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NPTEL ONLINE
CERTIFICATION COURSE

Failure Analysis and Prevention

Industrial Engineering Tools for FA: Failure Mode & Effect Analysis

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What Is A Failure Mode?

- **A Failure Mode** is:
 - The way in which the component, subassembly, product, input, or process can fail to perform its intended function
 - Things that can go wrong



Benefits of FMEA

- Methodology that facilitates process improvement
- Identifies and eliminates concerns early in the development of a process or design
- Focuses on prevention



Approach of FMEA

- A structured approach for :
 - Identifying the ways in which a product or process can fail
 - Estimating risk associated with specific causes
 - Prioritizing the actions that should be taken to reduce risk
 - Evaluating design validation plan (design FMEA) or current control plan (process FMEA)

When to Conduct an FMEA

- Investigation for the process improvement investigation
- Design of new systems, products, and processes
- Modification of existing designs or processes
- Existing designs for new applications



The FMEA Form

Process/Product Failure Modes and Effects Analysis Form (FMEA)

Prepared by: _____		Page ____ of ____	
FMEA Date (Orig): _____ (Rev): _____			

Prepared by: _____	Page ____ of ____		
FMEA Date (Orig): _____ (Rev): _____			

Process Step / Input	Potential Failure Mode	Potential Failure Effects	SEVERITY	Potential Causes	OCCURRENCE	Current Controls	DETECTION	RPN	Actions Recommended	Resp.	Actions Taken	SEVERITY	OCCURRENCE	DETECTION	RPN
What is the process step and input under investigation?	In what ways does the Key Input go wrong?	What is the impact on the Key Output Variables (Customer Requirements)?		What causes the Key Input to go wrong?		What are the existing controls and procedures (inspection and test) that prevent either the cause or the Failure Mode?			What are the actions for reducing the occurrence of the cause, or improving detection?		What are the completed actions taken with the recalculated RPN?				
								0							0
								0							0
								0							0
								0							0
								0							0

Identify failure modes and their effects

Identify causes of the failure modes and controls

Prioritize

Determine and assess actions

FMEA: A Team Tool

- A team approach is necessary.
- Team should be led by the Process Owner who is the responsible manufacturing engineer or technical person, or other similar individual familiar with FMEA.
- The following should be considered for team members:
 - Design Engineers
 - Process Engineers
 - Materials Suppliers
 - Customers
 - Operators
 - Reliability
 - Suppliers

FMEA Procedure

1. For each process input (start with high value inputs), determine the ways in which the input can go wrong (failure mode)
2. For each failure mode, determine effects
 - Select a severity level for each effect
3. Identify potential causes of each failure mode
 - Select an occurrence level for each cause
4. List current controls for each cause
 - Select a detection level for each cause

FMEA Procedure (Cont.)

5. Calculate the Risk Priority Number (RPN)
6. Develop recommended actions, assign responsible persons, and take actions
 - Give priority to high RPNs
 - MUST look at severities rated a 10
7. Assign the predicted severity, occurrence, and detection levels and compare RPNs



Severity, Occurrence, and Detection

- Severity
 - Importance of the effect on requirements
- Occurrence
 - Frequency with which a given cause occurs and creates failure modes (obtain from past data if possible)
- Detection
 - The ability of the current control scheme to detect (then prevent) a given cause (may be difficult to estimate early in process operations).



Rating Scales

- There are a wide variety of scoring “anchors”, both quantitative or qualitative
- Two types of scales are 1-5 or 1-10
- The 1-5 scale makes it easier for the teams to decide on scores
- The 1-10 scale may allow for better precision in estimates and a wide variation in scores (most common)

Rating Scales

- Severity
 - 1 = Not Severe, 10 = Very Severe
- Occurrence
 - 1 = Not Likely, 10 = Very Likely
- Detection
 - 1 = Easy to Detect, 10 = Not easy to Detect

Risk Priority Number (RPN)

- RPN is the product of the severity, occurrence, and detection scores.

$$\text{Severity} \times \text{Occurrence} \times \text{Detection} = \text{RPN}$$

The following detection ranking may be used:

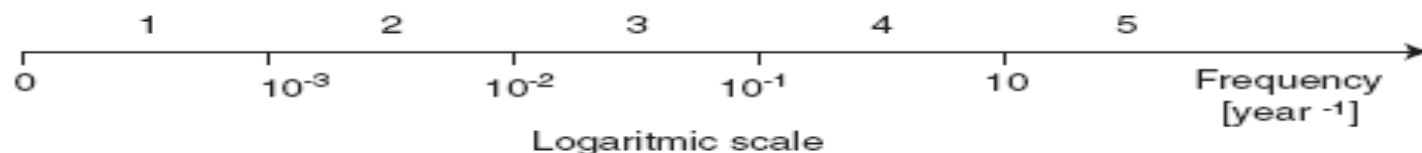
Rank	Description
1-2	Very high probability that the defect will be detected. Verification and/or controls will almost certainly detect the existence of a deficiency or defect.
3-4	High probability that the defect will be detected. Verification and/or controls have a good chance of detecting the existence of a deficiency/defect.
5-7	Moderate probability that the defect will be detected. Verification and/or controls are likely to detect the existence of a deficiency or defect.
8-9	Low probability that the defect will be detected. Verification and/or control not likely to detect the existence of a deficiency or defect.
10	Very low (or zero) probability that the defect will be detected. Verification and/or controls will not or cannot detect the existence of a deficiency/defect.

– Source: SEMATEC (1992)



Classification of occurrence:

1	Very unlikely	Once per 1000 years or more seldom
2	Remote	Once per 100 years
3	Occasional	Once per 10 years
4	Probable	Once per year
5	Frequent	Once per month or more often



The following severity classes for health and safety effects are sometimes adopted:

Rank	Severity class	Description
10	Catastrophic	Failure results in major injury or death of personnel.
7-9	Critical	Failure results in minor injury to personnel, personnel exposure to harmful chemicals or radiation, or fire or a release of chemical to the environment.
4-6	Major	Failure results in a low level of exposure to personnel, or activates facility alarm system.
1-3	Minor	Failure results in minor system damage but does not cause injury to personnel, allow any kind of exposure to operational or service personnel or allow any release of chemicals into the environment



In some application the following severity classes are used

Rank	Description
10	Failure will result in major customer dissatisfaction and cause non-system operation or non-compliance with government regulations.
8-9	Failure will result in high degree of customer dissatisfaction and cause non-functionality of system.
6-7	Failure will result in customer dissatisfaction and annoyance and/or deterioration of part of system performance.
3-5	Failure will result in slight customer annoyance and/or slight deterioration of part of system performance.
1-2	Failure is of such minor nature that the customer (internal or external) will probably not detect the failure.

– Source: SEMATECH (1992)



FAILURE MODE & EFFECTS ANALYSIS (FMEA)

Process Name: Left Front Seat Belt Install

Failure Mode	A) Severity Rate 1-10 10 = Most Severe	B) Probability of Occurrence Rate 1-10 10 = Highest Probability	C) Probability of Detection Rate 1 - 10 10 = Lowest Probability	Risk Preference Number (RPN) $A \times B \times C$
1) Select Wrong Color Seat Belt	5	4	3	60
2) Seat Belt Bolt Not Fully Tightened	9	2	8	144
3) Trim Cover Clip Misaligned	2	3	4	24

Process Step	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Classification	Potential Cause(s) of Failure	Occurrence	Current Process Controls Preventive	Current Process Controls Detection	Detection	RPN
Mixing the ingredients	Use less baking powder than specified - 45g	The bread don't rise enough	4							
Timing to bread past rise	Wait less than the necessary - 1h	The bread don't rise enough	4							
Baking the bread	Oven temperature higher than specified - 200 degrees Celcius	The bread burned	9	c						
	Oven time bigger than the specified in recipe - 1h		9	c						

Process Step	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Classification	Potential Cause(s) of Failure	Occurrence	Current Process Controls Preventive	Current Process Controls Detection	Detection	RPN
Mixing the ingredients	Use less baking powder than specified - 45g	The bread don't rise enough	4		The balance scale is not calibrated	1	Calibration program	Check the scale before use with master	2	8
Timing to bread past rise	Wait less than the necessary - 1h	The bread don't rise enough	4		There is no alarm clock in the kitchen	2	–	Visual check	8	64
Baking the bread	Oven temperature higher than specified - 200 degrees Celcius	The bread burned	9	c	The oven's pyrometer is not working	2	Calibration program	Visual check each 15 minutes	8	144
	Oven time bigger than the specified in recipe - 1h		9	c	There is no alarm clock in the kitchen	4	–	Visual check	8	288

Example: Worksheet for Air Bag

Part or Process Name Automotive Passenger Air Bag System						Suppliers & Parts Affected					
Design Mfg Responsibility						Model Date					
Other Areas Involved						Engineering Change Level					
Process Operation, Product Function or Purpose	Potential Failure Mode	Potential Effect(s) of Failure	S E V	C C	Potential Cause(s) of Failure	O C C	Current Controls Evaluation Method	D E T	S * O	R P N	Recommended Action(s)
Inflate Air Bag	Bag Does Not Open on Impact	Injure passenger	8	*	Sensor is not functioning properly	2	light to notify that system is malfunctioning	6	16	96	Add Redundant Sensor to monitor Impact
Restrain Passenger	Occupant Unable to Withstand Inflation Force	Injure Lightweight Passenger	8	*	passenger not wearing seat belt	4	none	10	32	320	1) Install switch which deactivates air bag system unless seat belt is worn
		Bruise passenger in crash	3		force regulator not working	2	repeatability tests in lab	3	6	18	2) consumer education of air bag system potential failures