

Using FMEAs (Failure Modes and Effects Analyses) to Assess Risk

Learn Why FMEAs Are a Preferred Tool of Reliability Professionals

FMEA/FMECAs (Failure Mode and Effects Analyses/Failure Mode, Effects, and Criticality Analyses) represent one of the most commonly used tools in reliability assessment programs. In a survey published by the Reliability Analysis Center¹ (RAC), 70% of respondents identified FMECA as one of the most important reliability tasks in use for reliability programs. Due to their flexible yet organized approach, it is easy to see why FMEAs are a tool of choice for many reliability professionals.

Because FMEAs can be approached and organized in a multitude of formats, they can easily be adapted to customer needs. Enabling the analyst to evaluate at a high level or at a very detailed level, FMEAs provide a valuable way to assess risk and to plan and organize an effective approach to address reliability issues. Additionally, FMEAs can be applied to a wide range of industries because they can be used to evaluate hardware systems, process control systems, and even human tasks in a *Human Factors Process FMEA*.

FMEAs are an easily understood and effective technique. In basic terms, FMEAs take a bottom-up approach to system analysis. The first step in the FMEA process is to break down a system or process into discrete elements. In the case of hardware, a system even as large as an airplane can be broken down into a number of assemblies or subsystems and ultimately into individual components. The level of hierarchical breakdown can be to any level desired by the analyst.

Once the breakdown is complete, the next step is to determine the ways in which each element could potentially fail. Then, each failure mode is evaluated independently, and a determination is made as to what the effect of that failure is at the current level, and then the resulting effect on the entire system. In the case of large, complex systems, such as an airplane, the overall analysis can become very large. In general, an approach on this scale will break the system down into smaller, manageable subsystems with different groups responsible for analyzing each subsystem. The results are then "rolled up" into the overall system level FMEA.

Therefore, the basic components of a FMEA consist of some type of hierarchical breakdown, an outlining of all possible **Failure Modes** of all elements, and then a determination of the **Effects** of these failure modes. The power in FMEAs is realized when this analysis is extended to include information relating to the risk of these potential system failures. *The idea is to be able to use a FMEA to assess which failure modes require effort to prevent, mitigate, detect, or ignore.* This assessment of criticality in a FMEA lays the groundwork for an organized approach to risk management. By using FMEAs to assign and categorize failure modes, the resulting categories can each have a defined plan of action. For example, high risk items must be flagged, and a plan to eliminate them formulated and deployed. Medium level items may require some type of detection mechanism to be designed. Low risk items perhaps require no action.

The issue then becomes how to adequately assess the risk levels of failure modes. There are some industry-adopted approaches to quantifying risk in FMEAs, as well as a number of user-defined approaches. Well-designed commercially available FMEA software will support any of these approaches to risk assessment. Four main approaches will be discussed here:

1. Mode Criticality
2. Risk Priority Numbers (RPN)
3. Criticality Rank

4. Risk Level

Mode Criticality

Mode criticality is one of the more quantified methods used to analyze criticality. Mode criticality is a numerical value that can be calculated and applied to each failure mode. Mode criticalities are based on a FMECA approach defined in MIL-STD-1629, a commonly used FMECA methodology. Applied more easily in a hardware environment, mode criticalities are based on actual failure rate values. For example, if the failure rate of a component of the system is established in some manner, the analyst then assigns a *mode percentage* to each possible failure mode of the component. For example, if a component has two failure modes, perhaps one occurs 75% of the time, and the other occurs 25% of the time. (There are databases available to automate this task. They offer lists of failure modes for components and their associated mode percentages.)

Using this information, a *mode failure rate* can be calculated by multiplying the failure rate by the mode percentage. The analyst must also assess the *failure effect probability*, or the probability that the given failure effect is likely to occur. The equation for mode criticality is given by:

Mode Criticality = Failure Effect Probability * Mode Failure Rate * Operating Time of the System

The results of all mode criticalities can then be sorted or grouped, and the analyst can pinpoint those items of high criticality that need to be addressed.

Risk Priority Number (RPN)

Risk Priority Numbers or RPNs are also numerical assessments of risk. RPNs are based on a FMEA approach adopted in FMEA methodologies such as those defined by SAE, AIAG, and Ford. RPN values range from 1 to 1000. To use RPNs, the analyst evaluates each failure mode and determines the *Severity*, *Occurrence*, and *Detection* level in each case. All three of these parameters are based on a 1-10 scale. A score of 10 indicates the most severe, most likely to occur, and least likely to be detected failure mode. The calculation of RPN is then defined as:

Risk Priority Number (RPN) = Severity * Occurrence * Detection

Because RPNs fall into a well-defined 1-1000 scale, analysts often break RPN values into various range levels. Items within the high risk range can then be addressed. Sometimes, a report of RPN values in a Pareto, color-coded format is useful.

**POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
(PROCESS FMEA)**

Item: Front Door L.H./NBHX-0005-A
 Model Year(s)/Vehicle(s): TSSX/Lion 4dr Wagon
 Process Responsibility: _____
 Core Team: _____



FMEA Number: _____
 Prepared By: _____
 FMEA Date (Orig.): _____ (Rev.) _____
 Key Date: _____

Process Function Requirements	Potential Failure Mode	Potential Effects of Failure	S	I	C	Potential Causes(s)/ Mechanisms of Failure	D	Current Process Controls	D	R	P	R	Recommended Actions	Responsibility & Target Completion Date	Action Results				
															Actions Taken	S	O	D	R
Manual application of wax inside door. To cover inner door, lower surfaces at minimum wax thickness to retard corrosion.	insufficient wax coverage of specified surface.	Deteriorated life of door leading to -unsatisfactory appearance due to rust through paint over time -impaired function of interior door hardware.	7	X		Manually inserted spray head not inserted far enough.	8	Visually check each hour - 1 limit for film thickness (depth meter) and coverage.	5	280			Acc positive depth stop to sprayer. Automate spraying.	Mfg. Engrg. 6X 10 15 Mfg. Engrg. 6X 12 15	Stop added, sprayer checked on line.	7	2	5	70
						Spray head clogged - viscosity too high - Temperature too low - Pressure too low	5	Test spray system at start-up and after idle periods, and preventive maintenance program to clean heads.	3	105	Use Design of Experiments (DOE) on viscosity vs temperature vs pressure.	Mfg. Engrg. 6X 10 01	Temp and press limits were determined and limit controls have been installed - control charts - show process is in control. Cpk = 1.55	7	1	3	21		
						Spray head performed due to impact.	2	Preventive maintenance programs to maintain head.	2	25	None								
						Spray time insufficient	8	Operator instructions and/or ramping (no doors / shift) to check for coverage of critical areas.	7	392	install spray timer.	Mfg. Engrg. 6X 08 15	Automatic spray timer installed - operator starts spray; timer controls shut-off-control charts - show process is in control. Cpk = 2.05	7	1	7	49		

Figure 1: Example FMEA Report Showing High RPN Values in Red

Criticality Rank

Criticality rank is an approach described in the SAE FMEA 5580 document. Criticality ranking provides a systematic way to rank failure modes. The criticality rank is a value based on a multi-criterion, Pareto ranking system. Failure modes are assessed by the analyst in terms of severity and probability of occurrence. The actual weighting scale used for these values can be set by the user or be based on industry-accepted scales. Criticality rank is defined by going through all failure modes, finding *non-dominated* failure modes, or failure modes that are not outranked in terms of severity or probability of occurrence. The first set of non-dominated failure modes is assigned a rank of 1, and then the next level of non-dominated modes is assigned a rank of 2. This procedure continues until all failure modes have been ranked. Once again, the result is a categorized breakdown of failure modes based on risk.

Risk Level

Lastly, a risk level assessment technique is introduced in the book *FMEA - Failure Modes & Effect Analysis - Predicting & Preventing Problems Before They Occur* by Paul Palady. This approach allows the analyst to group failure modes into established categories to ensure that the most critical items are evaluated. A graphical representation is used, where the x axis is a specified risk value such as severity. The y axis is a secondary risk factor such as occurrence. The graph is broken into three distinct areas by lines that intersect both axes. By then graphing each failure mode, they will fall into one of the three graph areas: high, medium, or low.

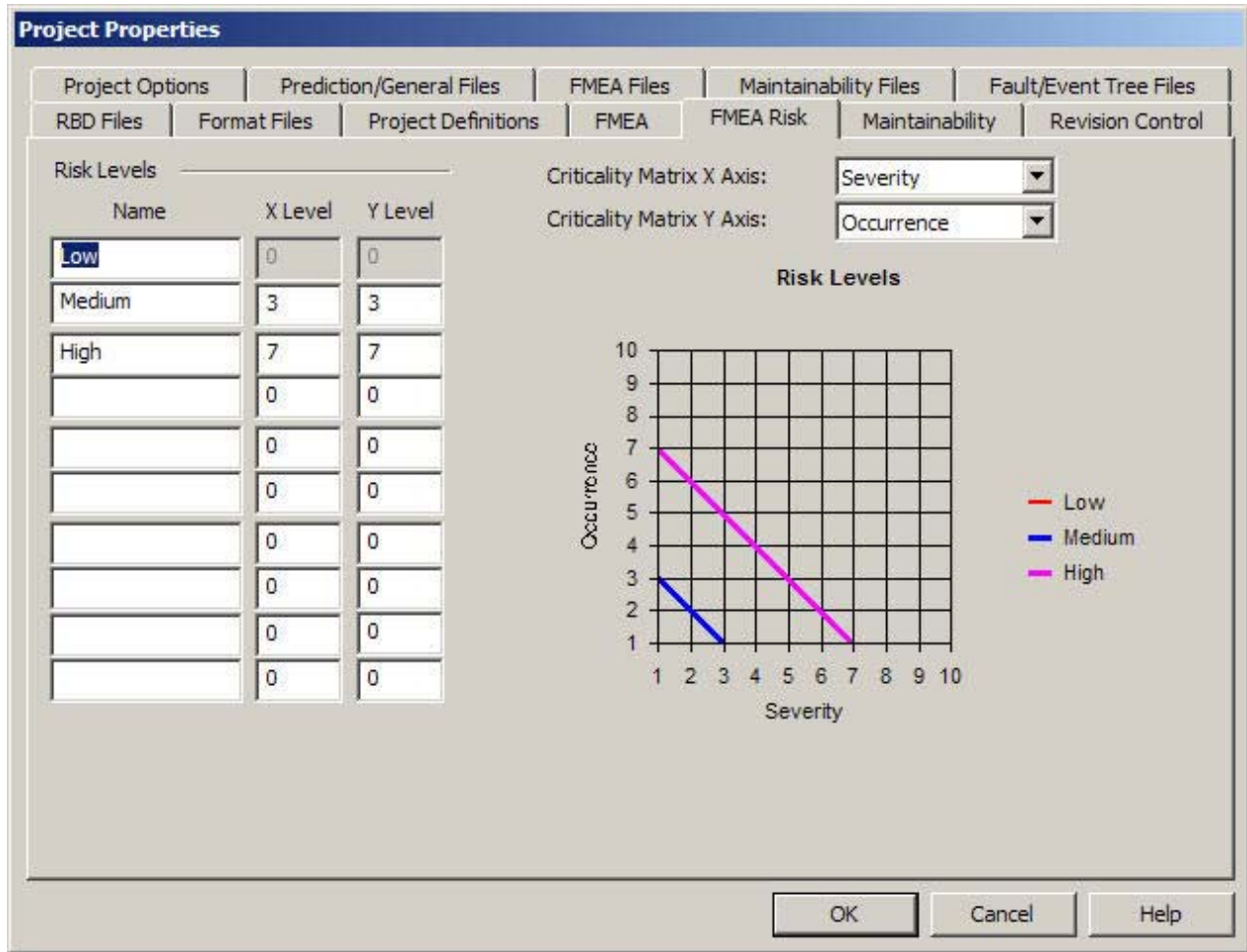


Figure 2: Defining FMEA Risk Levels Using the Risk Level Approach

Conclusion

Each technique has advantages, and a combination of approaches may be used as well. All methods feature a way to allow the FMEA analyst to gather failure mode information to ensure that the most significant failure modes are addressed. By using the organized framework of a FMEA to perform this assessment, you can have confidence that risk areas have been evaluated and quantified.

If you would like additional information about FMEAs and the risk assessment methods implemented in Relex FMEA, please e-mail info@relexsoftware.com.

¹The Reliability Analysis Center (RAC) is a Department of Defense (DoD) chartered Information Analysis Center (IAC) sponsored by the Defense Technical Information Center (DTIC), the central facility for the collection and dissemination of scientific and technical information for the U.S. Department of Defense.