Prioritizing the Risk Priority Numbers in FMECA – A Heuristic Approach

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**ABSTRACT:**

Risk management is one of the most important fields that diagnose hazards and traces by the application of various tools available. In any mines or industries it is necessary to estimate and predict the risk associated with the components/equipment or machineries in order to avoid the loss/damage. One of the tools often used for assessing the risk is Failure Mode Effect and Criticality Analysis (FMECA) which addresses causes, effects and risk of each failure mode. Risk priority number(RPN) evaluates the risk associated with each failure mode, which is obtained by the multiple of severity, occurrence and detection rankings. It is very convenient to point out the failure mode with the highest risk if the values of RPN are different. However, it is very difficult to come to a decision if the entire failure modes have the identical values of RPN. This is the major drawback that was found during FMECA analysis. This paper proposes a new methodology to overcome the drawbacks that was found in traditional FMECA.

***Key Words: RPN, FMECA, Failure Mode, Criticality, Severity, Occurrence, Detection.***

# **Introduction**

Failure Mode and Effects Analysis, known as FMEA in short, was later developed as Failure Modes, Effects, and Criticality Analysis, known as FMECA in short. FMECA is used to identify all the failure modes in a system design. The primary objective of FMECA is to determine the features of product design, production or operation and distribution that are critical to the various modes of failure, in order to reduce failure. It is also intended to identify all catastrophic and critical failure probabilities so that they can be minimized at the earliest. Hence, FMECA should be started as soon as the preliminary design information is available and investigation should be extended as more information is made available in suspected problem areas. [1]

FMEA and FMECA are methodologies designed to identify potential failure modes for a product or process, to assess the risk associated with those failure modes, to rank the issues in terms of importance, and to identify and carry out corrective actions to address the most serious concerns. Although the purpose, terminology, and other details can vary according to type (for example, Process FMEA, Design FMEA, etc.), the basic methodology is similar for all.The FMECA process will address all the problems concerning design, manufacturing, process, safety, and environment. The consequences of these problems are addressed in the stage of studying the failure mode during FMECA. Preventive measures for failures should always be given top priority where an individual’s well-being in the work place is concerned. FMECA uses all the available experience, from design, technology, purchasing, production/operation, to distribution, marketing, service, etc., to identify the importance levels or criticality of potential problems and simulate action toreduce these levels. FMECA should be a major consideration at thedesignstate ofa productor service. FMECA can be applied to any stage of design, development, production/operation or usage, but since its main aim is to prevent failure, it is most suitablyapplied at the design stage to identify and eliminate causes. Design FMEA and Process FMEA are discussed and a brief comparative study has been made. However, with more complex product or service systems, it can be appropriate to consider these as smaller units or subsystems, each one being the subject of a separate FMECA. [2]

# **Literature review**

**Xiaoqing Cheng et al. (2013) [4]** analysed the reliability of metro door system using FMECA. Initially, a statistical view was made for the various failed door components and sorted the components of major failure. Among various door components, EDCU was failed for 138 times in a period of 18 months. A total of 443 failures were occurred which includes door closing limit, nut component, EDCU and portable mast mounting that occupies 67% of total failures. Further they carried out the criticality analysis to evaluate the risk of each failure mode. After analysing all the failure modes through FMECA, it was concluded that the criticality of EDCU and door closing limit have greater criticality than others and major concerned has be to done for these critical failures in the maintenance operations. **D. Ćatić et al. (2014) [5]** studied the failure causes of drum brakes of a motor vehicle and analysed the criticality. They started analysing the failure causes using fault tree analysis (FTA). Further they carried out the criticality analysis for the drum brake elements for a 28 different failure modes. The results showed that the worn of brake shoe’s has the highest criticality followed by failure modes of drum.**R.S. Mhetre & R.J.Dhake (2012) [6]** have conducted a case study in a medium scaled company which manufactures precision sheet metal parts. For the production of metal parts various machinery like CNC press brakes, CNC laser cutting, CNC punching were used. Authors aimed to enhance reliability by reducing errors and shorten the development duration using tools like FMECA and ishikawa diagram. Authors carried out a case study based on the complaints received from the customers and the complaints were fitment problem with mating part, aesthetically poor and cracks. Customer complaints were observed to be 87 out of 211 for bending workstation. The root cause analysis showed that incorrect setting, lack of maintenance and raw material variation. The highest RPN was found as 480 for blank not resting properly in failure mode. Finally they have concluded that by following a standard set-up procedure set-up time will be reduced and part accuracy is improved thereby increasing the press break efficiency.**Bharath. G& R. Prakash (2014) [7]**in a paper carried out an analysis of criticality for a bleed valve used in fuel pump using FMECA. Initially they categorised the components of bleed valve which consists valve body, steel ball, spring and valve stop. The major defect that was found during the operation of bleed valve is the slit leakage which results in minimizing and fluctuating performance in the engine. In this case study they have found two failure mode namely material wear and loosing stiffness for four different components and the highest RPN was obtained for the spring component. Finally they concluded  Proper care and maintenance should be given to assembly parts while scheduling preventive maintenance. **Tejaskumar S. Parsana & Mihir T. Patel (2014) [8]**attempted FMEA tool for analysing and rectifying problems in manufacturing process of cylinder head company also to enhance the reliability. Firstly authors studies various operations carried out for manufacturing of cylinder head. Then they have sorted out the potential failure modes followed by their effects. Later the calculation of severity, occurrence and detection was done in order to find out the risk priority number. After analysing all the failure modes and allotting S, O and D, the highest RPN was found for Nozzle bore with a value of 54. At the end they concluded that the manufacturing efficiency and the quality can be improved by FMEA analysis and thus reducing the number of defects.

# **FMEC Analysis Groundwork**

1. **Identifying the component functions**

Before going into the deep study of FMECA, analyser should be familiar with the components description and its functions. So that, one can easily analyse the causes and effects. After having a sound knowledge on the components data, analyser should specify each and every function of the component. These are the preliminaries for any study for carry for on FMECA.

1. **Identifying Potential Failure Mode**

The first basic step for any study to proceed with FMEC analysis is to identify all the potential failure modes of a system/component or equipment. This is done by considering the previous track record which can be available in the log records or excel document with maintenance operator. After deciding the time period for the study, one has to consider all the failures which have occurred in the past and then convert them in to technical terms. For example: broken, fractured, burnt, deformed etc.,

1. **Potential Effects of Failure**

Every failed component has an effect, which has to be noted immediately after the failure occurred. The effect may vary from minor to major based on the type of failure mode. After identifying the failure mode, it is necessary to analyse and brainstorm all the possible effect on the environment.

# **FMECA Methodology**

Figure 1 shows the process flow chart that carried out in FMECA methodology. FMECA process can be described in two phases. The first phase is to point and know the potential failure modes and their effects. The second phase is to carry out risk analyses to determine the severity of the failure modes.At the end of the first phase, the detailed design is completed, and the design drawing is developed. At the second phase of FMEA, engineers in the FMEA team analyse and rank the risk of each failure, and then revise each design detail and make required modifications. The most serious failure has the highest rank and is considered first in the design revision. The design is revised to ensure that the probability of occurrence of the highest ranked failure is minimized.The data and the content or lyric used in the FMEA process should come from the company’s own production lines, the customers, and the field data of similar products. Therefore, the FMEA team has to work with the customers to gather the required information to develop an effective FMEA report.



# **Key Inputs of FMEC Analysis**

1. **Severity(s)**

The estimation of the seriousness of the failure mode effect is measured by the variable known as severity. In other terms, it is a numerical measure of how serious is the effect of failure mode on the considered factors. Generally, it is represented with letter S. the degree of severity is generally taken depending upon different factors such as human risk, production, cost etc.The degree of severity is generally measured on the scale of 1 to 10, where 10 is the most severe. Severity classification categories that are consistent with MIL-STD-882 are defined as follows

 **Table 1 Severity Ranking**

|  |  |  |
| --- | --- | --- |
| **Effect** | **Criteria: Severity of Effect** | **Ranking** |
| Hazardous -Without warning | Very High severity ranking when a potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulation without warning. | 10 |
| Hazardous – With warning | Very High severity ranking when a potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulation with warning. | 9 |
| Very High | Vehicle / item inoperable, with loss of primary function. | 8 |
| High | Vehicle / item operable, but at reduced level of performance. Customer dissatisfied. | 7 |
| Moderate | Vehicle / item operable, but Comfort/Convenience items inoperable. Customer experiences discomfort. | 6 |
| Low | Vehicle / item operable, but Comfort/Convenience items operable at reduced level of performance. Customer experiences some discomfort. | 5 |
| Very Low | Fit & Finish/ squeak & Rattle item doesn’t conform. Defect noticed by most customers. | 4 |
| Minor | Fit & Finish/ squeak & Rattle item doesn’t conform. Defect noticed by average customer. | 3 |
| Very Minor | Fit & Finish/ squeak & Rattle item doesn’t conform. Defect noticed by discriminating customer. | 2 |
| None | No Effect | 1 |

1. **Occurrence(O)**

Occurrence measures the chance of occurring a specific failure mode/event in the specified time period. It also quantifies the probability that a desired failure mode will actually identified. The likelihood of occurrence ranking number has a meaning rather than a value. Ranking is allotted for each failure mode separately based on the frequency of occurrence. The degree of occurrence is measured on a scale of 1 to10, where 10 signify the highest probability of occurrence. Normally the rating is given by occurrence rates.Removing or controlling one or more of the causes/mechanisms of the failure mode through a design change is the only way a reduction in the occurrence ranking can be effected. Estimate the likelihood of occurrence of potential failure cause/mechanism on a 1 to 10 scale where 10 denotes the highest probability of occurrence. Only occurrences resulting in the failure mode should be considered for this ranking; failure detecting measures are not considered here.

**Table 2Occurrence Ranking**

|  |  |  |
| --- | --- | --- |
| **Probability of Failures** | **Possible Failure Rates** | **Ranking** |
| Very High – Failure almost inevitable | > = 1 in 2 | 10 |
| 1 in 3 | 9 |
| High : Repeated Failures- | 1 in 8 | 8 |
| 1in 20 | 7 |
| Moderate : Occasional failures | 1in 80 | 6 |
| 1 in 400 | 5 |
| 1 in 2,000 | 4 |
| Low : Relatively Low Failures | 1 in 15,000 | 3 |
| 1 in 1,50,000 | 2 |
| Remote : Failure is unlikely | < = 1 in 1,500,000 | 1 |

1. **Detection(D)**

Detection is the ability to detect the cause/mechanism/weakness of actual or potential failure. In Design FMEA, this must occur before the component, subsystem, or system is released for production. In Process/Service FMEA it must occur in time to prevent distribution in case of a product or catastrophe in case of an Asset / Maintainable Unit. In order to achieve a lower ranking, generally the planned control (e.g. preventative activities) has to be improved. In System FMEA it must occur before the scheduled maintenance. The level of detection is measured on a scale of 1 to 10, where 10 signify virtually no ability to detect the fault.

Table 3Detection Ranking

|  |  |  |
| --- | --- | --- |
| **Detection** | **Criteria: Likelihood of Detection** | **Ranking** |
| Absolute Uncertainty | Design Control will not and/or cannot detect a potential cause/mechanism and subsequent failure mode; or there is no Design Control. | 10 |
| Very Remote | Very remote chance the Design Control will detect a potential cause/mechanism and subsequent failure mode. | 9 |
| Remote | Remote chance the Design Control will detect a potential cause/mechanism and subsequent failure mode. | 8 |
| Very Low | Very Low chance the Design Control will detect a potential cause/mechanism and subsequent failure mode | 7 |
| Low | Low chance the Design Control will detect a potential cause/mechanism and subsequent failure mode. | 6 |
| Moderate | Moderate chance the Design Control will detect a potential cause/mechanism and subsequent failure mode. | 5 |
| Moderately High | Moderately high chance the Design Control will detect a potential cause/mechanism and subsequent failure mode. | 4 |
| High | High chance the Design Control will detect a potential cause/mechanism and subsequent failure mode. | 3 |
| Very High | Very High chance the Design Control will detect a potential cause/mechanism and subsequent failure mode. | 2 |
| Almost Certain | Design Control will almost certainly detect a potential cause/mechanism and subsequent failure mode. | 1 |

# **Risk Priority Number**

One common approach in FMECA calculates a Risk Priority Number (RPN). A risk priority number (RPN) is a numerical and relative “measure of the overall risk” corresponding to a particular failure mechanism and is computed by multiplying the severity, occurrence, and detection numbers.

***RPN = Severity × Occurrence × Detection***

# ***Inputs for the Calculation of RPN***

The Risk Priority Number (RPN) is calculated using three inputs namely Severity (S), Occurrence (O) and Detection (D). The RPN is used to prioritize the failures so that the instances of failure can be minimized by taking necessary preventive measures and corrective actions. The product of severity, occurrence and detection gives the RPN.

# **Drawbacks of FMECA**

D1: ***Ranking allocation Criterion***

: The rankings of severity and occurrence may vary from person to person. Although FMEC analysis provides the guidelines for the Ranking a criterion, but it does not give any range between which it can be given.

D2: ***Difficulty in Ranking Detection***

While calculating the RPN value which is the product of severity, occurrence and detection, it is very difficult for one to detect a particular failure mode in advance. Hence the ranking for detection is a difficult task. This is one of the major drawbacksin FMEC analysis.

D3: ***Identical RPN***

One of the major drawbacks in FMECA is getting identical RPN. The RPN is a valuable tool for setting priority. In the conventional approach, higher RPN values represent higher priority. As well known that RPN is the product of S, O, D and only 120 different RPN values are possible, while some can’t occur like 17, 22, 925 and some may occur multiple times like 60, 72 and 120. It is very convenient to point out the failure mode with the highest risk if the values of RPN are different. However, it is very difficult to come to a decision if the entire failure modes have the identical values of RPN.

# **Remedies to overcome the drawbacks**

D1: ***Establishment of Range***

Before ranking severity or occurrence, a criterion on which the raking is to be made should be established. Failure mode severity can be allotted based on the sever effect on environment, or profit, or production or image etc. If a case has to be taken that the severity is ranked depending on the production loss due to the absence of machinery, then the failure mode which has more repair time has to be ranked most severe. This can be done using Total Time toRepair (TTR) which implies the time taken for repairing a particular failure. If time spent for a repair to correct the failure is high, then the unavailability of that machine is more in the field. This in turn causes a lot of production loss. In this paper it is considered that if there is huge production loss then it is taken as the most sever failure. In this paper a sample data was taken for a period and the criteria for severity ranking was established based on the time taken to repair the failure.

|  |  |  |
| --- | --- | --- |
| Duration of interruption(In hours)  | Criterion | Severity Rank |
| >2250 | Dangerously High | 10 |
| 2000-2250 | Extremely High | 9 |
| 1750-2000 | Very High | 8 |
| 1500-1750 | High | 7 |
| 1250-1500 | Moderate | 6 |
| 1000-1250 | Low | 5 |
| 750-1000 | Very Low | 4 |
| 500-750 | Minor | 3 |
| 250-500 | Very Minor | 2 |
| 0-250 | None | 1 |

Each failure has certain value of occurring in the considered time. The repetition of each failure has evaluated and the count has taken in the presiding column. In this paper, daily occurring failure has taken as the most occurring one and ranked as 10. If the occurrence of a failure mode is 24, it is considered as occurring monthly. The approximation of failure frequency was taken for occurrence ranking based on the ranking scale.

|  |  |  |
| --- | --- | --- |
| Occurrences | Criterion | Rank |
| Daily | Very High | 10 |
| Weekly | High | 9 |
| Fortnight | 8 |
| Monthly | Moderate | 7 |
| Bimonthly | 6 |
| Quarterly | 5 |
| Half-yearly | Low | 4 |
| Yearly | 3 |
| 2 years | Remote | 2 |
| >2 years | 1 |

D2: ***Use of Cause and Effect diagram, Brainstorm and Questioner form.***

Detection is one of the most critical factor for establishing scale and rankings. No confined method has been developed to detect a failure. Detection ranks can be given based on the results of survey, cause and effect diagram and brain storming session. A questionnaire has prepared by the team,which consists multiple choice questions for the purpose of survey. Survey was done with the help of a questionnaire having multiple choice answers, prepared by the team by interviewing the experts in the fields. Detection rankings were made based on the survey results and also the detection ratings can be for each of the problem by the following ways

1. Comparison method

2. Brain storming

3. Cause and effect diagram

D3: ***Priority based RPN ranking***

**When RPN value is equal**

**(i) Severity occurrence multiple**

 As a general rule, any failure mode that has effect resulting in severity 9 or 10 would have top priority. Severity is given the most weight when assessing risk. Next, the severity and occurrence (S\*O) combination would be considered, since this in effect, represents the criticality.

Equal R.P.N value

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **S** | **O** | **D** | **S\*O** | **RPN=S\*O\*D** | **RANKING** |
| 2 | 10 | 10 | 20 | 200 | 3 |
| 10 | 10 | 2 | 100 | 200 | 1 |
| 10 | 2 | 10 | 20 | 200 | 2 |

In the above table RPN value is equal. so, severity is given more importance. If severity is equal for any mode, then criticality(S\*O) is given importance.

**(ii) High severity failure mode**

This is special case while considering the “threshold values” for RPN values when assessing the risk. In this case lowest RPN value is more critical

For example Higher severity consideration

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S** | **O** | **D** | **RPN** | **RANKING** |
| 10 | 2 | 2 | 40 | 1 |
| 3 | 10 | 2 | 60 | 2 |
| 2 | 5 | 10 | 100 | 3 |

Here, the failure modes with lowest RPN values are more critical. Because in RPN analysis severity is given most priority. In this case there is a large difference in severities of three modes, and higher severity case has lowest RPN. So, case failure mode 1 is taken as first ranking irrespective of RPN.

**(iii) Maximin Approach**

A new approach has introduced in this paper to prioritize the risk priority numbers when the RPN values are identical. In general cases, it is very difficult to come to a decision when two or more failure modes have the identical RPN value. So it is desired to arrive a mechanics to prioritize the identical RPN values. This analysis was designed with an assumption that all the three variables, i.e., severity, occurrence and detection are equally important.

**Step:1**

First sort out the maximum values of S, O, D for each failure mode separately. For example if there are five failure modesand the severity ranking for these five failure mode be 3, 6, 5, 8 and 4. Among these, the maximum value is 8. Similarly procedure in continued for occurrence and detection. So there will be three maximum values for S, O, D. Among these three maximum values, find out the minimum value. This value becomes the Comparative code.

**Step: 2**

After calculating the comparative code, see the number of places for each failure mode for which the S, O , D values are greater that the comparative code.

For example: if comparative code is 6

FM1 5, 8, 7

FM2 2, 4, 9

FM3 1, 6, 9

In FM1 there are two values greater than 6

In FM2 there is one value greater than 6

In FM3 there is one value greater than 6

N (FM1) = 2; N (FM2) = 1; N (FM3) = 1

Critical failure mode becomes, maximum of N (FMi)’in this case FM1 is the critical failure.

But for remaining two failure modes there is a similar value. So it can be preceded to the next level.

**Step: 3**

Critical Failure Mode (CFM)

N(FM2) = max { 3-4 , 8-6 , 5-5 }

 = max {1, 2, 0 } = 2

N(FM3) = max { 4-8 , 6-5 , 5-3 }

 = max {4, 1, 2 } = 4

# **Conclusion**

FMECA is a useful tool in analyzing all the potential failure modes of a system/equipment and component. Initially a brief review has been done in the form of literature and the methodology and the basic ground work for FMECA was described. Later on the drawbacks which are encountered during the analysis of FMECA was sorted and pointed out which are ranking allocation criterion, difficulty in detection ranking and identical RPN’s. These drawbacks are rectified and presented in the form of remedies. Among all the drawbacks the major drawback which was found is encountering the identical RPN’s. This problem can be solved by identifying the priority constant. Maximin approach which was described in this paper is helpful in avoiding and overcoming such circumstances.

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