APPLICATION OF THE FAILURE MODE AND EFFECT ANALYSIS METHOD IN QUALITY CONTROL OF STREET LAMP POLE PRODUCTION PROCESS IN MEDAN CITY

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Received	: 26 April 2026	Accepted	: 20 May 2026
Revised	: 03 May 2026	Published	: 17 June 2026

Abstract
The production process for galvanized street lamp poles in Medan City involves six main stages, each of which can lead to product failures. The absence of a standardized, documented quality control system means these potential failures cannot be proactively identified or controlled. This study aims to identify potential failures, calculate Risk Priority Numbers (RPNs), and formulate quality control action recommendations using the Failure Mode and Effects Analysis (FMEA) method. The study employed a descriptive, qualitative approach with a single-case study design. Data were collected through in-depth interviews, direct observation, and documentation studies involving four key informants. The results identified eleven (11) potential failures across six production process stages. Three failures were categorized as top priority, with the highest RPN values: weld defects—porosity, undercut, and incomplete fusion (RPN 315); zinc coating thickness below the minimum standard (RPN 288); and defective products passing through to the shipping stage (RPN 280). Recommended control actions include developing standard operating procedures, implementing a welder certification program, conducting batch-by-batch zinc thickness testing, adopting standardized inspection checklists, and periodically calibrating measuring instruments.

Keywords: Failure Mode and Effect Analysis, Quality Control, Risk Priority Number, Galvanized Street Lamp Pole, Steel Fabrication

INTRODUCTION

The steel fabrication industry is a manufacturing sector with a fairly complex production process. The production process consists of several interrelated stages, from material cutting and component forming to welding and finishing, and finally to galvanizing. Each stage has the potential to fail, which can directly affect the quality of the final product. Without a structured quality control system, these potential failures are difficult to identify and prevent before they impact the product reaching the customer. Quality control in the manufacturing process is a critical factor in determining the consistency and reliability of the resulting product. Wicaksono et al. (2023) stated that effective quality control focuses not only on final product inspection but also on systematically managing each stage of the production process to prevent product defects early. A proactive approach to quality control has proven more efficient than a reactive approach that only addresses problems after failures occur.

One quality control method widely used in the manufacturing industry is Failure Mode and Effects Analysis (FMEA). FMEA is a systematic method for identifying potential failures at each stage of the production process, analyzing their impacts, and determining appropriate control measures based on risk priority. Aprianto et al. (2021) explained that FMEA helps steel fabrication companies shift their focus from addressing existing problems to preventing them before they impact product quality and customer satisfaction. Based on the operational conditions of the street lamp pole fabrication industry in Medan City, during the production process of galvanized street lamp poles, several issues related to quality control of the production process are identified, as follows:

1. The production process for galvanized street lamp poles in Medan City consists of several stages, each of which can fail. However, there is no standard method for systematically identifying and controlling these potential failures.
2. The street lamp pole fabrication industry in Medan City generally lacks structured quality control documentation at each stage of the production process, the consistency of galvanized street lamp pole product quality cannot be fully guaranteed.

3. Potential process failures have never been identified in a structured manner, so preventive measures against product defects cannot be implemented proactively before failures affect the final product's quality.
4. The lack of application of the FMEA method as a quality control tool in Medan City has resulted in the company being unable to prioritize control actions based on measurable risk levels at each stage of the production process.

Aprianto et al. (2021) conducted a literature review of 30 articles implementing the FMEA method in various industries in Asia. The study results showed that the FMEA method is often integrated with other methods such as Quality Function Deployment (QFD), Root Cause Analysis (RCA), and Six Sigma to address quality issues more comprehensively. This research provides the main conceptual foundation for understanding the FMEA framework applied in this study. Wicaksono et al. (2023) applied the FMEA method to the quality control of a centrifugal pump maintenance process at PT. X. The results showed that the RPN calculation obtained the highest value of 336, making this process a top priority for stricter control measures. This study provides a concrete illustration of FMEA application in an industrial context and of how to interpret RPN values in quality control decision-making.

Saidatuningtyas and Rizal (2023) applied the Six Sigma DMAIC method to the quality control of steel construction products for bridges at a steel fabrication plant. This study found that the steel fabrication process has several critical points that require special attention in quality control. The results of this study are relevant as a reference for the operational context of a steel fabrication industry similar to the street lamp pole fabrication industry in Medan City. Wicaksono and Yuamita (2022) applied FMEA and Fault Tree Analysis (FTA) methods to identify and minimize can defects in the sardine production process at PT XYZ. Of the seven types of defects identified, the RPN calculation results were used to determine the five priority defects with the highest RPN values that required immediate corrective action. This study demonstrated the effectiveness of combining FMEA and the Pareto principle in prioritizing quality control measures. Ridwan et al. (2023) applied FTA and FMEA methods to the quality control of oil palm seedlings. This study demonstrated that combining the two methods could identify failure causes more comprehensively, from root causes to their impacts. Given these conditions, research is needed to apply the FMEA method to the quality control of the galvanized street lamp pole production process in Medan City, thereby systematically identifying, analyzing, and controlling potential process failures.

LITERATURE REVIEW

Quality Control in the Manufacturing Industry

Quality control is a series of activities carried out to ensure that the resulting product meets established requirements and specifications. Saidatuningtyas and Rizal (2023) state that quality control in the steel fabrication industry comprises two main approaches: inspection-based and process-based. The process-based approach is considered more effective because it focuses on preventing failures early in the production process, rather than simply detecting nonconformities after the product is completed. Wicaksono et al. (2023) emphasize that a standardized measurement system, documented inspection procedures, and a structured corrective action mechanism must support effective quality control in manufacturing. These three elements complement each other and form the foundation of a quality control system capable of maintaining consistent product quality on an ongoing basis.

Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a risk analysis method used systematically to identify potential failure modes in a process or product, analyze the impact of each failure (effect), identify the causes of failure, and determine appropriate control measures based on risk priority. Aprianto et al. (2021) explain that FMEA is a tool that systematically identifies the effects or consequences of system or process failures and reduces or eliminates the likelihood of failure occurring in various industrial sectors in Asia.

In its implementation, FMEA uses three risk assessment parameters: Severity (S), Occurrence (O), and Detection (D). Severity measures the impact of a failure on product quality or customer satisfaction. Occurrence measures the frequency of failures in the production process. Detection measures how easily the failure can be detected before it impacts the final product. These three parameters are scored on a scale of 1 to 10, then multiplied to produce a Risk Priority Number (RPN) using the formula:

$$\mathbf{RPN = S \times O \times D}$$

A high RPN value indicates that a potential failure warrants immediate control action. In their research, Wicaksono and Yuamita (2022) demonstrated that applying FMEA with RPN calculations can identify critical failures in the production process and provide targeted corrective action recommendations to minimize product defects.

Application of FMEA in Steel Fabrication Production Process

The application of FMEA in the steel fabrication production process involves identifying each process stage that has the potential to cause failure, then analyzing the impact, causes, and detection mechanisms for each potential failure. The production process for galvanized street lamp poles in Medan City involves six main stages, each with different failure characteristics. At the material receiving stage, common potential failures include non-conformance of steel plate dimensions and thickness with established specifications. At the cutting stage, potential failures include deviations in cut dimensions due to blade wear or incorrect machine settings. At the bending stage, failures can include imprecise bend angles or cracks in the bend area. At the welding stage, potential failures include weld defects such as porosity, undercuts, and incomplete fusion, which can reduce joint strength. At the galvanizing stage, a common failure is zinc coating thickness that does not meet minimum standards, which directly affects the product's corrosion resistance (Ridwan et al., 2023). Applying FMEA to each process stage enables companies to compile a comprehensive risk list, prioritize control actions based on RPN, and design appropriate control procedures for each identified potential failure. Saidatuningtyas and Rizal (2023) demonstrated that the systematic application of quality control methods in the steel fabrication industry significantly reduced product defect levels.

Galvanized Street Lamp Poles as a Steel Fabrication Product

Galvanized street lamp poles are infrastructure components manufactured through a steel fabrication process and galvanized to enhance corrosion resistance. These products must meet the technical standards set by the Ministry of Transportation regarding dimensions, structural strength, and the thickness of the galvanized layer. The production process for galvanized street lamp poles involves several critical technical stages. The main raw material, SPHC mild steel plate, is cut to a pre-designed pattern and then shaped into a pole profile by bending on a hydraulic bending machine. The pole components are then joined through welding using an electric arc welding technique. The semi-finished product is then hot-dip galvanized, in which the pole is dipped into a bath of molten zinc at 450–460°C to form a protective zinc coating. The complexity of this production process makes galvanized street lamp poles highly relevant for FMEA analysis, as each stage carries the potential for failure that can significantly impact product quality and safety in the field.

Research Framework

This research focuses on applying the FMEA method to quality control in the production process of galvanized street lamp poles in Medan City. The starting point of the research was the existing condition of the street lamp pole fabrication industry in Medan City, which lacks a standardized quality control method. Consequently, potential failures at each stage of the production process cannot be systematically identified and controlled.

The analysis process began with observations and interviews to understand the actual conditions at each stage of the production process. The results of these observations and interviews were used to compile an FMEA analysis. This analysis included identifying potential failures, analyzing their impact and causes, assessing the S, O, and D parameters, and calculating the RPN for each potential failure. Based on these RPN values, control priorities were determined, and recommendations for appropriate, applicable quality control actions for the street lamp pole fabrication industry in Medan City were formulated. The flowchart of this research framework is presented in Figure 1.

Figure 1: Research Thinking Framework

METHOD

This research uses a qualitative descriptive approach with a single case study design. The qualitative approach was chosen because this study aims to apply the Failure Mode and Effect Analysis (FMEA) method to quality control in the production process of galvanized street lamp poles in Medan City. It requires an in-depth understanding of the actual conditions of the production process, the characteristics of potential failures, and the specific operational context of the steel fabrication industry. Despite using a qualitative approach, this study also incorporates quantitative elements in the FMEA analysis process, specifically in the assessment of Severity (S), Occurrence (O), and Detection (D) values, and in the calculation of the Risk Priority Number (RPN). This combination of approaches allows the researcher to obtain a comprehensive picture of potential production process failures qualitatively and to prioritize them quantitatively using the RPN value.

The research method used in this study is a descriptive-analytical method, with FMEA as the primary analytical tool. The descriptive-analytical method is used to systematically and accurately describe the actual conditions of the galvanized street lamp pole production process in Medan City. Then, it analyzes potential failures at each process stage using the FMEA framework to generate recommendations for targeted quality control actions. This research is a field research conducted directly at the operational location of the galvanized street lamp pole fabrication industry in Medan City, North Sumatra Province. The unit of analysis in this study is the production process for galvanized street lamp poles in Medan City, comprising six main stages: material receipt, cutting, bending, welding, galvanization, and final quality control. The flow of the research method used is presented in Figure 2 below.

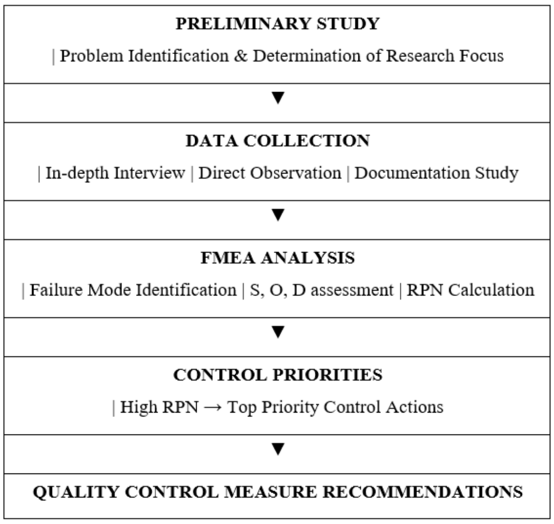

Figure 2: Research Method Flow

Data collection in this study was conducted using three main complementary techniques: in-depth interviews, direct observation, and document analysis. Informants were selected using purposive sampling, based on specific considerations relevant to the research objectives. The informant selection criteria included: (1) holding a position and responsibility directly related to the galvanized street lamp pole production process; (2) having adequate knowledge and experience regarding the actual conditions of the production process and the types of failures that have occurred; and (3) being willing to participate in the research interview process.

Data analysis in this study used the FMEA approach integrated with the interactive analysis model of Castleberry & Nolen (2018). More specifically, the data analysis process in this study consisted of four main stages: data condensation, preparation of the FMEA worksheet, RPN calculation and prioritization, and conclusion drawing and verification.

Table 1. Stages of Data Analysis Techniques

No.	Analysis Stage	Activity	Output
1.	Data Condensation	Sorting and focusing data from interviews, observations, and documentation on aspects of failure mode, effect, cause, and current control for each stage of the production process.	Codified data for each stage of the production process is ready to be entered into the FMEA worksheet.
2.	FMEA Worksheet Preparation	Fill in the FMEA worksheet with failure mode, effect, cause, and current control based on the results of data condensation, then assess the S, O, and D parameters through agreement with key informants.	Complete FMEA worksheet with S, O, and D values for each potential failure at all stages of the production process.
3.	RPN and Priority Calculation	Calculate the RPN (S × O × D) for each potential failure, sort them from highest to lowest, and assign priority to those that require immediate control action.	A list of potential priority failures based on RPN values as a basis for quality control action recommendations.
4.	Conclusion Drawing and Verification	Formulate quality control action recommendations for each potential priority failure and verify through source triangulation and technique triangulation.	Recommendations for valid, reliable, and applicable quality control measures for street lamp pole producers in Medan City

Source: Processed by Researchers (2025)

RESULTS AND DISCUSSION

A. FMEA Analysis Model or Framework

The model or framework produced in this study is the application of the Failure Mode and Effect Analysis (FMEA) method as a quality control system for the production process of galvanized street lamp poles in Medan City. The FMEA model includes six stages of the galvanized street lamp pole production process, namely: (1) material receipt; (2) cutting; (3) bending; (4) welding; (5) galvanization; and (6) final quality control. For each stage, the FMEA model identifies potential failure modes, impacts of failure (effects), causes of failure (causes), and current controls, then assesses three risk parameters, namely Severity (S), Occurrence (O), and Detection (D) on a scale of 1 to 10 to produce a Risk Priority Number (RPN) value with the formula:

$$\mathbf{RPN = S \times O \times D}$$

Four main aspects form the basis of the FMEA model design in this study:

1) Failure Mode Identification — Mapping all potential failures that could occur at each stage of the production process based on data from in-depth interviews, direct observations, and a study of production record documentation.
2) Effect & Cause Analysis — Analyzing the impact of each failure on final product quality and customer satisfaction, and identifying the root cause of the failure for each identified failure mode.
3) Quantitative Risk Assessment — Objectively assessing the S, O, and D values through agreement with key informants, then calculating the RPN value to determine measurable quality control priorities.
4) Control Action Recommendation — Formulating specific and applicable quality control action recommendations for each priority failure, including preventive and detective actions appropriate to the capacity of the street lamp pole fabrication industry in Medan City.

B. Design Results

The designed FMEA model has been compiled into a comprehensive worksheet covering all stages of the galvanized street lamp pole production process in Medan City. The resulting design includes three main elements:

a) Product
1. Complete FMEA worksheet that includes identification of failure modes, effects, causes, S, O, D, RPN values, and recommended control actions for all stages of the galvanized street lamp pole production process.
2. Failure priority list based on RPN value as a structured quality control guide for the street lamp pole fabrication industry in Medan City.

b) Process
1. Quality control management that includes systematic identification of failure modes at each process stage, quantitative risk assessment, and prioritization of control actions.
2. Critical evaluation of the failure detection mechanisms currently implemented in Medan City and recommendations for strengthening them.

c) Strategy
1. Utilization of RPN values as Key Performance Indicators (KPIs) for quality control to prioritize the allocation of control resources more effectively.
2. FMEA-based proactive quality control approach as an alternative to the reactive approach currently implemented in Medan City.

Identify Failure Mode, Effect, and Cause

Based on in-depth interviews with four key informants and direct observations on the production floor of a street lamp pole fabrication industry in Medan City, potential failures were identified at each stage of the galvanized street lamp pole production process. Failure modes, effects, and causes were systematically identified for each stage of the process, as follows:

a. Material Receiving Process
During the material acceptance stage, potential failures identified included discrepancies in the dimensions and thickness of steel plates with established specifications, as well as surface defects in incoming materials. The impact of these failures is that the material does not meet specifications, potentially leading to failures in subsequent process stages. The primary causes of these failures were weak incoming material inspection procedures and the absence of documented inspection standards.

b. Cutting Process

During the cutting stage, potential failures include deviations in the dimensions of the cut product from the established specifications. This results in semi-finished products that do not meet the required dimensions, necessitating rework or even material rejection. The main causes are wear on the CNC plasma cutting machine blade, incorrect machine parameter settings, and the lack of standardized periodic calibration procedures.

c. Bending Process
During bending, potential failures include inaccurate bend angles and cracks in the bending area. This results in the pole components not meeting the specified geometry specifications, affecting the structural strength and aesthetics of the final product. The main causes are material that does not meet hardness specifications, incorrect pressure settings on the hydraulic bending machine, and a lack of regular bend angle checks throughout the process.

d. Welding Process
During the welding stage, potential failures include weld defects such as porosity, undercuts, incomplete fusion, and weld cracks. The impact of these failures is critical because they directly reduce the weld joint's strength, potentially threatening the safety of product users. The main causes are uneven welder competence, improper welding parameter settings, and the absence of standardized visual inspection procedures for welds.

e. Galvanizing Process
During the galvanization stage, potential failures include zinc coating thickness below the minimum standard (<85 μm), surface defects such as bare spots and dross inclusions, and non-uniformity of the zinc coating across the entire product surface. The impact of these failures is a significant reduction in the product's corrosion resistance, which is the primary function of galvanizing. The main causes are poorly controlled galvanizing bath temperature, contamination on the material surface before galvanizing, and inappropriate dipping time.

f. Final Quality Control Process
In the final quality control stage, potential failures include passing defective products through to shipping due to incomplete inspections, as well as the final product's dimensions not meeting customer specifications. The impact of non-conforming products reaching customers can lead to complaints, product returns, and damage to the company's reputation. The main causes are the lack of a standardized inspection checklist, uneven inspector competency, and the lack of calibrated measuring instruments.

Assessment of S, O, D Values and RPN Calculation

The assessment of Severity (S), Occurrence (O), and Detection (D) values was conducted through a discussion and agreement process with four key research informants. The assessment used a scale of 1 to 10 with the following criteria:

a) Severity Criteria (S): 1–2 = very light impact does not affect function; 3–4 = light impact, product can still be repaired; 5–6 = moderate impact, requires rework; 7–8 = high impact, product rejected; 9–10 = very high impact, threatens user safety.
b) Occurrence Criteria (O): 1–2 = very rare (< 1 time per 1,000 units); 3–4 = rare (1–10 times per 1,000 units); 5–6 = sometimes (10–100 times per 1,000 units); 7–8 = often (> 100 times per 1,000 units); 9–10 = almost always occurs.
c) Detection Criteria (D): 1–2 = almost certain to be detected before reaching the customer; 3–4 = highly likely to be detected; 5–6 = moderately likely to be detected; 7–8 = low likelihood to be detected; 9–10 = almost impossible to detect.

C. Analysis and Evaluation of FMEA Results

Based on the FMEA worksheet, the RPN values for each potential failure in the galvanized street lamp pole production process in Medan City were obtained. The FMEA results were analyzed and evaluated by ranking the RPN values from highest to lowest to determine quality control priorities. The order of potential failures, based on the RPN values from highest to lowest, is as follows:

Table 2. Analysis and Evaluation of FMEA Results

Rank	Process Stages	Failure Mode	Current Control	S	O	D	RPN	Priority Status
1	Welding	Welding defects: porosity, undercuts, incomplete fusion	Occasional visual inspections	9	5	7	**315**	TOP PRIORITY
2	Galvanizing	Zinc layer thickness < 85 µm	Daily temperature checks	8	6	6	**288**	TOP PRIORITY
3	Final Quality Control	Defective product passed through to shipment	Visual inspections	8	5	7	**280**	TOP PRIORITY
4	Bending	Cracks in the bending area	No control	8	4	7	**224**	HIGH PRIORITY
5	Cutting	Dimensions of the cut result are not as specified	Occasional checks	6	6	6	**216**	HIGH PRIORITY
6	Final Quality Control	Product dimensions are not as specified	Manual measurements	7	4	7	**196**	HIGH PRIORITY
7	Welding	Weld crack	No control	9	3	7	**189**	MEDIUM PRIORITY
8	Material Receipt	Plate dimensions/thickness are not correct	Occasional visual inspection	6	5	6	**180**	MEDIUM PRIORITY
9	Bending	The bend angle is not precise	Occasional manual check	6	5	6	**180**	MEDIUM PRIORITY
10	Material Receipt	Material surface defects	No control	6	4	7	**168**	MEDIUM PRIORITY
11	Galvanizing	Bare spots and dross inclusions	Occasional visual inspection	6	5	5	**150**	LOW PRIORITY

Source: Processed by Researchers (2025)

From the FMEA analysis results, there are three potential failures with the Top Priority category (RPN ≥ 280), namely: (1) weld defects in the welding process with an RPN of 315; (2) substandard zinc layer thickness in the galvanizing process with an RPN of 288; and (3) the passing of defective products to the shipping stage during the final quality control process with an RPN of 280. These three failures require immediate and intensive control measures.

In addition to the RPN value, it is important to note that two potential failures in the welding process, namely weld defects (S = 9) and weld cracks (S = 9), have the highest Severity value because they are directly related to the safety of product users. These two failures receive special attention regardless of their RPN value.

D. Validation of Results

Validation of the FMEA worksheet results was carried out through two mechanisms: source triangulation and technique triangulation. Source triangulation was carried out by comparing and matching information regarding potential failures, causes, and impacts obtained from four key informants—the Operations Manager, the ISO & Purchasing Admin, the Quality Control Admin, and the Production Supervisor. Consistency in information between informants is an indicator of the validity of the data used to compile the FMEA worksheet.

Technical triangulation was conducted by comparing data from three data collection techniques: in-depth interviews, direct observation on the production floor, and documentation studies of production records. The agreement between these three data sources strengthened the reliability of the resulting FMEA worksheet. The triangulation results demonstrated adequate data consistency across sources and techniques; the resulting FMEA worksheet was declared valid and reliable as a basis for recommending quality control measures for the street lamp pole fabrication industry in Medan City.

E. Recommended Quality Control Actions

Based on the results of the FMEA analysis and the priority of RPN values, the following recommendations for specific, applicable quality control actions for the street lamp pole fabrication industry in Medan City are formulated, sorted by priority of handling.

a) Top Priority — Welding (RPN 315)

1. Implementing certification programs and periodically improving welder competency in accordance with AWS (American Welding Society) standards.
2. Compile and implement welding procedure SOPs that include welding parameters (current, voltage, speed), preheating procedures, and cooling procedures.
3. Implement 100% visual inspection on every weld joint using a standardized checklist, and conduct Non-Destructive Testing (NDT) periodically.

b) Top Priority — Galvanization (RPN 288)

1. Develop SOPs for controlling the galvanizing process, including pre-treatment procedures (degreasing, pickling, fluxing), controlling the galvanizing bath temperature (450–460°C), and minimum dipping time.
2. Conduct zinc layer thickness testing for each batch using a calibrated thickness gauge, with a minimum target thickness of 85 µm, as per SNI 8011:2014.
3. Create a galvanizing process control card that records bath temperature, dip time, and thickness test results for each production batch.

c) Top Priority — Final Quality Control (RPN 280)

1. Develop a standardized final inspection checklist that includes verifying dimensions, weld quality, galvanizing thickness, surface defects, and product completeness, in accordance with customer specifications.
2. Conduct regular inspector training programs to improve competence and consistency of inspection results.
3. Implement a 100% inspection system before shipment with documented inspection data records for each product unit.

d) High and Medium Priority — Cutting, Bending, and Material Receiving

1. Create an SOP for incoming material inspection that includes a checklist for verifying the dimensions, thickness, and surface condition of steel plates, with periodic calibration of measuring instruments.
2. Establish a schedule for CNC plasma cutting machine calibration and periodic blade replacement, and an SOP for checking the dimensions of cut results every 10 production units.
3. Developing SOP for setting bending machine parameters and using standard angle molds, accompanied by 100% visual inspection of the bending area to detect cracks early.

The implementation of all recommended quality control measures is expected to significantly reduce the RPN at all stages of the production process, thereby sustainably increasing the consistency of galvanized street lamp pole quality in Medan City.

CONCLUSION

Based on the results of the study on the application of the FMEA method to the quality control process of galvanized street lamp pole production in Medan City, the following conclusions can be drawn:

1. Eleven (11) potential failures were identified across six stages of the galvanized street lamp pole production process, including material receipt, cutting, bending, welding, galvanization, and final quality control. Each potential failure was analyzed based on its failure mode, effect, and cause, along with existing controls.
2. The Risk Priority Number (RPN) calculation results indicate that three potential failures are categorized as Top Priority: (a) welding defects—porosity, undercuts, incomplete fusion (RPN 315); (b) zinc coating

thickness below the minimum standard (RPN 288); and (c) defective products passing through to the shipping stage (RPN 280). The highest RPN value was obtained for the welding process, which also has the highest Severity value (S=9) because it directly affects the safety of product users.

3. Recommendations for quality control measures have been formulated for each potential priority failure, including developing SOPs, implementing a welder certification program, conducting batch zinc thickness testing, and periodically calibrating measuring instruments, along with a standardized inspection checklist. Implementation of these recommendations is expected to reduce the RPN and improve product quality consistency significantly.

SUGGESTION

Based on the research conclusions, several suggestions are put forward as follows:

1. Street lamp pole fabrication industry players in Medan City are advised to immediately follow up on recommendations for quality control measures arising from this research, prioritizing welding and galvanization processes as the most critical areas based on the RPN values.
2. The prepared FMEA worksheet should be used as a living quality control document, updated regularly in line with changes in the production process or the emergence of new potential failures.
3. Further research is recommended to verify the RPN value after implementing control measures and to assess the recommendations' effectiveness quantitatively.
4. Companies are advised to use this FMEA worksheet as a foundation in preparing to implement the ISO 9001:2015 Quality Management System in stages.

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