Failure Mode Analysis of an Auto Palletizing System Using FMEA at PT XYZ

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Abstract

The Auto Palletizing System played a role in the end-of-line production process by automatically arranging products onto pallets to maintain production continuity and operational efficiency. However, recurring failures within the system caused production downtime and reduced equipment reliability. This study aimed to identify failure modes, evaluate their risk levels, and determine improvement priorities using the Failure Mode and Effects Analysis (FMEA) method. A quantitative case study approach was employed using operational failure data collected from January to April 2026 through field observations, maintenance records, and interviews with production and maintenance personnel at PT XYZ. Each failure mode was evaluated based on Severity, Occurrence, and Detection ratings to calculate the Risk Priority Number (RPN). The results identified seven failure modes affecting the Auto Palletizing system. Five failure modes were classified as critical, namely Pallet Conveyor Jam (RPN 336), Gripper/Robot Error (288), Pallet Stuck (270), Carton Miss Orientation (256), and Carton Falling (245). These failures were identified as the primary contributors to production interruptions and system downtime. The study concluded that FMEA effectively prioritized critical failure modes and provided a systematic basis for determining improvement priorities to enhance the reliability and operational performance of the Auto Palletizing system.

Keywords: *Failure Mode and Effects Analysis, Auto Palletizing System, Risk Priority Number Downtime Reliability.*

A. INTRODUCTION

The manufacturing industry continuously seeks to improve productivity, product quality, and operational efficiency to remain competitive in an increasingly dynamic business environment. One of the key factors affecting manufacturing performance is equipment reliability because unexpected machine failures may interrupt production processes, increase downtime, reduce equipment availability, and increase maintenance costs. Therefore, effective risk management has become an essential aspect of maintaining production continuity and improving operational performance (Adelard et al., 2026; Hopkin, 2018; Sidoarjo et al., 2024).

The implementation of automation technology has significantly improved manufacturing processes by reducing manual operations, increasing production consistency, and enhancing operational efficiency. One of the automation systems commonly implemented in manufacturing industries is the auto palletizing system, which automatically arranges finished products onto pallets before storage and distribution. The system integrates conveyors, sensors, robotic mechanisms, grippers, and control systems to ensure continuous material handling operations (Groover, 2014) However, because the system consists of numerous interconnected mechanical and electrical components, failures occurring in a single subsystem may interrupt the entire production process and reduce equipment reliability (Carlson, 2012; Robin A. Popple, 2009)

PT XYZ has implemented an auto palletizing system to support production activities and improve material handling efficiency. Nevertheless, operational records showed that the system still experienced recurring failures that caused production downtime and disrupted manufacturing operations. These failures affected production continuity, reduced equipment availability, and increased maintenance activities. Maintenance actions were generally performed after failures occurred, resulting in a reactive maintenance approach. Consequently, a systematic analysis is required to identify critical failure modes and determine maintenance priorities based on their level of risk.

Failure Mode and Effects Analysis (FMEA) is a systematic risk assessment method used to identify potential failure modes, evaluate their effects, analyze their causes, and determine the priority of corrective actions. The method evaluates each failure mode using three parameters, namely Severity, Occurrence, and Detection, which are combined to calculate the Risk Priority Number (RPN). Failure modes with higher RPN values indicate greater operational risks and should receive higher priority for maintenance improvement (D. H. Stamatis, 2003).

The application of FMEA has been widely reported in manufacturing industries. (Prasetya et al., 2021) demonstrated that FMEA effectively identifies production risks and determines improvement priorities based on Risk Priority Number values. Similarly, (Sukania & Wijaya, 2023) applied FMEA to production equipment maintenance and concluded that systematic failure analysis supports more effective maintenance planning while improving equipment reliability. Similarly, (Kusumawati et al., 2024) applied FMEA to analyze machine failures and determine repair priorities based on Risk Priority Number (RPN) values, demonstrating that failure risk prioritization can support more systematic maintenance and corrective decision-making. In addition, (Suprapto & Nuriyanto, 2025) analyzed palletizer performance using Overall Equipment Effectiveness (OEE) and FMEA and identified several critical failure modes that significantly contributed to production downtime. OEE-based reliability evaluation has likewise been applied by (Septian et al., 2021) in assessing chip mounter machine maintenance and by (Wahid et al., 2021) in a bottle production process, both grounded in the OEE framework introduced as part of the Total Productive Maintenance (TPM) concept. These studies indicate that FMEA is an effective tool for prioritizing operational risks and supporting maintenance decision-making in manufacturing systems.

FMEA has also been applied to manufacturing processes to determine the dominant causes of failures and prioritize corrective actions. Hapiuzin et al. (2022) combined Fishbone, Nominal Group Technique, and FMEA to evaluate factors causing delivery delays and identified the most dominant failure factors based on RPN values. (Siahaan, 2022) applied FMEA to analyze occupational accident risks in the production department and demonstrated the usefulness of FMEA in identifying and prioritizing potential risks. Meanwhile, Adillah et al. (2024) analyzed the causes of defects in packaged lubricant products using FMEA and identified critical failure factors based on their RPN values. These findings indicate that FMEA is not only applicable to machine maintenance but can also be used to evaluate risks associated with production processes and operational activities.

Several studies have also applied FMEA in combination with root cause analysis tools to strengthen failure prioritization. Aristriyana & Jig (2023) combined Fishbone Diagram and FMEA to analyze product defects in a manufacturing company, showing that integrating both methods allows failure causes to be traced more systematically across man, method, and material factors. This approach builds on the Fishbone Diagram technique originally developed by (Ishikawa, 1985) to categorize failure causes into man, machine, method, material, measurement, and environment factors. Similarly, Nayoga & Mukhtar (2024.) combined FMEA and Fault Tree Analysis (FTA) to identify the causes of defects in laminated door production and formulate improvement actions. Sinambela et al. (2025) also combined FMEA and FTA to analyze visual welding defects in steel structure production and identified critical causes based on RPN values. In a similar vein, Eviyanti (2021) applied Fishbone Diagram analysis to evaluate manufacturing defects in aluminum equipment production, while (Tri Wibowo et al., 2025) applied conventional FMEA to identify and analyze failure risks within a general production system, and (Sidoarjo et al., 2024b) examined maintenance strategies for printing machines in a textile company. These studies reinforce the relevance of systematic failure identification across diverse manufacturing contexts.

In the context of preventive maintenance planning, (Islam et al., 2021) applied a Fuzzy FMEA approach building on the fuzzy logic prioritization technique originally, while (Sitinjak & Silalahi, 2023) used an Analytical Hierarchy Process combined with sensitivity analysis to evaluate preventive maintenance strategies for heavy equipment. These studies confirm that FMEA remains a flexible framework that can be adapted or combined with other analytical tools depending on the operational context of the equipment being studied.

In terms of risk prioritization refinement, (Al Saadi, 2026) proposed an Economic Risk Priority Number (ERPN) that integrates cost factors into the conventional RPN calculation, demonstrating that traditional RPN may underestimate the economic impact of certain failure modes in industrial systems. This finding is relevant to the present study, as it highlights the importance of not only ranking failure modes by RPN but also considering their broader operational consequences when determining maintenance priorities.

Regarding the mechanical components specific to palletizing systems, (Mohd Nor, 2025) examined the performance of pneumatic grippers in palletizing applications and found that inconsistent air supply and low deformation resistance of pneumatic grippers are common contributors to carton drops and misalignment during handling. This finding directly supports the failure causes identified in the Gripper/Robot Error and Carton Falling failure modes observed in the present study.

Despite the extensive implementation of FMEA in manufacturing industries, previous studies have primarily focused on general production equipment or combined FMEA with other analytical approaches such as Overall Equipment Effectiveness (OEE), Lean Manufacturing, and Value Stream Mapping. Studies specifically investigating operational failures in auto palletizing systems using actual downtime data remain limited. Furthermore, research focusing solely on conventional FMEA to prioritize failure modes in automated palletizing systems is still relatively scarce. This condition demonstrates the need for further investigation to evaluate operational risks in auto palletizing systems based on actual operational data using the conventional FMEA approach.

Therefore, this study applied Failure Mode and Effects Analysis (FMEA) to identify and prioritize failure modes occurring in the auto palletizing system at PT XYZ. Historical downtime data collected during the observation period were analyzed to identify failure modes, determine Severity, Occurrence, and Detection ratings, and calculate the Risk Priority Number for each identified failure mode. The results of this study are expected to provide objective information regarding critical operational failures that require priority maintenance.

The contribution of this study lies in the application of conventional FMEA using actual operational downtime data from an industrial auto palletizing system. The findings provide practical information for maintenance decision-making by identifying critical failure modes that contribute most significantly to production downtime. Consequently, the results are expected to support improvements in equipment reliability, reduce production downtime, and enhance manufacturing operational performance.

B. METHODS

This study employed a quantitative descriptive approach to identify and prioritize failure modes in the auto palletizing system at PT XYZ using Failure Mode and Effects Analysis (FMEA). The method was selected because it provides a systematic approach to identifying potential failure modes, evaluating their effects, determining their causes, and prioritizing corrective actions based on the associated level of risk (D. H. Stamatis, 2003). The analysis was conducted using historical downtime data collected from January to April 2026 and expert judgment provided by the Executive Engineering to evaluate the operational risks of the auto palletizing system.

The research was conducted at PT XYZ, a manufacturing company operating in the consumer goods industry. The object of this study was the auto palletizing system located at the end of the production line. The research focused on identifying potential failure modes that contributed to production downtime during the observation period from January to April 2026. The assessment of Severity (S), Occurrence (O), and Detection (D) was carried out using expert judgment provided by the Executive Engineering, who is responsible for monitoring equipment reliability and coordinating maintenance activities. The assessment process was supported by actual operational data, including historical downtime records, maintenance reports, and production documentation. Combining expert judgment with operational data ensured that the assigned ratings accurately reflected the actual operating conditions of the auto palletizing system.

Primary data were obtained through direct observation of the auto palletizing system and semi-structured interviews with the Executive Engineering. The interviews aimed to identify potential failure modes, determine the causes and effects of each failure, evaluate the effectiveness of existing controls, and assign the Severity, Occurrence, and Detection ratings. Secondary data consisted of historical downtime records, preventive and corrective maintenance reports, production records, and equipment documentation collected from January to April 2026. These data were used to verify the frequency of equipment failures and support the risk assessment process.

Failure Mode and Effects Analysis (FMEA) was employed to identify and evaluate the risks associated with failures in the auto palletizing system. The analysis began by identifying all failure modes based on historical downtime records and maintenance documentation. Each identified failure mode was subsequently analyzed by determining its potential effects, possible causes, existing control methods, and corresponding risk level.

The risk assessment was performed using three evaluation parameters: Severity (S), Occurrence (O), and Detection (D). Severity represents the seriousness of the consequences caused by a failure, Occurrence indicates the likelihood of the failure occurring, and Detection measures the ability of existing control mechanisms to detect failures before they affect the production process (D. H. Stamatis, 2003).

The assessment criteria for Severity, Occurrence, and Detection are presented in Tables 1–3.

Table 1 Severity Rating Scale

Score	Severity Level	Description
1	Minor	Negligible effect on system operation. No damage to the product or equipment, no safety risk, and no disruption to production or project activities.
2	Very Low	Very slight impact causing only minor inconvenience without significant consequences to system performance or production.
3	Low	Minor impact requiring small adjustments or minor repairs without significantly affecting system performance or production continuity.
4	Moderate Low	Noticeable impact that may require limited downtime, minor rework, or corrective action while maintaining acceptable system performance.
5	Moderate	Moderate impact requiring corrective action. The failure may cause temporary production delays or a slight reduction in system performance.

6	Moderate High	Significant impact requiring immediate attention. The failure may result in considerable rework, noticeable quality problems, or moderate production downtime.
7	High	Serious failure affecting a primary system function. It may cause equipment damage, major production interruption, or require component replacement and technical intervention.
8	Very High	Very serious failure resulting in loss of system functionality, significant equipment damage, or a high potential safety risk.
9	Critical	Extremely severe failure causing major production losses, extensive equipment damage, or a serious risk of permanent injury to personnel.
10	Hazardous	Catastrophic failure posing an immediate threat to safety, causing extensive asset damage, severe operational disruption, regulatory non-compliance, or irreparable organizational losses.

Table 2 Occurrence Rating Scale

Score	Occurrence Level	Description
1	Remote	Failure is highly unlikely to occur. No previous occurrence has been recorded under normal operating conditions.
2	Very Low	Failure is highly improbable and may occur only under exceptional or unusual operating conditions.
3	Low	Failure is unlikely to occur frequently and may be observed only occasionally during system operation.
4	Moderate Low	Failure occurs infrequently and may be experienced only after extended operating periods or under specific conditions.
5	Moderate	Failure may occur occasionally during the system lifecycle and is considered reasonably possible based on operational experience.
6	Moderate High	Failure is likely to occur repeatedly and requires increased operational attention and monitoring.
7	High	Failure occurs frequently during normal operation and has a significant influence on system reliability and production performance.
8	Very High	Failure occurs very frequently and is expected to recur within relatively short operating intervals.
9	Constant	Failure occurs almost continuously and represents a recurring operational problem that substantially affects system performance.

10	Almost Certain	Failure is virtually certain to occur or has been repeatedly observed under normal operating conditions.

Table 3 Detection Rating Scale

Score	Detection Level	Description
1	Certain	The existing control system is almost certain to detect the failure before it affects the production process or system performance.
2	Very High	The failure has a very high probability of being detected through reliable monitoring systems or established inspection procedures.
3	High	The failure is likely to be detected by existing control mechanisms during routine inspection or normal system monitoring.
4	Moderate High	The failure has a good probability of being detected, although detection may require additional inspection or specific operating conditions.
5	Moderate	The failure has a moderate probability of detection. Existing controls may identify the failure, but their effectiveness is not always consistent.
6	Moderate Low	The probability of detection is relatively low because existing control methods are only partially effective in identifying failures.
7	Low	The failure is difficult to detect due to limited or ineffective control mechanisms, increasing the likelihood that it will remain unnoticed during operation.
8	Very Low	The failure has a very low probability of being detected because monitoring or inspection systems provide minimal warning before failure occurs.
9	Remote	The failure is rarely detected before causing significant operational effects and is generally identified only after substantial system degradation or damage has occurred.
10	Not Detectable	No effective detection or monitoring mechanism exists. The failure is identified only after its full consequences have occurred.

After assigning the Severity, Occurrence, and Detection scores, the Risk Priority Number (RPN) for each failure mode was calculated using Equation (1).

$$\boxed{\boldsymbol{RPN = S \times O \times D}}$$

where:
S = Severity
O = Occurrence
D = Detection

The resulting RPN values were ranked to determine maintenance priorities. Failure modes with RPN values > 200 were categorized as critical and selected for further analysis.

The collected data were analyzed descriptively using the FMEA framework. Historical downtime records were first classified according to the identified failure modes. Subsequently, the Severity, Occurrence, and Detection ratings were assigned through expert judgment supported by actual operational data. The Risk Priority Number (RPN) for each failure mode was then calculated using Equation (1).

The resulting RPN values were ranked to determine the priority level of each failure mode. Failure modes with RPN values > 200 were categorized as critical and selected for further discussion, whereas failure modes with lower RPN values were excluded from further analysis. The analysis results were presented in tabular form to facilitate comparison among failure modes and support maintenance decision-making within the auto palletizing system.

C. RESULTS AND DISCUSSION

This section presents the findings obtained from the Failure Mode and Effects Analysis (FMEA) conducted on the auto palletizing system at PT XYZ. The analysis was performed using historical downtime records, maintenance reports, direct observations, and expert judgment from the Executive Engineering. The identified failure modes were evaluated based on Severity (S), Occurrence (O), and Detection (D) ratings to determine their corresponding Risk Priority Number (RPN). The results were then ranked to identify the most critical failure modes requiring immediate attention.

1. Identification of Failure Modes

The first stage of the analysis involved identifying potential failure modes that occurred in the Auto Palletizing System during the observation period from January to April 2026. Failure identification was carried out using historical downtime records, maintenance reports, direct observations, and interviews with the Executive Engineering. This process ensured that the identified failure modes accurately represented the operational conditions of the production system.

The identification process revealed several failure modes affecting the reliability of the Auto Palletizing System. These failures were associated with the pallet dispenser, conveyor system, sensors, robot gripper, and carton handling mechanism. Each identified failure mode was subsequently evaluated using the FMEA method to determine its Severity (S), Occurrence (O), Detection (D), and Risk Priority Number (RPN).

2. Failure Mode and Effects Analysis

Each identified failure mode was evaluated using the three FMEA parameters, namely Severity (S), Occurrence (O), and Detection (D). The assessment was conducted through expert judgment provided by the Executive Engineering and supported by actual operational data obtained from historical downtime records and maintenance documentation.

The Severity rating represented the impact of a failure on the production process, the Occurrence rating indicated the frequency of failure occurrence, and the Detection rating reflected the capability of the existing control system to detect failures before they affected production. The Risk Priority Number (RPN) was calculated by multiplying the three parameters to determine the priority level of each failure mode.

Table 4 Failure Mode and Effects Analysis of the Auto Palletizing System

No	Failure Mode	Failure Effect	Failure Cause	S	O	D	RPN
1	Pallet Conveyor Jam	The pallet becomes jammed on the supply conveyor, interrupting pallet delivery to the robot palletizer and stopping the palletizing process until operator intervention is performed.	○ Incorrect roller alignment during installation ○ Bearing seizure caused by wood debris contamination ○ Guide rail misalignment ○ Non-standard or deformed pallets ○ Excessive roller spacing	7	6	8	336
2	Gripper/Robot Error	The robot palletizer stops operating due to gripper or robot system failures, interrupting the entire palletizing process until diagnosis and system reset are completed.	○ Insufficient pneumatic pressure ○ Pneumatic hose leakage ○ Servo motor overload or position deviation ○ Communication failure between the robot controller and servo drive	8	6	6	288

			○ Incorrect robot program parameters ○ Safety interlock activation				
3	Pallet Stuck	The pallet fails to exit the dispenser, preventing pallet supply to the robot and causing the palletizing process to stop, resulting in product accumulation in the packing area.	○ Oversized pallet dimensions ○ Pallet deformation ○ Wooden protrusions or debris obstructing the dispenser mechanism ○ Misaligned pallet stacking.	6	9	5	270
4	Carton Miss Orientation	Incorrect carton orientation prevents the robot from performing the picking operation, resulting in conveyor blockage and production interruption until carton position is corrected.	○ Inappropriate guide rail design ○ Excessive carton angular deviation ○ Carton collision during conveying ○ Conveyor speed causing carton rotation or displacement	4	8	8	256
5	Carton Falling	Cartons fall from the gripper or pallet stack during the stacking process, causing product damage, manual handling, and temporary production interruption.	○ Insufficient gripper clamping force ○ Improper servo calibration ○ Unsuitable gripper surface material ○ Pallet position deviation	5	7	7	245

			○ Carton flap reopening during transfer				
6	Sensor Error	Sensors fail to detect the presence or position of pallets or cartons accurately, generating false alarms or emergency stops that interrupt conveyor and robot operations.	○ Sensor contamination by dust or wood debris ○ Sensor misalignment due to vibration ○ Loose sensor cable connections	7	5	5	175
7	Arrangement NG	Cartons are stacked in an incorrect pattern, reducing stacking quality and requiring manual correction before production continues.	○ Pallet position deviation ○ unstable pallet stopper ○ robot coordinate calibration error ○ conveyor vibration ○ incorrect stacking pattern parameters	3	2	5	30

The FMEA evaluation identified five critical failure modes with RPN values greater than 200, namely Pallet Conveyor Jam (RPN = 336), Gripper/Robot Error (RPN = 288), Pallet Stuck (RPN = 270), Carton Miss Orientation (RPN = 256), and Carton Falling (RPN = 245). These failure modes were classified as critical because they represented the highest operational risks within the Auto Palletizing System and therefore became the primary focus for maintenance prioritization and further discussion. Conversely, failure modes with RPN values below 200, including Sensor Error (RPN = 175) and Arrangement NG (RPN = 30), were categorized as non-critical and were not discussed further in this study.

The results indicate that the majority of critical failure modes were associated with the pallet handling, material transfer, robotic handling, and carton positioning processes. Since these functions are directly related to the continuity of palletizing operations, failures occurring in these areas can significantly increase production downtime, reduce equipment reliability, and interrupt the overall production flow.

3. Discussion of Critical Failure Modes

The FMEA analysis identified Pallet Conveyor Jam as the most critical failure mode, with the highest RPN value of 336. This failure occurred when pallets became jammed on the supply conveyor before reaching the robot palletizer, interrupting pallet delivery and stopping the palletizing process until operator intervention was performed. The high RPN value reflects the combination of a significant operational impact, relatively frequent occurrence, and limited detection capability under the existing control system. According to (D. H. Stamatis, 2003), failure modes with high Severity, Occurrence, and Detection ratings should receive the highest priority because they pose the greatest operational risk and have the strongest influence on production continuity.

The second highest RPN value (288) was obtained by Gripper/Robot Error. This failure interrupted the robot palletizer operation due to problems in the pneumatic system, servo motor, communication between the robot controller and servo drive, or incorrect robot program parameters. As a result, the entire palletizing process stopped until system diagnosis and reset were completed. Because the robot is the primary handling component within the Auto Palletizing System, failures in this subsystem directly affect production continuity and equipment availability. Similar findings were reported by (Sukania & Wijaya, 2023), who concluded that failures in automated handling equipment contribute significantly to production downtime and should therefore be prioritized in maintenance planning.

The third critical failure mode was Pallet Stuck, which obtained an RPN value of 270. This failure prevented empty pallets from being released properly from the pallet dispenser, causing the robot to lose pallet supply and resulting in product accumulation in the packing area. The failure was primarily associated with non-standard pallet dimensions, pallet deformation, wooden debris, and pallet misalignment inside the dispenser. Since the pallet dispenser is the initial stage of the palletizing process, any disruption at this point immediately interrupts downstream operations and reduces overall system productivity.

The fourth critical failure mode was Carton Miss Orientation, with an RPN value of 256. This failure occurred when cartons entered the robot pick area in an incorrect orientation, preventing the robot from performing the picking operation successfully. Consequently, the production process was interrupted until manual correction of the carton position was completed. The relatively high RPN indicates that the existing passive guiding mechanism was insufficient to ensure consistent carton positioning under varying operating conditions. This finding suggests that improving carton guidance or implementing an automatic vision-based inspection system could significantly reduce the occurrence of this failure.

The fifth critical failure mode was Carton Falling, which obtained an RPN value of 245. This failure occurred when cartons slipped from the robot gripper or fell during the stacking process, causing product damage, manual restacking, and temporary production interruption. The primary causes included insufficient gripping force, improper servo calibration, unsuitable gripper surface material, pallet position deviation, and carton flap reopening during transfer. Repeated carton falling not only reduced production efficiency but also increased handling time and the risk of product defects. These findings are consistent with (Prasetya et al., 2021) who reported that failure modes with high RPN values should receive priority because they have a substantial impact on equipment reliability and production performance.

The causes identified for Gripper/Robot Error and Carton Falling in this study are consistent with findings reported by (Mohd Nor, 2025) who noted that pneumatic gripper systems are particularly susceptible to performance degradation caused by inconsistent air pressure, resulting in dropped or misaligned cartons during handling. This similarity suggests that the failure patterns observed at PT XYZ are not isolated cases but reflect a broader reliability challenge commonly associated with pneumatic gripper technology in palletizing applications.

Furthermore, the prioritization approach adopted in this study aligns with the recommendation of (Al Saadi, 2026), who emphasized that RPN-based prioritization should be complemented with contextual operational judgment, since failure modes with similar RPN values may still differ significantly in their actual impact on production continuity. This supports the decision to focus improvement efforts on the five critical failure modes identified in this study, as each carries distinct operational consequences despite their comparable RPN scores.

Overall, the FMEA results demonstrate that failures related to pallet transfer, robotic handling, pallet dispensing, and carton positioning represent the dominant operational risks within the Auto Palletizing System at PT XYZ. Prioritizing failure modes based on Risk Priority Number (RPN) enables the company to identify maintenance priorities objectively and allocate improvement efforts to the most critical operational problems. These findings confirm that the application of FMEA provides an effective framework for evaluating operational risks, improving maintenance planning, reducing production downtime, and enhancing equipment reliability in automated manufacturing systems.

D. CONCLUSION

This study applied the Failure Mode and Effects Analysis (FMEA) method to identify and prioritize failure modes in the Auto Palletizing System at PT XYZ. The analysis was conducted using historical downtime records, maintenance documentation, direct observations, and expert judgment from the Executive Engineering to evaluate operational risks based on Severity (S), Occurrence (O), Detection (D), and the resulting Risk Priority Number (RPN).

The results identified five critical failure modes with RPN values greater than 200, namely Pallet Conveyor Jam (RPN = 336), Gripper/Robot Error (RPN = 288), Pallet Stuck (RPN = 270), Carton Miss Orientation (RPN = 256), and Carton Falling (RPN = 245). These failure modes represented the main contributors to operational disruption and production downtime within the Auto Palletizing System. The implementation of FMEA successfully prioritized failure modes based on their risk levels, providing a systematic approach for determining maintenance priorities and supporting more effective risk management in automated manufacturing systems.

This study was limited to operational risk analysis using the FMEA method based on historical downtime data and expert judgment. Future research is recommended to evaluate the effectiveness of improvement actions by comparing system performance before and after implementation, including reductions in downtime, improvements in equipment reliability, and enhancement of overall system performance.

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