniform conveyor speed setting (1:1:1) across all conveyor sections. Without speed differentiation, no stretching effect is created to separate Gift Box (GB) packages, causing continuous product accumulation and the loss of spacing before the coding station.

2) Basic Event C2: Sensor Detects Only One Unit Due to No Gap

Because there is no gap between packages, the photoelectric sensor interprets multiple GB packages as a single continuous object. Consequently, the Inkjet Printer issues only one printing command, resulting in only the first package being coded while the remaining packages experience missing code defects.

4. Failure Path D: Sensor Misalignment Due to Physical Impact

This failure path was analyzed using an OR logic gate because sensor misalignment alone can directly cause missing code.

1) Basic Event D1: Sensor Hit by Tilted GB Packages

Product accumulation causes GB packages to tilt and collide with the sensor housing. Repeated impacts loosen the sensor mount, creating sensor misalignment and preventing accurate product detection. As a result, the control system fails to trigger the Inkjet Printer, leading directly to missing code defects.

**Analysis of Poka-Yoke-Based Improvement Implementation (Improvement Stage)**

1. Analysis of AND Logic Gates for Path A of the Guided Roll System (Product Stuck Prevention)



**Figure 2.** Guide Roll

Source: (2026 Research)

2. AND Logic Gate Analysis Path B WIP Input Gate Restriction (Overload Prevention)



**Figure 3.** Acrylic cover

Source: (2026 Research)

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3. AND Logic Gate Analysis of Path C of Differential Speed Inverter and Timer-Based Auto Rejector System
- a. Progressive Speed Control (Differential Speed Inverter) Upstream improvements are made by changing the frequency parameters of the drive motor inverter to create a stepped speed with a ratio of 1:1.5:2.

- 1) The input conveyor (before coding) is set at base speed (1.0).
- 2) The coding conveyor (printer & sensor area) is increased to speed (1.5).
- 3) The output conveyor (after coding) is increased to maximum speed (2.0).



**Figure 4.** Mechanical speed engineering of conveyor

Source: (Research 2026)

- b. Automatic Control Interlock Based on Sensor Time Limit (Failsafe Timer Logic) This Layer 2 System is designed as an absolute failure protection (failsafe system) if an anomaly occurs upstream where the product continues to move in a tightly packed condition without any gaps.

- 1) Warning Signal (Audio Alarm) The Buzzer component will immediately sound loudly to provide an instant alarm to the operator regarding the presence of a buildup on the coding line.
- 2) Execution Signal (Mechanical Rejection) Simultaneously, the pneumatic push lever (Pneumatic Rejector) installed on the output conveyor (speed 2 seconds) will immediately fire automatically, ejecting the tightly packed product line out of the main line so that it does not pass through to the packing process in an uncoded condition.



**Figure 5.** Timer-Based Auto Rejector System

Source: (2026 Research)

4. OR Logic Gate Analysis of D Path Hanging Sensor Position Engineering (Top-Down Sensor Orientation)



**Figure 6.** Sensor Position Engineering

Source: (2026 Research)

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## Control Phase

The Control phase is the final stage of the DMAIC methodology, aiming to ensure that the implemented improvements are standardized, sustainable, and prevent process regression. Improvements including the installation of Guidece Roll, conveyor speed adjustment, transparent acrylic cover, sensor relocation, and an automatic rejector were implemented to eliminate the main causes of missing code defects and replace manual practices. Process capability was re-evaluated using DPMO and Sigma Level, followed by SOP standardization.

### 1. Process Standardization (SOP Update)

The Standard Operating Procedure (SOP) for the coding and packing stations was updated to integrate Poka-Yoke mechanisms into daily operations. The main revisions include:

- Machine Preparation: Inspect the Guidece Roll, activate the Failsafe Timer with the correct set-point, and clean the coding sensor regularly.
- Failsafe and Rejector Settings: Replace manual inspection with automatic detection, adjust the Failsafe Timer according to conveyor speed, and ensure the rejector system is ready before production.
- Coding Process: The system automatically detects missing code defects and rejects defective products.
- Jamming Handling: Operators must use the emergency stop during product jams and are prohibited from manually pushing accumulated products.

### 2. Comparison Before and After Improvement

The implementation of the *Poka-Yoke* system has resulted in significant changes in the stability of the coding process on the *Gift Box* packaging production line. The table below summarizes the operational comparison between the system conditions before improvement, which still relied heavily on manual intervention, and those after improvement, which have been integrated with an automated system.

**Table 3** Comparison of Conditions Before and After Improvement

| Comparison Aspect              |  | Before Improvement                                                 | After Improvement                                                                                  |
|--------------------------------|--|--------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Packaging Flap Handling Method |  | Manual; the flap often opens and becomes stuck ( <i>jamming</i> ). | Automatic; the <i>Guidece Roll</i> locks the position of the packaging flap to maintain stability. |
| Product Detection Mechanism    |  | Visual observation by the operator (subjective).                   | <i>Failsafe</i> sensor detects products in <i>real-time</i> .                                      |
| Defective Product Handling     |  | Manually handled by the operator after products accumulate.        | Automatically handled by the <i>Rejector</i> (immediately rejected).                               |
| Product Flow Consistency       |  | The <i>gap</i> is frequently lost due to <i>overload</i> .         | Maintained through the <i>Failsafe Timer</i> system and <i>speed ratio</i> .                       |
| Jamming Control                |  | <i>Reactive</i> (stops when a failure occurs).                     | <i>Preventive</i> (prevents <i>jamming</i> before it occurs).                                      |

Source: Research Results (2026)

### 3. Post-Improvement Process Evaluation

The effectiveness of the implemented improvements Guidece Roll, conveyor speed adjustment, transparent acrylic cover, sensor relocation, and automatic rejector was evaluated by collecting production and missing code defect data. DPMO and Sigma Level were recalculated to measure process capability improvements quantitatively.

Post-improvement data were collected using systematic sampling twice a week over three months (March–May 2026) to capture operational variations across work shifts and workload conditions, providing a representative assessment of overall process stability after the Poka-Yoke implementation.

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1. Calculating DPMO (Defects Per Million Opportunities)

$$DPMO = \frac{\text{Total Defects}}{\text{Total Production} \times \text{Opportunities}} \times 1.000.000$$

$$DPMO = \frac{1.337}{1.732.752 \times 3} \times 1.000.000$$

$$DPMO = 257,20$$

2. Finding the Sigma Value

$$\text{Sigma} = \text{NORMSINV} (1 - DPMO / 1.000.000) + 1,5$$

$$\text{Sigma} = \text{NORMSINV} (1 - 257,20 / 1.000.000) + 1,5$$

$$\text{Sigma} = 4,98$$

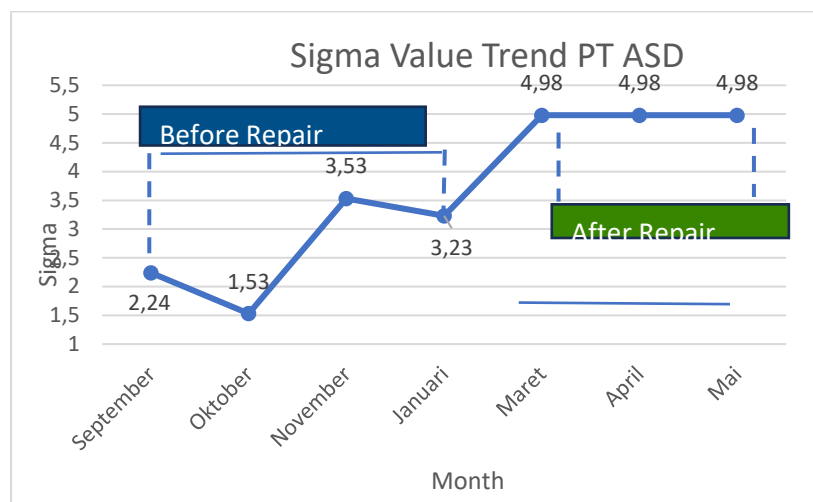


Figure 7. Sigma Value Trend (September 2025 – May 2026)

Source: Data Processing Results (2026)

The post-improvement process achieved a Sigma Level of 4.98, indicating a highly stable coding process after implementing the proposed improvements. This significant increase demonstrates that the technical interventions effectively reduced process variability compared with the initial condition. A 4.98 Sigma level reflects a high-quality process with a very low probability of defects. The historical production data were obtained from the Quality Control (QC) records of the BC production line at PT ASD. The research identifies the observation period as July 2025 to January 2026. However, the detailed production table currently contains data for September, October, November, and January, with total production of 1,982,232 units. Therefore, the detailed monthly data for July, August, and December should be verified against the original QC records before the table is finalized. Based on the available records, the highest codification defect was Missing Code, with 426,096 units, followed by Unclear/Incomplete Gift Box Code with 13,968 units and Duplicate GB Code with 19,584 units. The Pareto analysis showed that Missing Code accounted for 92.7% of the total recorded codification defects [10].

The dominance of Missing Code is consistent with the Pareto principle, which suggests that improvement efforts should initially be directed toward the defect category contributing the largest proportion of the overall problem [11]. In this study, the Pareto result was not only used to describe the distribution of defects but also served as the basis for selecting the critical problem for further root-cause analysis [12]. This approach is consistent with the DMAIC framework, particularly the Define and Measure phases, which emphasize identifying the critical quality problem based on empirical process data rather than relying solely on

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operational assumptions. The theoretical basis for this approach is also established in the manuscript through Six Sigma and DMAIC literature [13].

The Measure phase was conducted to quantify the initial capability of the Gift Box coding process using DPMO and Sigma Level. The available operational data in Table 3 consist of 1,982,232 production units and 459,648 recorded defects across three defect opportunities per unit. The resulting process capability was 77,296.44 DPMO and 2.93 Sigma. The baseline value indicates that the coding process still exhibited considerable process variation before improvement [14]. This condition can be related to the operational findings obtained through observation and interviews [15]. The coding process depended on the synchronization between conveyor movement, product spacing, photoelectric sensor detection, and operator intervention. When the spacing between Gift Boxes disappeared, the sensor could not reliably distinguish individual packages, creating a direct mechanism for Missing Code defects [16].

The relationship between process capability and operational variation supports the theoretical role of the Measure phase in DMAIC. According to the theoretical framework used in this study, DPMO provides a quantitative representation of the number of defects relative to available opportunities, while Sigma Level provides an indicator of process capability. Therefore, the value of 2.93 Sigma provides a quantitative baseline against which the effectiveness of subsequent interventions can be evaluated. The finding can also be positioned within the previous research summarized in the manuscript. The State of the Art identifies studies applying DMAIC to quality improvement in packaging processes. For example, [17] reported that printing defects accounted for 79% of total defects in a flexible-packaging process and used DMAIC to structure the improvement process. The present study extends this type of application by integrating FTA into the Analyze phase and subsequently translating the identified failure mechanisms into Poka-Yoke-based engineering solutions [18].

The Analyze phase was conducted after Missing Code had been identified as the dominant defect. Field observations and interviews revealed that the defect was associated with several interacting conditions. An open Gift Box flap could become stuck on the guide rail, causing product accumulation [19]. Operators subsequently pushed the accumulated products manually, resulting in tightly packed products entering the coding area. In addition, incorrect WIP loading could overload the conveyor, while the uniform conveyor speed ratio of 1:1:1 prevented sufficient spacing between successive packages. The loss of physical spacing had a direct effect on sensor performance. According to the technical observations documented in the research, the photoelectric sensor could interpret several closely packed Gift Boxes as a single object. Consequently, the print head generated only one printing command, leaving subsequent packages without codes. Repeated product accumulation also caused physical impacts on the sensor housing, which could loosen the sensor mounting and alter its alignment [20].

FTA was then used to structure these observations into four major failure paths: guide-rail product accumulation, incorrect WIP input, uniform conveyor-speed synchronization, and sensor misalignment caused by physical impact. This structure demonstrates that Missing Code was not simply an isolated printer failure but resulted from interactions between mechanical flow, operating procedures, conveyor parameters, and sensor detection. The use of FTA therefore provided a logical bridge between the observed defect and the technical interventions implemented in the Improve phase [21]. This finding is relevant to the previous studies summarized in the manuscript. [22] for example, applied FMEA and FTA to printing-process defects in the offset-printing industry and used FTA to identify failure paths associated with folding-box printing. However, the study identified in the State of the Art was primarily concerned with static failure-risk mapping. The present research incorporates FTA within the DMAIC cycle so that the identified failure paths directly determine the design of corrective actions [23]. The distinction is important because the FTA result

in this study was not treated as the final analytical output. Instead, each identified failure path was translated into a corresponding Poka-Yoke intervention. Thus, the role of FTA was extended from identifying causes toward supporting the engineering design of the improvement system [24].

Based on the FTA results, the Improve phase developed several Poka-Yoke interventions addressing the identified failure mechanisms. The improvements consisted of the installation of a Guidece Roll, an Acrylic Tunnel, adjustment of conveyor speed through a Differential Speed Inverter, implementation of Failsafe Timer Logic with an automatic Rejector, and modification of the sensor orientation to a top-down position [25]. The relationship between the identified causes and the improvement mechanisms can be described as follows. The Guidece Roll was used to stabilize the position of the Gift Box flap and reduce the possibility of jamming at the guide rail. The Acrylic Tunnel restricted uncontrolled WIP input and reduced the potential for product accumulation. The Differential Speed Inverter changed the conveyor speed configuration from the previous 1:1:1 condition to a differentiated speed arrangement, thereby creating a physical gap between packages. The Failsafe Timer and automatic Rejector provided an automated response when abnormal product accumulation or missing-code conditions were detected [26].

These interventions reflect the theoretical principle of Poka-Yoke described in the manuscript, namely that errors should be prevented or detected at the process source rather than relying primarily on final inspection. The implementation therefore shifted the coding process from a condition dominated by manual intervention toward a system incorporating automatic detection, prevention, and rejection mechanisms. The operational comparison in Table 3 further demonstrates this change. Before improvement, operators relied on manual visual observation, manually handled defective products, and reacted to jamming after accumulation occurred. After improvement, product detection became sensor-based, defective products were automatically rejected, product spacing was controlled through the Failsafe Timer and conveyor speed configuration, and jamming prevention became more proactive.

This result is also relevant to the State of the Art presented in the thesis. [27] combined FTA, FMEA, and Poka-Yoke to reduce stamping-machine breakdown time through physical modification, while the present study applies the integration specifically to coding accuracy in Gift Box packaging. Meanwhile, the study by [28] used DMAIC in flexible packaging but did not employ the hierarchical failure analysis provided by FTA. Consequently, the present research combines DMAIC as the improvement framework, FTA as the causal-analysis mechanism, and Poka-Yoke as the error-prevention mechanism within one improvement sequence. The effectiveness of the improvement was evaluated by comparing process capability before and after implementation. Before improvement, the process operated at 77,296.44 DPMO and 2.93 Sigma. After implementation, post-improvement data were collected for three months, from March to May 2026, using systematic sampling twice per week. The total recorded production during this period was 1,732,752 units with 1,337 defects across three opportunities per unit. The resulting DPMO was 257.20, while the Sigma Level increased to 4.98. The change in DPMO represents a substantial reduction in the frequency of defects. At the same time, the increase in Sigma Level from 2.93 to 4.98 indicates an improvement in the measured process capability. The improvement was also accompanied by changes in the physical and operational characteristics of the process. The improvement can be interpreted according to the complementary functions of the three methods. DMAIC provided the systematic structure for defining the problem, measuring baseline performance, analyzing causes, implementing improvements, and controlling the resulting process [29].

The result is consistent with the State of the Art presented in the research. [30] demonstrated that combining FTA, FMEA, and Poka-Yoke could reduce stamping-machine breakdown time by 45.7%, while [31] demonstrated the usefulness of FTA in identifying failure mechanisms in printing processes. Keanoubie and

Kusumastuti (2025) demonstrated the application of DMAIC in flexible packaging, particularly where printing defects represented a substantial portion of total defects. The present research differs in the way these methods are positioned sequentially. Rather than using DMAIC, FTA, and Poka-Yoke as independent tools, the study connects them through a causal improvement chain: DMAIC identifies and measures the quality problem; FTA explains the failure mechanism; Poka-Yoke addresses the identified mechanism; and the Control phase evaluates and standardizes the improvement [32]. The Control phase was implemented to ensure that the improvement did not depend solely on individual operator behavior. The SOP for the coding and packing stations was revised to incorporate the Guidece Roll inspection, Failsafe Timer settings, sensor cleaning, automatic Rejector readiness, and specific procedures for handling product accumulation [33]. From a quality-management perspective, this result is consistent with the Control principle of DMAIC, which requires successful improvements to be standardized and continuously monitored to prevent process regression. The thesis theoretical framework also emphasizes that the Control phase functions to maintain the improvements achieved during the previous phases [34]. Overall, the results show that the integrated DMAIC FTA Poka-Yoke approach was associated with an improvement in the measured Gift Box coding process from 2.93 Sigma to 4.98 Sigma, accompanied by a reduction in DPMO from 77,296.44 to 257.20.

## Results Analysis

This analysis addresses the research objectives using field observations and production data collected from July 2025 to January 2026.

### 1. Defect Level and Coding Defect Characteristics

Based on QC historical data and the Measure phase, the Gift Box coding process at PT ASD achieved a process capability of 2.93 Sigma with a DPMO of 77,296.44, indicating high process variability. Missing Code was the dominant defect, accounting for 426,096 units (92.7%) of total defects. Pareto analysis confirmed Missing Code as the highest improvement priority.

### 2. Root Cause Analysis Using Fault Tree Analysis (FTA)

Based on interviews, Fishbone analysis, and Fault Tree Analysis (FTA), the top event (Missing Code) was traced to four major failure paths:

- Path A: Product accumulation caused by unlocked flaps stuck on the guide rail and manual pushing by operators.
- Path B: Overloading due to incorrect WIP input by helpers.
- Path C: Uniform conveyor speed ratio (1:1:1), eliminating gaps between products.
- Path D: Sensor misalignment caused by repeated impacts from tilted packages.

The analysis concludes that the primary problem lies not in the printer itself but in the sensor's inability to detect individual packages due to the loss of physical gaps caused by mechanical and operational factors.

### 3. Poka-Yoke Implementation and DMAIC Effectiveness

Following the FTA results, permanent corrective actions were developed using Poka-Yoke within the DMAIC framework. Improvements included installing a Guidece Roll, adjusting conveyor speed ratios to create automatic product gaps, adding an acrylic cover on the input conveyor, relocating the sensor, and implementing an automatic rejector.

#### a. DMAIC Effectiveness

The DMAIC implementation shifted quality control from reactive manual inspection to a preventive error-proofing system. Conveyor speed differentiation restored product spacing, enabling accurate sensor detection. The Guidece Roll stabilized package positioning and prevented sensor impacts, while the acrylic cover and automatic rejector eliminated overload conditions and automatically removed products with Missing Code defects.

Implementation of the DMAIC (Define, Measure, Analyze, Improve, Control), FTA (Fault Tree Analysis), and Poka-Yoke (Error-Proofing) Methods to Reduce Codification Defects in Gift Box Packaging at PT ASD. Rakay Edhiargo

b. Control (Sustainability)

The Control phase ensured long-term process stability through updated Standard Operating Procedures (SOPs). The new SOP standardized validated conveyor speed settings, introduced structured troubleshooting procedures for jams and sensor calibration, and integrated the Poka-Yoke system into daily operations. This standardization ensures consistent process performance regardless of shift or personnel changes, enabling the BC division of PT ASD to maintain sustainable quality improvements and prevent the recurrence of Missing Code defects.

#### 4. Conclusion

Based on the DMAIC analysis, the Measure phase showed that Missing Code was the dominant defect in the Gift Box coding process. The initial process performance reached 77,296.44 DPMO with a Sigma level of 2.93, indicating substantial opportunities for improvement in the coding process. In the Analyze phase, the application of Fault Tree Analysis (FTA) identified four interconnected failure pathways contributing to the occurrence of Missing Code: (a) mechanical obstructions at the guide rail, (b) irregularities in WIP material input, (c) mismatched conveyor speed ratios, and (d) photoelectric sensor misalignment. These findings demonstrate that the defect was associated not only with the coding equipment itself but also with interactions among material flow, mechanical conditions, operating procedures, conveyor parameters, and detection systems. The Improve phase translated the identified root causes into Poka-Yoke-based engineering improvements, consisting of the Guide Roll, Acrylic Tunnel, Differential Speed and Failsafe Timer system, and Top-Down Sensor Orientation. The implementation was followed by a reduction in DPMO from 77,296.44 to 257.20 and an increase in process performance from 2.93 Sigma to 4.98 Sigma. The Control phase further supported the sustainability of the improvement through standardization of operating procedures, sensor inspection, parameter control, and automatic rejection mechanisms.

The contribution of this research to quality control in the manufacturing industry lies in demonstrating an integrated quality-improvement framework that connects quantitative process measurement with systematic failure analysis and error-proofing mechanisms. Rather than relying primarily on manual inspection, the proposed approach shifts quality control toward prevention and automatic detection at the source of failure. The practical implication for manufacturing operations is that similar coding and packaging processes can use the identified approach to reduce dependence on subjective inspection, improve product-flow stability, detect abnormal conditions earlier, and minimize the occurrence of defective products reaching subsequent processes. The results also provide a practical reference for integrating mechanical modification, process-parameter control, sensor optimization, and automatic rejection into a single quality-control system. This study has several limitations. First, the historical defect analysis was based on QC production records available for the research period, while the post-improvement evaluation was conducted over three months, from March to May 2026, using systematic sampling twice per week. Therefore, the observed post-improvement performance represents the conditions during the evaluation period and does not yet establish long-term performance under all possible production conditions. Second, the research focused specifically on the Gift Box coding process at PT ASD, so the findings should be interpreted within the operational characteristics of the investigated production line. Third, the study primarily evaluated quality performance through DPMO and Sigma Level and did not quantify other potential effects, such as maintenance costs, rework costs, productivity, or Overall Equipment Effectiveness (OEE). Future research should therefore extend the observation period to evaluate the long-term stability and sustainability of the proposed improvements under different production volumes, shifts, and operating conditions. Subsequent studies may also incorporate additional performance indicators, such as OEE, rework costs, downtime, maintenance costs,

and productivity, to provide a broader assessment of the economic and operational implications of the improvement.

## 5. References

- [1] R. A. Aminuddin AP, H. Hakim, A. Andrie, and A. E. Apsari, "Implementasi Fault Tre Analysis penyebab defect kemasan gula rafinasi," *Journal Industrial Engineering and Management (JUST-ME)*, vol. 5, no. 1, pp. 51–56, 2024, doi: 10.47398/justme.v5i01.60.
- [2] J. Antony and M. Sony, "Implementing total quality management in manufacturing industries: Lessons from case studies," *The TQM Journal*, vol. 34, no. 5, pp. 1047–1063, 2022, doi: 10.1108/TQM-10-2021-0300.
- [3] M. Bujna and M. Prístavka, "Quantitative Fault Tree Analysis in Manufacturing Systems," *Applied Sciences*, vol. 13, no. 5, 2023.
- [4] L. Chen, R. Patel, and A. Desai, "Machine learning for quality control in the food industry: A review," *Foods*, vol. 14, no. 19, p. 3424, 2025.
- [5] S. Chen, "Data-driven quality control for food packaging lines," *Journal of Food Engineering*, vol. 350, p. 111252, 2023, doi: 10.1016/j.jfoodeng.2023.111252.
- [6] T. DeGroff and L. Hou, "Fault Tree Analysis for modern risk management systems," *Systems Engineering*, vol. 28, no. 1, 2025.
- [7] R. Erviyana *et al.*, "Application of DMAIC for quality improvement," *Journal of Quality Engineering*, 2022.
- [8] A. Firdaus and S. Rahmawati, "Effectiveness of DMAIC implementation in industrial processes," *Journal of Industrial Engineering Innovations*, 2023.
- [9] M. García and J. López, "Risk analysis and fault tree modeling in industrial systems," *Safety Science*, vol. 139, p. 105259, 2021.
- [10] M. George *et al.*, "Lean Six Sigma: DMAIC framework application," *International Journal of Quality Management*, 2020.
- [11] D. L. Goetsch and S. B. Davis, *Quality Management for Organizational Excellence: Introduction to Total Quality*. Pearson, 2020.
- [12] A. Gupta and R. Singh, "Application of Fault Tree Analysis for food safety risk assessment," *Journal of Food Safety*, vol. 42, no. 3, 2022.
- [13] M. Hansen, *Quality Management Tools and Techniques*. TechPress, 2021.
- [14] S. Imam and W. Prastiwinarti, "Analisis tingkat kecacatan produk cetak kemasan karton lipat dengan pendekatan DMAIC Six Sigma," vol. 19, no. 2, 2020.
- [15] P. Kotler and K. L. Keller, *Marketing Management*. Pearson, 2021.
- [16] M. R. Kurniawan and A. S. Cahyana, "Packaging quality control analysis using Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA)," 2022.
- [17] M. Lestari and A. Hidayat, "Penerapan Six Sigma untuk pengendalian kualitas keripik singkong di IKM Gazal Makmur," *Journal of Food Engineering & Technology*, vol. 5, no. 2, pp. 78–89, 2025.
- [18] X. Li, Y. Chen, and L. Zhang, "Fault Tree Analysis and Boolean logic application in reliability engineering," *Reliability Engineering & System Safety*, vol. 210, p. 107523, 2021.
- [19] D. C. Montgomery, *Introduction to Statistical Quality Control*. John Wiley & Sons, 2022.
- [20] M. A. Sadikin, "Defect reduction in the manufacturing industry: Systematic literature review," *International Journal of Industrial Engineering and Engineering Management*, vol. 5, no. 2, pp. 73–83, 2023, doi: 10.24002/ijieem.v5i2.7495.
- [21] S. Pamungkas, E. Suhendar, and R. Usman, "Implementasi metode Lean Six Sigma dan Fault Tree Analysis untuk peningkatan kualitas produk kulit kebab Labanese di PT Bangaji Citrarasa Lestari,"

*Performa: Media Ilmiah Teknik Industri*, vol. 22, no. 2, p. 98, 2023, doi: 10.20961/performa.22.2.80462.

- [22] R. Prasad *et al.*, "Impact of Six Sigma on defect reduction," *International Journal of Productivity*, 2021.
- [23] F. Psarommatis, J. Sousa, J. P. Mendonça, and D. Kiritsis, "Zero-defect manufacturing: The approach for higher manufacturing sustainability in the era of Industry 4.0: A position paper," *International Journal of Production Research*, vol. 60, no. 1, pp. 73–91, 2022, doi: 10.1080/00207543.2021.1987551.
- [24] D. Putra and A. Nugroho, "Sustaining process control in DMAIC implementation," *Journal of Continuous Improvement*, 2024.
- [25] D. Romero and J. Stahre, "Digital Lean Manufacturing and intelligent Poka-Yoke systems," *Procedia CIRP*, vol. 107, pp. 60–65, 2022.
- [26] J. Romero *et al.*, "Evolution of Poka-Yoke in Industry 4.0," *Journal of Smart Manufacturing*, 2022.
- [27] D. Roy and A. Singh, "Packaging quality failures and safety issues in food products," *Food Control*, vol. 129, 2021, doi: 10.1016/j.foodcont.2021.108254.
- [28] P. Sharma and V. Kumar, "Data-driven improvement strategies in DMAIC," *Operations and Quality Review*, 2022.
- [29] A. F. Tasyari, B. Purwanggono, and A. P. Hapsari, "Perbaikan sistem pengendalian kualitas produk saus botol plastik untuk menurunkan reject rate dengan metode DMAIC dan Poka Yoke," 2024.
- [30] J. Trojanowska and E. Dostatni, "Smart pick-to-light systems as Poka-Yoke in Industry 4.0," *Sensors*, vol. 23, no. 4, 2023.
- [31] J. Trojanowska, J. Husár, S. Hrehová, and L. Knapčíková, "Poka Yoke in smart production systems with pick-to-light implementation to increase efficiency," *Applied Sciences*, vol. 13, no. 21, p. 11715, 2023, doi: 10.3390/app132111715.
- [32] A. Wahid, "Application of Fault Tree Analysis to identify critical defects in plastic bottle packaging," *Journal of Packaging Technology and Research*, vol. 7, no. 3, pp. 215–229, 2023, doi: 10.1007/s41783-022-00107-w.
- [33] A. D. W. Wibowo, M. Suef, and P. D. Karningsih, "FTA-FMEA and Poka-Yoke analysis to reduce stamping machine breakdown time," in *Proc.*, pp. 205–221, 2024, doi: 10.2991/978-94-6463-566-9\_15.
- [34] T. Zeller and A. Montrone, "Fault Tree Analysis in modern reliability engineering," *Reliability Systems Review*, 2021.