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İSTANBUL OKANUNIVERSITY

FACULTY OF ENGINEERINGAND NATURAL SCIENCES

DEPARTMENT OF INDUSTRIAL ENGINEERING

PROJECT NAME

Analyzing the Defects in Production Lines with FMEA Method and Making Investigations for These Defects

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İSTANBUL

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"As required by academic rules and ethicalprinciples, I have explicitly cited the sources of all material that does not originate from thisstudy; all information used in this project was gathered andpresented in compliance with these guidelines."

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SUMMARY

GRADUATION PROJECT

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Analyzing the Defects in Production Lines with FMEA Method and Making Investigations for These Defects

Using the Failure Modes and Effects Analysis (FMEA) method, this graduation project seeks to discover, evaluate, and rank possible failure modes in a production line. This study, which was carried out in an automation firm that supplies OEMs, focuses on the assembly, welding, and painting lines—all of which are essential to serial manufacturing.

The objective of this project is to reduce production risks, improve product quality, and increase operational efficiency by identifying and rating possible defects using the Risk Priority Number (RPN). The methodology is supported by a review of the literature and on-site observations. The findings highlight important mistakes as well as suggestions for avoidance.

Keywords:

FMEA, Production Line, Risk Assessment, Failure Mode, RPN, Quality Improvement, Automation

ACKNOWLEDGMENT

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I also want to express my gratitude to the technical team and management of the automation company where this study was carried out for granting on-site observations and access to real-world data. This study was useful and applicable because of their participation and openness.

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1) Introduction

Businesses are constantly under pressure to improve productivity, cut waste, and produce high-quality goods in the cutthroat industrial environment of today. FMEA, or Failure Modes and Effects Analysis, is a proactive technique for identifying, assessing, and averting possible failures in production systems among the many tools used in quality and risk management. Two senior Industrial Engineering students planned and carried out this study with the goal of using FMEA as a practical tool that is directly integrated into actual factory operations rather than as a theoretical concept.

Our graduation project involved close collaboration with an automation company that supplies major Original Equipment Manufacturers (OEMs). This gave us the opportunity to watch live production processes, spot real or possible failure modes, and determine Risk Priority Numbers (RPNs), which rank risks according to their detection, occurrence, and severity. In addition to identifying important risks, our study sought to suggest preventive measures that would raise overall production quality, safety, and cost effectiveness.

In this thesis, we all aimed to close the gap between scholarly research and practical industrial use. We created an organized FMEA model tailored to the business's production lines by carrying out field research, reviewing relevant literature, and making firsthand observations. We think this strategy benefits the business and improves our abilities as aspiring industrial engineers.

1.1) Objective of Study

The main objective of this study is to identify and evaluate potential errors in an automation company's production process using the FMEA methodology. By determining the Risk Priority Number (RPN) for each failure mode, the goal is to recommend corrective actions that will reduce risk, boost productivity, and maintain product quality at the desired levels.

1.2) Scope of Study

The welding, assembly, and painting lines of a specific automation company's production lines are the only ones included in this study. Only the mechanical and operational problems observed on the job site were considered. The scope did not include human error, environmental effects, or issues with outside supplies.

1.3) Significance of Study

FMEAiswidely used in the automotive and aerospace industries. By applying this method in an actualfactory, this study bridges the gap between theory and practice. It facilitates early risk detection, which saves time and money in mass production. It's also critical to offer specificremediation methods to lower elevated RPN scores.

1.4) Statement of Problem

Despite greater automation, undetected or recurrent failures still occur on manufacturing lines. These errors lead to production delays, quality issues, and monetary loss. This project aims to address the lack of a systematic method for identifying and prioritizing risks before they actually fail.

2) System Study & Analysis

2.1) Principles of System Analysis

System analysis comprises a systematic evaluation of the production steps to identify inputs, processes, and outputs. In this study, each workstation is inspected to determine possible failure mechanisms and their locations. Emphasis is placed on comprehending the function of each line and the interaction between human operators and machines.

2.2) Existing System with Limitations

The current system uses standard automated lines for assembly, welding, and painting. However, the company lacks a systematic approach to error prevention. Most failures are remedied after flaws are discovered. Ineffective resource allocation and troubleshooting are the results of inadequate risk prioritization and documentation.

3) Requirements Specification

The current system uses standard automated lines for assembly, welding, and painting. However, the company lacks a systematic approach to error prevention. Most failures are remedied after flaws are discovered. Ineffective resource allocation and troubleshooting are the results of inadequate risk prioritization and documentation.

3.1) Hardware Requirements

In addition to the standard equipment that the company already uses, such as: • Inspection tools (micrometers, calipers, torque meters); • Production line machinery (welding robots, assembly units, paint booths); and

•No extra physical hardware was required because this study was carried out in an actual factory environment.

•Computers that record failure data and compute RPNs

3.2) Software Requirements

The software tools listed below were employed for analysis and documentation:

•SolidWorks (indirectly): For data visualization, RPN value computation, and FMEA table generation;

•To understand technical drawings and station components, use Microsoft Excel.

•PDF Reader: For reading academic publications and related literatüre

4) Project System Modules or Components

This project was finished by following a set of systematic steps designed to apply the FMEA method in a real-world production environment. The study began with a review of the literature, which helped us understand how FMEA has been used in various industries and provided a theoretical foundation for our own application.

After gaining sufficient background information, we observed welding, assembly, and painting processes while conducting fieldwork in an automation company. These results were supported by technical staff interviews, which enabled us to identify failure modes that could affect product quality or process flow.

Using the collected data, we created an extensive FMEA table. For each failure, we assigned values for Severity, Occurrence, and Detection and calculated the Risk Priority Number (RPN). This allowed us to focus on the most critical issues and prioritize risks.

Based on the RPN results, we recommended corrective actions like operator training, error-proofing strategies, and control system adjustments. Every recommendation was developed with consideration for the production environment, considering its feasibility and effectiveness.

By employing a modular and systematic approach, we ensured that every stage of the project—from theory to analysis—was rational, practical, and in accordance with real industrial needs.

4.1) Component-1: Literature Review and Theoretical Background

During this stage, scholarly and commercial publications about the FMEA approach were gathered. The computation of RPN scores and how they influence risk prioritization were the main topics of discussion. We reviewed the works of Ülgü et al. (2024), Zeng et al. (2010), and Chen (2007).

4.2 Component-2: On-site Observation and Failure Detection

To examine procedures and document failure modes, several plant visits were conducted. Failures were grouped according to the line (welding, assembly, etc.) and how they affected output.

4.3 Component-3: FMEA Table Creation and RPN Calculation

A table for FMEA was created. Severity (S), Occurrence (O), and Detection (D) were used to rate each failure. The following formula was used to determine the RPN values:

$RPN = S \times O \times D$

4.4 Component-4: Risk Evaluation and Prioritization

RPN scores were used to rank the hazards into three categories: Low (needing periodic review), Medium (needing monitoring), and High (needing prompt action)

4.5 Component-5: Suggestions and Reporting

For high RPN failures, practical suggestions were offered, such as design revision, operator training, and preventive maintenance.

5) Description and Evaluation of the Proposed System

The study's suggested strategy is predicated on the methodical use of Failure Modes and Effects Analysis (FMEA) to pinpoint and minimize production line hazards for an automated business. This strategy avoids the usage of reactive techniques by proactively identifying possible failures and evaluating their effects prior to production disruption.

By using the FMEA method, we were able to analyze processes in detail and carefully assess each possible failure using three criteria: detection, occurrence, and severity. We were able to rank the failure modes according to criticality by using this scoring process to determine the Risk Priority Number (RPN) for each failure mode.

Based on this assessment, we found that the riveting and final check procedures had the most risks due to the possibility of measurement errors and part mismatches. In addition to identifying these hazards, the suggested system served as the foundation for recommendations of workable remedial measures, including the addition of error-proofing devices, increased setup precision, and reinforced control systems.

The suggested methodology provides a more preventive and data-driven approach than the current system, which tended to handle problems after they arose. It fosters a culture of continuous improvement, improves communication between the production and quality divisions, and strengthens decision-making.

As a result, the FMEA-based approach offers a precise framework for successfully prioritizing issues, controlling process dependability, and promoting long-term production efficiency.

5.1) Advantages of the Proposed System

•**Early risk detection:** Failures that were anticipated to occur but had not yet happened were noted.

•**Setting priorities for corrective actions**: By concentrating on high RPN failures, resources were distributed efficiently.

•**Better product quality:** Better output consistency was assured by lowering potential faults.

•**Cost savings:** Taking preventative action was less expensive than fixing problems as they happened.

•**Raised awareness:** Quality control and maintenance gained more attention from management and operators.

5.2) Disadvantages and Shortcomings of the Proposed System

•**Subjectivity in scoring:** Detection in particular was vulnerable to evaluator prejudice, as were other RPN components.
• **Needs frequent updates:** As production changes, the FMEA table needs to be updated on a regular basis.
•**Limited scope:** Supplier-related problems and human factor errors were not included in the current analysis.

• **Difficulties with data collection:** Line staff did not always document all failures.

5.3 FMEA Table and RPN Evaluation

The automation company's production lines underwent a thorough Failure Modes and Effects Analysis (FMEA). Field observations and conversations with technical staff were used to get the data. Severity (SEV), Occurrence (OCC), and Detection (DET) were used to assess each failure mode, and the conventional formula was used to determine the Risk Priority Number (RPN):
RPN = SEV × OCC × DET

Process Step or Variable or Key Input	Potatial Failure Mode	Potancial Effect on Customer Because of Defect	SEV
Riveting Process	Incorrect preassembled sub assy with wrong rivet	Observance of legal and security rools not guaranteed	10
Riveting Process	Companents preassembled in wrong direction.	Customer annoyance because assembly not possible	6
Riveting Process	Wrong bracket type	Customer annoyance because assembly not possible	6
Riveting Process	Rivet heigt out of tolerance	Observance of legal and security rools not guaranteed	10
Riveting Process	Rivet heigt out of tolerance	Observance of legal and security rools not guaranteed	10
Final Check	Check not performed	Product not functional	10
Final Check	Barcode not readable	Scrap is too high	4
Final Check	Rivet heigt out of tolerance	Observance of legal and security rools not guaranteed	10
Labelling Process	Label is not printed	Customer annoyance because assembly not possible	6
Labelling Process	Label with wrong content printed	Customer annoyance because assembly not possible	6

Figure 1. Table of FMEA.

Potantial Causes	Preventive Action	OCC	Current Process Controls	DET	RPN
wrong rivet supplied to the line.	kamban system First part aproval	3	100% rivet height measurement before riveting	3	90
Companents not correct positioned pre-assembled	Standart work insuruction	4	Poka-Yoke nest in station Further assembly not-possible due 100% automatic inquries companent correct positioned present	2	48
Wrong bracket placed into the nest	kamban system Station startup procedure Poka-Yoke nest	2	Sensor check for presence of loweer bracket in the nest	2	24
Riveting distance is out of spec.	setup via scanning	4	measurement unit connected with station	3	120
Riveting force is out of spec.	setup via scanning	4	measurement unit connected with station	3	120
no execution of check	sequential programing of PLC according to process flow chart	2	machine acceptance with test trials and use of failure possiblty matrix	3	60
Scanner beam is covered by mechanical parts	Process release	3	PLC programme can not continue to flow	3	36
Riveting distance is out of spec.	setup via scanning	4	3D camera control with setup parameter	1	40
Label roll is wrong inserted into the machine	Sercical manual of printer and SWI	2	Check by scanner for readability and correct content	3	36
Incorrect comminication between PLC and printer	PLC controled process flow	2	Checking content with internal traceability system	2	24

Figure 2. Table of FMEA. (It is the continuation of the FMEA table, the order is the same, it is shown section by section because it will not fit on the page as a single whole.)

The topthree failure modes according to their RPN scores are listed below:

Process Step	**Failure Mode**	**RPN**
Riveting Process	Rivet height out of tolerance	120
Riveting Process	Rivet height out of tolerance (force-related)	120
Riveting Process	Incorrect preassembled sub-assy with wrong rivet	90

Observations:
•With several high-RPN failure mechanisms, the riveting process seems to be the most crucial station.

Rivet height failures can result in non-compliance with safety and legal requirements, raising thepossibility of recalls or unhappy customers. They are also extremely serious and challenging to identify before they affect the functionality of the finished product.

Suggested Actions:
•Equip riveting stations with sophisticated Poka-Yoke (error-proofing) systems.
•Increase the frequency of measuring system calibrations and implement notifications for tolerance violations.
•Enhance operator education about validations of station setup and routine work procedures.
•Use real-time sensor feedback to incorporate a redundant rivet height verification phase.

6) Justification of the Proposed System

The FMEA method's use in this project is justified by its ability to systematically identify and rank potential risks before they materialize into failures. Problems are usually fixed reactively, that is, after defects have already impacted quality or delivery, in many manufacturing environments. In contrast, FMEA provides a systematic approach that empowers teams to take proactive actions.

The factory we visited has production lines that must meet strict time and quality requirements. Any delay or missed mistake could affect the workflow overall. In processes like riveting and final checks, where measurement errors or part mismatches may lead to rework or customer complaints, the proposed method enables early identification of weak points.

By evaluating each failure mode based on its severity, likelihood, and detectability, the company can easily identify its most significant risks. Better resource allocation, quicker adoption of preventive measures, and more informed decision-making are all made possible by this.

All things considered, the system is a valuable tool for continuous industrial improvement because it provides a practical and expandable model that can be utilized in different factories or even other stations.

6.1) Input Specification

Field notes from assembly, painting, and welding lines. information gathered from operator comments regarding past failures. techniques for detecting, occurrence, and severity that are based on literature. Process flowcharts and technical drawings for improved failure visualization.

6.2) Output Specification

•RPN scores for every risk and their ranking; • Suggestions for remedial measures; • A comprehensive FMEA table containing all detected failure modes

•Determining which high-risk stations require immediate improvement

•A condensed report to aid in managerial decision-making

7) System Model (Unified Modeling Language - UML)

Simplified UML-style diagrams can be used to describe the logical flow of the FMEA approach for clarity and organized thought, even though this is not a software-based project.

7.1) Use Case Diagram

Actors: Quality Supervisor, Production Operator, and Industrial Engineer
Use cases include:
• Process observation

Determine the mode of failure; score SEV, OCC, and DET; compute RPN; suggest a remedy; and keep an eye on the modified procedure.

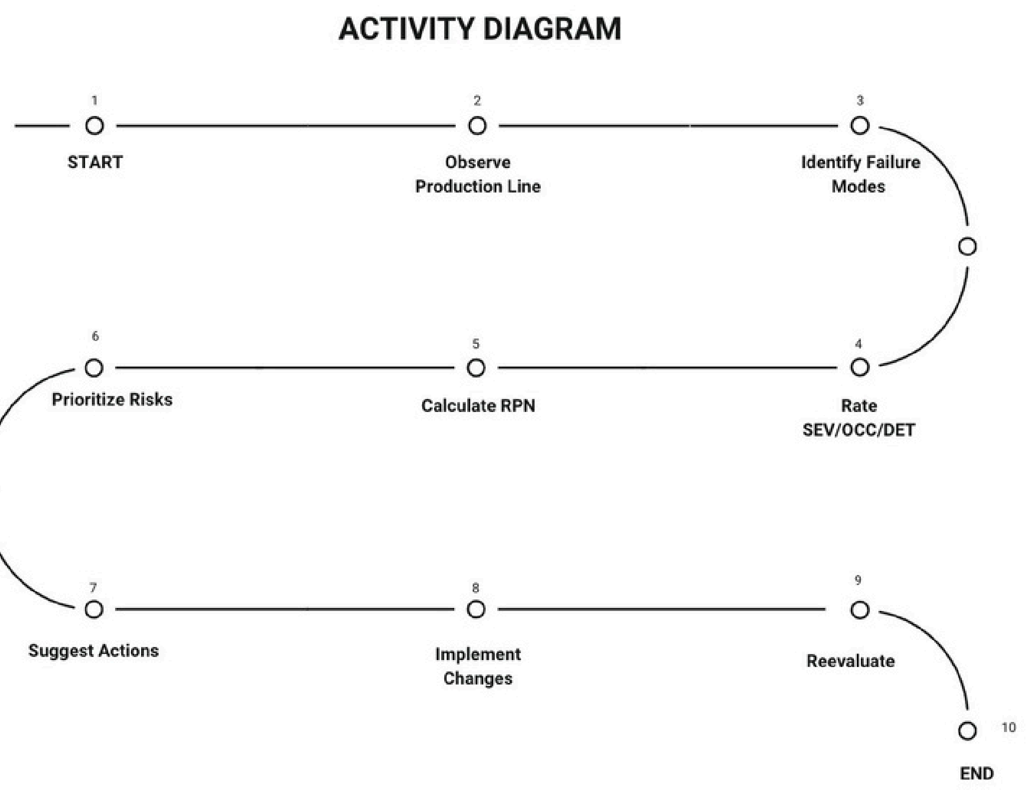

Figure 3. Use Activity Diagram of System.

7.2) Activity Diagrams

The activity diagram created for this project shows the logical order of steps followed when using the FMEA approach. The first step is to choose which manufacturing process will be studied, and then it moves progressively through risk assessment, monitoring, failure detection, and prioritization.

Every effort is made to ensure that potential failure modes are not only identified but also assessed based on their detectability, frequency, and severity. After RPN values are calculated, critical hazards are identified and related improvement measures are recommended.

This figure illustrates the continuous improvement philosophy and shows how a methodical approach such as FMEA may guide decision-making in real-world industrial settings. As the system is reassessed to verify improvements and ensure sustainability after corrective actions, italso illustrates the process's cyclical nature.

7.3) System and Program Flowchart

The flowchart made for this project illustrates the sequential reasoning and decision-making framework that underpin the application of the FMEA method within the selected production line. It serves as a guide for understanding how potential hazards are identified, analyzed, and managed throughout the system.

At the beginning of the process, a specific production area, such as the riveting or final control station, is observed. Engineers and observers work together to identify possible failure modes based on equipment behavior, quality issues, or past experiences. When failures are discovered, their effects and root causes are carefully examined.

Each failure is then evaluated according to three main criteria: occurrence (the probability that the issue will occur), severity (the gravity of the impact), and detection (the ease or difficulty of identifying the issue before it affects the customer). These values are then multiplied to determine the RPN, which determines the risk's priority level.

An important place in the flowchart is the decision node where the RPN is assessed. If the calculated RPN exceeds a predefined threshold (e.g., 80), the failure mode is considered high risk and must be addressed immediately. At this stage, appropriate preventive or corrective actions are recommended, such as improvements to sensors, operator training, or equipment modifications.

Another decision point is evaluating the suggested remedy's viability. If the activity is judged suitable and effective in the current production environment, it is added to the action plan. If not, a new strategy for improvement is developed.

After the corrective actions are put into place, the system is reevaluated to ascertain the intervention's effectiveness. This ensures that the process remains adaptable and dynamic, allowing for continuous improvement in quality.

In addition to highlighting the structured nature of FMEA, the flowchart emphasizes the importance of feedback and adaptation in industrial engineering applications. By applying this logic model, organizations can reduce process risks, improve overall operational efficiency, and make well-informed decisions.

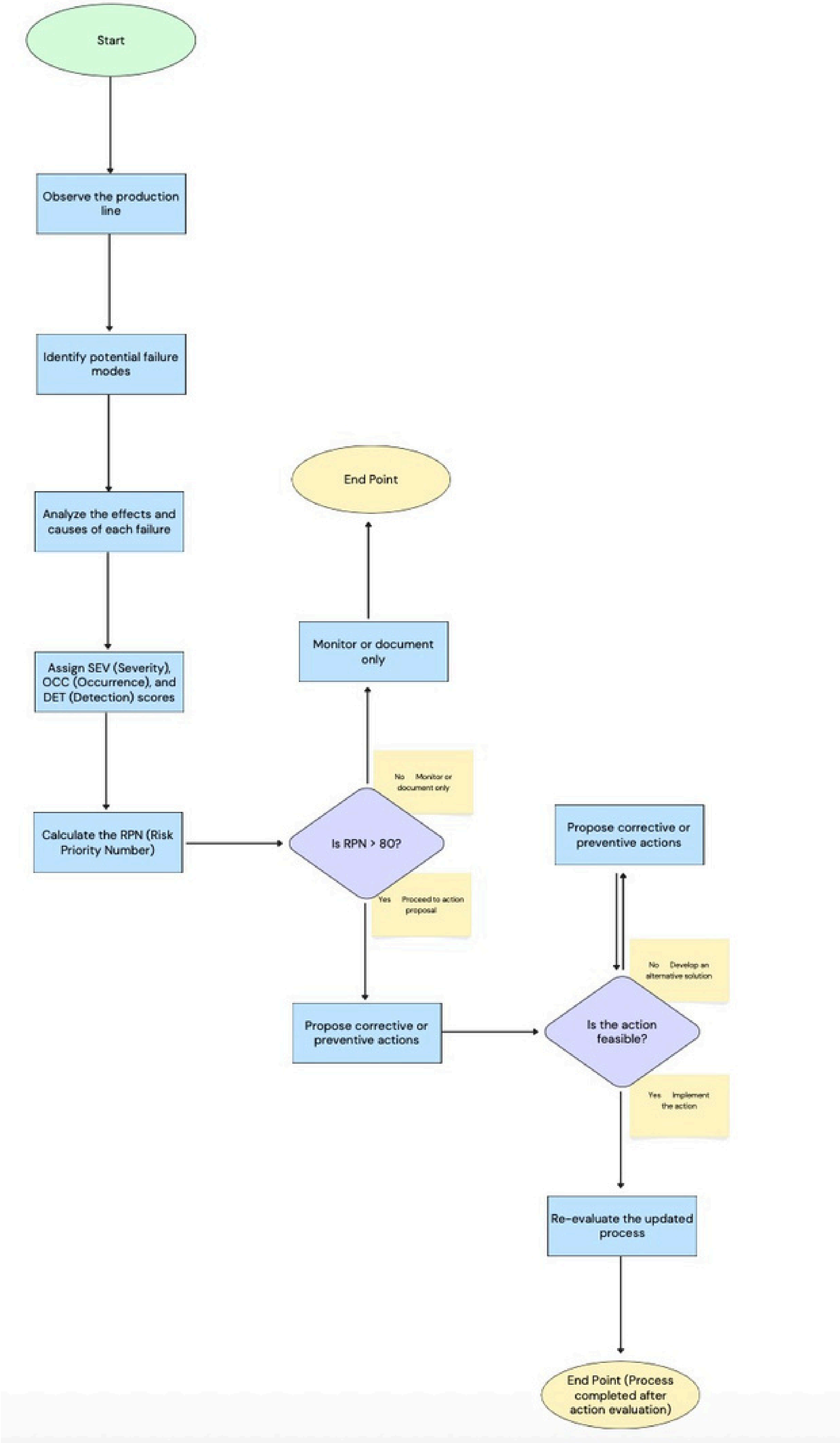

Figure 4. FLOWCHART Diagram of System.

Flowchart Design Conventions

The common forms and components of flowchart diagrams are described in this section along with their intended implications in process modeling. When visualizing procedural logic, these norms aid in ensuring readability, consistency, and clarity.

1. Initial Action (Green Oval) represents the process's beginning point. This form is where every flowchart starts. It starts the series of actions to be taken and usually has a single incoming path.

2. The Next Step (blue rectangle) denotes a task or process activity that needs to be carried out. This form, which is most frequently used in flowcharts, denotes operational processes like data entry, observations, and assessments.

3. The Purple Diamond, or Decision Point
used when a conditional decision or assessment is necessary for the flow. A question with two or more possible responses (such as Yes/No) is represented by a diamond shape, and based on the answer, several process pathways may follow.

4. End Point (Yellow Oval): Indicates where a particular process flow ends. The related task or choice is finished once this shape is attained. To indicate closure, each flow should lead to an end point.

5. Yellow Box Sticky Notes
These are optional components that can be used to add more remarks, explanations, or reminders. Although they are not a part of the actual flow, they aid in making particular decisions or stages easier to understand.

6. Attachments (Arrows)
Arrows demonstrate the process flow's direction and the connections between the steps.
The standard directional flow from one step to the next is represented by a single arrow.
• ↔ Double arrow: Denotes feedback loops or bidirectional flow.
In order to preserve readability, connectors should always have a clear path and refrain from overlapping other shapes.

7.4) Sequence Diagram

The sequencediagram made for this project illustrates the chronological interactions between differentrolesand functional aspects during the application of the FMEA method. Instead of focusingonasoftware-based solution, this figure depicts the real-world interactions that take placebetweenprocess observers, engineers, and decision-makers during the risk assessment workflow.
Theprimaryparticipants (also known as "actors") in the sequence diagram are as follows:

•ProcessObserver: Responsible for monitoring and recording production line operations.

•FailureAnalyst: Evaluates the characteristics of identified failure modes.

•QualityEngineer: Assigns SEV, OCC, and DET scores and takes part in risk prioritization.

•DecisionMaker: Reviews calculated RPN values and initiates remedial action if required.

Thediagramshows the following chronological interaction:

1.TheProcessObserver begins by monitoring the production line and identifying potential issues.
2.Afterreceiving the observation, the Failure Analyst investigates the potential causes and effects.
3.TheQualityEngineer evaluates the occurrence, severity, and detection levels of the failure modeafterobtaining this data.
4.Thecalculated RPN value is sent to the decision maker.
5.IftheRPNexceeds a predetermined threshold (e.g., 80), the Decision Maker requests that theQualityEngineer recommend appropriate corrective or preventive actions.
6.Aftertheaction plan is finished, the process is reevaluated to see if the risk level has dropped.
7.Thecycleiscomplete, and if the updated condition is satisfactory, it is noted.

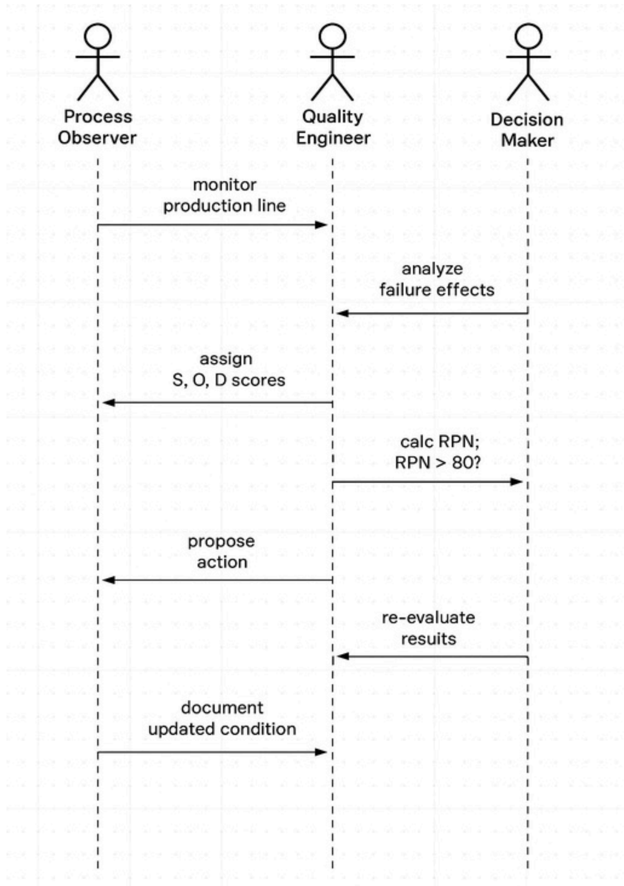

Figure 5. Sequence Diagram of System.

7.5) Class Diagram

Class diagrams are typically used in software development, but they can also be used to show the characteristics and interactions between parts of a production system. To illustrate the key players in the FMEA process and their relationships, the class diagram was modified for this project. The main class in this figure is called "Failure Mode," and it is linked to several characteristics, including severity, occurrence, detection, and computed RPN. Other auxiliary classes like "Production Process," "Root Cause," and "Control Measures" are linked to it.
Every form of failure has a specific production stage, one or more causes, and corresponding preventive measures.
This framework makes it easier to see how every failure is methodically examined and how remedial measures are determined. It also illustrates how FMEA is modular, allowing data to be updated, expanded, or reused across other product lines or process steps.

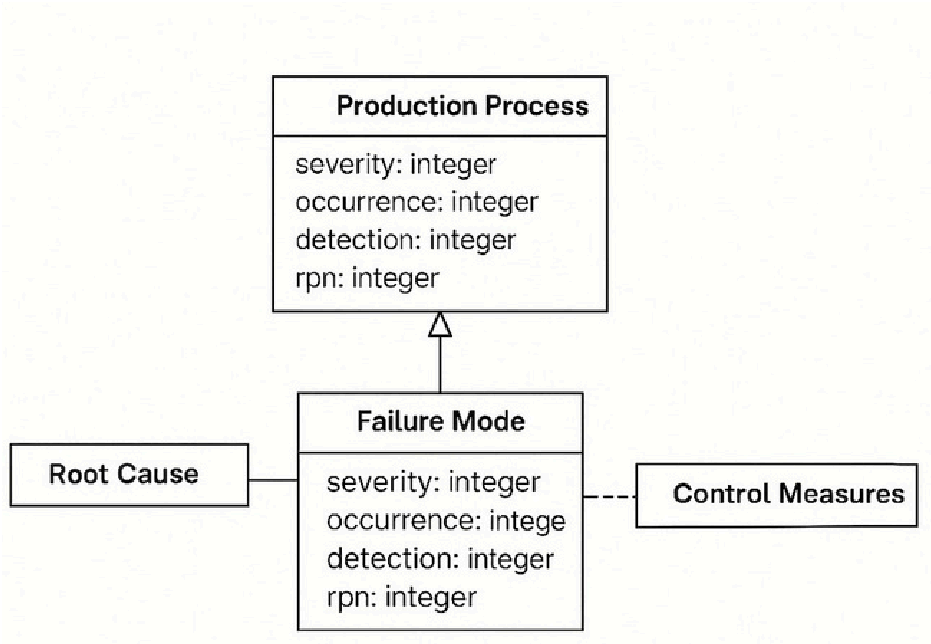

Figure 6. Class Diagram.

7.6) Component Diagram

The main functional components of the FMEA-based analysis system were depicted in this project using a modified component diagram. The graphic highlights the primary functional elements utilized throughout the FMEA process in place of software modules:
Field research, operator input, and visual inspections are all part of the Observation & Data Collection Module.
Each failure mode, its cause, and its possible impact are categorized and described by the Failure Analysis Module.

The scoring and evaluation module is in charge of determining RPN and allocating SEV, OCC, and DET scores.

- Decision Module: Assesses the risk's priority by comparing RPN readings to thresholds.
- Action Planning Module: Creates workable preventative and remedial strategies.
- Review & Monitoring Module: Used to reassess the procedure following the implementation of actions.

Through a structured information flow, each of these elements interacts with the others to guarantee that judgments about improvement and risk assessment are consistent and data-driven.

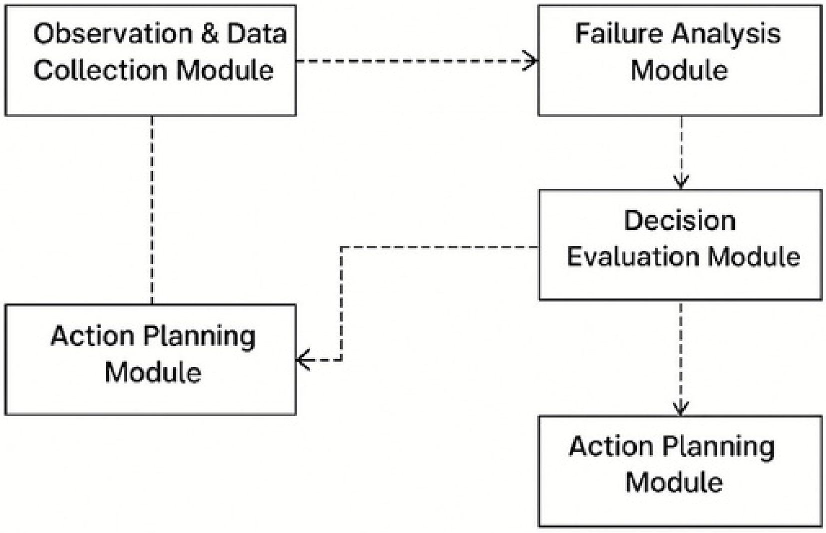

Figure 7. Component Diagram.

7.7 Optional – System Flow or Integration Note

Although it isn't a required component of every FMEA report, we thought it was helpful to include information about how the risk management system interacts with the larger production environment. Several important industrial systems are integrated with the FMEA workflow:

- Quality Assurance System: Root cause analysis and quality audits are supported by FMEA.
- Production Scheduling System: Reallocating resources or planning downtime may be necessary for preventive measures.
- Training & SOP System: Standard operating procedures are frequently updated in response to high-risk failure scenarios.
- Data Logging Tools: For trend analysis and traceability, scores, causes, and actions can be digitalized.

This integrative viewpoint guarantees that the FMEA procedure is not isolated but rather makes a significant contribution to the business's ongoing attempts at development.

8) Choice and Justification of Programming Language Used

Risk identification and prioritization are crucial for industrial production processes to maintain consistent product quality and operational efficiency. As a result, we chose to base our capstone project on the Failure Modes and Effects Analysis (FMEA) methodology. This method was selected after a careful comparison with other risk assessment tools, such as fault tree analysis (FTA), Pareto analysis, and statistical process control techniques.

The structured and preventive approach of FMEA distinguishes it from other methodologies in that it allows us to evaluate potential failure modes before they result in real production issues. It is also one of the most widely accepted risk analysis methods in manufacturing sectors like electronics, automotive, and aviation. Its systematic framework maintains evaluation uniformity while providing flexibility in different production settings.

Our choice was also influenced by the FMEA's quantitative scoring system, which allowed us to assign numerical values to the three components of risk: detection, occurrence, and severity. These ratings were used in part to calculate the Risk Priority Number (RPN), a numerical measure that compares the criticality of failure modes. This made it easier to rank issues using objective criteria rather than relying solely on anecdotal evidence or expert opinions.

In our case, the automation company's manufacturing line included a complex mix of mechanical processes, including final control, assembly, and riveting. During these phases, tolerance deviations, alignment issues, and sensor failures are typical and often difficult to identify without a comprehensive risk analysis system. Thanks to FMEA, we were able to foresee these weak points and offer targeted corrective actions based on RPN criteria.

The system also encouraged cross-functional teamwork because it needed input from other departments, including engineering, quality control, and production. This interaction not only improved the accuracy of failure identification but also ensured that proposed fixes were feasible and grounded in real-world operational conditions.

To sum up, FMEA was selected for practical and strategic reasons. It not only provided the company with a scalable tool that could be utilized again for risk assessments in the future, but it also supported our academic goal of applying engineering methods to practical problems. Its structured style, ease of use, and ability to prioritize tasks based on data made it the best choice for our project.

9) Conclusion

The FMEA methodology was effectively used in this study to identify and rank possible flaws in a manufacturing setting that relies on automation. The riveting process was found to have the most significant risks, especially with relation to tolerance deviations and part misalignment.

A systematic improvement roadmap was developed using RPN analysis, and it included recommendations for training interventions, improved sensor integration, and poka-yoke applications. The results show how industrial engineering techniques can lead to actual operational benefits, in addition to providing support for the particular organization in question.

The business may greatly lower manufacturing risks, enhance product quality, and boost efficiency by methodically using FMEA.

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