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FMEA– Failure Mode and Effects Analysis

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FMEA

The methodology of FMEA (Failure Mode and Effect Analysis) is a tool that search for ways to avoid, by analyzing potential faults and suggesting improvement actions, that failures occur on the process or product project. This is the basic goal of the FMEA so we can say that with its application we are decreasing the chances of the product or process to fail while it's operating. In other words, we are trying to increase its reliability which is the probability of failure of the product/process.

This kind of quality dimension, the reliability, has become increasingly important through time for the consumers because a failure in a product, even if it's immediately repaired by the technical assistance services and totally covered by the product guaranty, causes dissatisfaction to the consumer because it's depriving him of using the product for some time. Besides that, there are a lot of products that are often released to the market where some kinds of faults can have severe consequences for the costumer, such as plains and hospital equipments in which any kind of malfunction could imply life risk for the costumer.

Despite the FMEA methodology has been developed with a strong focuses on the projection of new products and processes, nowadays, by its large utility, it started to be applied and used in several ways. Therefore, the FMEA is currently used to reduce the probability of failures in the existent products/processes and to reduce the probability of failures in administrative processes. Besides this, it has been applied too in some specific applications

like the analysis of risk sources in engineering security and in the food industry.

Types of FMEA

There are several types of FMEAs but some are used much more often than others (like service and project types). FMEAs should always be done whenever failures would mean potential harm or injury to the user of the end item being designed. The types of FMEAs are:

- **Design**: analysis of products prior to production;
- **Concept**: analysis of systems or subsystems in the early design concept stages;
- **System**: focuses on global system functions;
- **Software**: focuses on software functions;
- **Equipment**: analysis of machinery and equipment design before purchase;
- **Process**: analysis of failures on the planning and execution of the process, therefore, the objective of this analysis is to avoid process faults, based on the non conformities of the product with the specifications of the project;
- **Service** (product): analysis of the faults that can occur with a product according to the specifications of the project. The main objective of this one is to avoid failures on the product or on the project process.

There is still another type of FMEA which is not so common: the administrative procedures FMEA. Its goal is the same, reduce failure risks, and it based on the analysis of potential faults in every step of the process.

Types of FMEAs applications

The FMEA analysis can be applied on the following situations:

- Decrease the probability of failures in projects of new products or processes;
- Reduction of the probability of potential failures on products/processes that are already operating;
- Increase the reliability of products or processes that are already operating by the analysis of the faults that have occurred;
- Reduction of the risk of errors and improve the quality of administrative procedures;
- Develop product or process requirements that minimize the likelihood of failures;
- Ensure that any failures that could occur will not injure or seriously impact the customer of the product/process;
- Track and manage potential risks in the design which contributes to the development of corporate memory and the success of future products as well;

- Identify design characteristics that contribute to failures and design them out of the system or at least minimize the resulting effects;
- Develop methods and procedures to develop and test the product/process to ensure that the failures have been successfully eliminated;
- Evaluate the requirements obtained from the customer or other participants in the design process to ensure that those requirements do not introduce potential failures.

Importance and benefits of FMEA

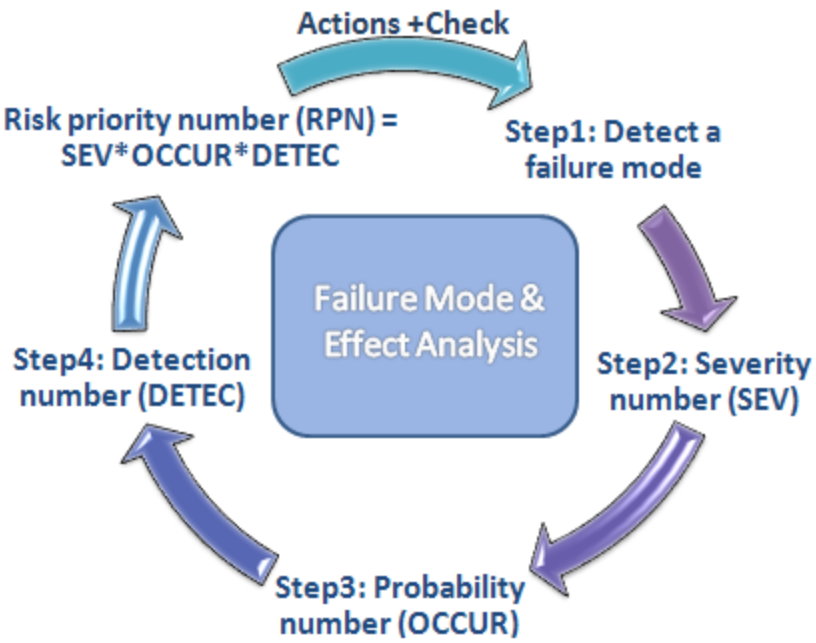
The FMEA methodology is important because it can provide a lot of improvements and benefits to the business, such as:

- Systematic ways of cataloguing information about the products/processes faults;
- Better knowledge of the products/processes problems;
- Improvement actions on the project of products/processes, based on correct data and appropriately monitored;
- Reduction of costs by preventing failures occurrence;
- Implementation of a new mentality inside the organization, like the concern about faults prevention, the cooperation and team work and the concerns about clients satisfaction:

- Early identification and elimination of potential product/process failures modes;
- Prioritize product/process deficiencies;
- Provide focus for improved testing and development;
- Improve company image and competitiveness.

FMEAs implementation and procedure

The FMEAs method is a simple and not very complex method that is compost by several phases but it's fair to say that the most important are the ones where severity, probability, and detection are discussed. In the picture below, we can see the whole life cycle of FMEAs method:



In FMEA, failures are prioritized according to how serious their consequences are, how frequently they occur and how easily they can be detected. It also documents current knowledge and actions about the risks of failures for use in continuous improvement. FMEA is used during the design stage with an aim to avoid future failures and later it is used for process control, before and during ongoing operation of the process. In other words, FMEA begins during the earliest conceptual stages and continues throughout the life of the product or service. After all the analysis and evaluation, the outcomes of the FMEA are actions to prevent or reduce the severity or likelihood of failures, starting with the highest-priority ones.

When dealing with potential failure modes like safety, cost, performance, quality, reliability, and their associated causes, FMEA can provide to the engineer a lot of information about how to alter the development/manufacturing process in order to avoid these failures. This way, FMEA provides an easy tool to determine which risks have the greatest concern and what actions to be made to prevent them.

The process for conducting a FMEA is straightforward. It is developed in three distinct phases where actions can be determined but it is also important to do pre-work ahead of the FMEA to assure that the robustness and past history are included in the analysis.

Pre-work

The robustness analysis can be obtained from interface matrices, boundary diagrams, and parameter diagrams. Because engineers tend to focus on what they control directly, a lot of failures

are due to noise factors and shared interfaces with other parts and/or systems.

The first step is to describe the product/process and its function. An understanding of the product or process under consideration is important to have clearly articulated. This understanding simplifies the process of analysis by helping the engineer identify those product/process uses that fall within the intended function and which ones fall outside. It is important to consider both intentional and unintentional uses since product failure often ends in litigation, which can be costly and consume time. After this, it's essential that the team creates a block diagram of the system needs to be created. This diagram gives an overview of the major components or process steps and how they are related and it shows the logical relationships of components and establishes a structure around which the FMEA can be developed. From this block diagram we can establish a coding system to identify system elements and it should always be included with the FMEA form.

Besides this, and based on the block diagram, it is needed to create a worksheet which contains all the important information about the system such as the items, functions, names of the components, revision dates, and so on. An example of a FMEA worksheet is given on page 15.

Severity

The first step is to identify and determine all failure modes based on the functional requirements and their effects. A failure mode is defined as the manner in which a component, subsystem, system,

process, etc, could potentially fail to meet the design intent. In that way, some examples of potential failure modes are:

- Corrosion;
- Hydrogen embrittlement;
- Electrical short or open;
- Torque fatigue;
- Deformation;
- Cracking.

A failure mode in one component can serve as the cause of a failure mode in another component so this is why each failure should be listed in technical terms and for function. At this point is possible to check similar products or processes and the failures that have been documented whether those failures are likely or not to occur.

After this, it's important to describe and consider the effects of those failure modes. A failure effect is defined as the result of a failure mode on the function of the product or process as perceived by the consumer, so for each failure mode identified the engineer should be able to determine the corresponding effect. This feedback is given by the consumers, for what they might see or experience. Some examples of failure effects are:

- Injury to the user;
- Inoperability of the product or process;
- Improper appearance of the product or process;
- Odors;
- Degraded performance;
- Noise.

To classify the severity (S) of the effect, we need to establish a numerical ranking for it. A common industry standard scale uses 1 to represent no effect and 10 to indicate a very severe state. This ranking is useful because it helps the analyst to determine whether a failure would be a minor nuisance or a catastrophic occurrence to the costumer and helps the engineer to prioritize the failures modes and their effects. According to the increase in the severity ranking, actions are taken to eliminate the failure mode or to protect the user from the effect.

Severity		
Index	**Severity**	**Criteria**
1	Minimum	The client barely knows that a failure occurred.
2 3	Low	Slightly decreasing on performance and light dissatisfaction by the client.
4 5 6	Moderated	Significative decreasing on performance and dissatisfaction by the client.
7 8	High	System stops working, big dissatisfaction by the client.
9 10	Very high	Same as previous but with security concerns.

Table 2 - Severity

Occurrence

The second step is to identify the causes for each failure mode and how many times it occurs which can be done by looking at

similar products or processes and the failure modes that have been documented for them. A failure cause is defined as a design weakness that may result in a failure and these causes should be identified, documented, and listed in technical terms. Some examples are:

- Improper torque applied;
- Contamination;
- Improper operating conditions;
- Erroneous algorithms;
- Excessive loading;
- Excessive voltage;
- Improper alignment.

To classify an occurrence (O), another ranking from 1 to 10 is applied. This numerical ranking indicates the probability of some cause to occur and it uses 1 to represent not likely and 10 to indicate inevitable.

Occurrence		
Index	**Occurrence**	**Proportion**
1	Minimum	1:1000000
2	Low	1:20000
3		1:4000
4	Moderated	1:1000
5		1:400
6		1:80
7	High	1:40
8		1:20
9	Very high	1:8
10		1:2

Table 3 - Occurrence

Detection

On the third step, the engineer should identify the current controls of the system, that prevent failure modes from occurring or which detect the failure before it reaches the customer. After, he should identify testing, analysis, monitoring, and other techniques that can or have been used on the same or similar products/processes to detect failures and from these controls the engineer can learn how likely it is for a failure to be identified or detected. From the combination of the previous 2 steps (severity and occurrence) a detection number (D) is given which ranks the ability of planned tests and inspections to remove defects or detect failure modes in time. The higher numbers measures the risk that the failure will escape detection, or in other words, that the chances of detection are low.

Detection		
Index	**Detection**	**Criteria**
1 2	Very high	It will be detected.
3 4	High	Big possibility of being detected.
5 6	Moderated	It will probably be detected.
7 8	Low	Probability it won't be detected.
9 10	Very low	It won't be detected.

Table 4 – Detection

Risk Priority Numbers (RPN)

After the analysis of the severity, occurrence and delectability, the RPN is easily calculated by multiplying the three numbers from before: RPM = S x O x D .

The RPN doesn’t play an important role in the choice of an action against failure modes, but has to be done for the entire process because once it is done it is easy to determine the areas of greatest concern. Once its calculated, the failure modes that have the highest RPN should be given the highest priority for corrective action but this doesn’t happen every time because there could be less severe failures but which occur more often and are less detectable.

When all the values are calculated some actions are taken. They could include specific inspection, testing or quality procedures, selection of different components or materials, monitoring mechanisms, inclusion of back-up systems or redundancy, redesign, limiting environmental stresses or operating range. After the actions are implemented, the new RPN should be checked and whenever a design or a process changes, an FMEA should be updated.

Product or Process					FMEA Type						FMEA Date					
FMEA Team Members											**Rev / Rev Date:**					
Process/Product Description or Purpose	Potential Failure Modes	Potential Effect(s) of Failure	SEV	CLASS	Potential Causes / Mechanisms of Failures	OCC	Current Design / Process Control Prevention Detection	DET	RPN	Recommended Actions	Who When	Actions Taken	SEV	OCC	DET	RPN

Table 1 - FMEA Form

References

- http://www.npd-solutions.com/fmea.html
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