ADVANCED FEASIBILITY ANALYSIS FOR PRODUCT PROJECT VALIDATION IN AUTOMOTIVE INDUSTRY

Alina Maria RUS[1,2] , Mihai Victor ZERBES[1], Călin George RUS[3] and Lucian Lobonț[1]

ABSTRACT: To be successful within the business environment, a company has to make significant efforts, to maintain or gain more competitive advantage in the area of activity, sell high volumes products, launch with quality and provide to the customers the desired variety of products. Over the years it was observed, that some organizations tend to be stolen by the high volumes sales mirage, and focusing too much only on the external strategies, the internal environment has been left aside. Those who maintained a dual interest on both internal/ external environment of the organization understood the need of investments dedicated to new products development, new technologies and process optimization strategies. From the process optimization activity, derived a significant number of new processes, or tools designed to improve and sustain a process. But before implementing these tools, it is mandatory to perform an analysis that could confirm the feasibility of the product, or will underline if it needs significant improvements.

KEY WORDS: FMECA, failure, feasibility, product validation.

1 INTRODUCTION

Failure modes, effects and criticality analysis (FMECA) is an established reliability engineering activity that also supports fault tolerant design, testability, safety, logistic support, and related functions. The technique has its roots in the analysis of electronic circuits made up of discrete components with well-defined failure modes. (SEMATECH, 1992)

The purpose of FMECA is to analyze the design characteristics relative to the planned manufacturing process to ensure that the resultant product meets customer needs and expectations. When potential failure modes are identified, corrective action can be taken to eliminate or continually reduce the potential for occurrence. The FMECA approach also documents the rationale for a particular manufacturing process.

[1]"Lucian Blaga" University of Sibiu, Faculty of Engineerin, Sibiu, Romania;
[2]General Motors Global Purchasing & Supply Chain Romania;
[3] "Eremia Grigorescu" Application School for Battle and Support Unit, Sibiu, Romania
E-mail: alinamariarus@ulbsibiu.ro;
mihai.zerbes@ulbsibiu.ro, rcg_calin@yahoo.com,
lucian.lobont@ulbsibiu.ro

FMECA provides an organized, critical analysis of potential failure modes of the system being defined and identifies associated causes.

It uses occurrence and detection probabilities in conjunction with a severity criteria to develop a risk priority number (RPN) for ranking corrective action considerations.

FMECA is a technique used to identify, prioritize, and eliminate potential failures from the system, design or process before they reach the customer (Omdahl, 1988). FMECA is a technique to "resolve potential problems in a system before they occur" (SEMATECH, 1992). The methodology was one of the first systematic techniques for failure analysis. Initially, the FMECA was called FMEA (Failure modes and effects analysis). The C in FMECA indicates that the criticality (or severity) of the various failure effects are considered and ranked. Developed by the U.S. Military, the first guideline was Military Procedure MIL-P-1629 "Procedures for performing a failure mode, effects and criticality analysis" dated November 9, 1949.

Today, FMEA is often used as a synonym for FMECA.

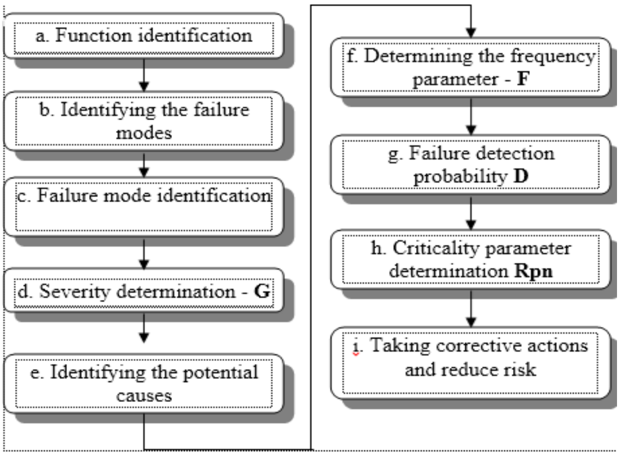

Figure 1. FMECA stages (Kifor & Oprean, 2006)

The distinction between the two terms has become blurred.

The m**o**st widely used reliability analysis technique in the initial stages of product/system development, FMECA is usually performed during the conceptual and initial design phases of the system in order to assure that all potential failure modes have been considered and the proper provisions have been made to eliminate these failures.

What can FMECA be used for (Rusand, 2004)? We can use FMECA for:

- Assist in selecting design alternatives with high reliability and high safety potential during the early design phases
- Ensure that all conceivable failure modes and their effects on operational success of the system have been considered
- List potential failures and identify the severity of their effects
- Develop early criteria for test planning and requirements for test equipment
- Provide historical documentation for future reference to aid in analysis of field failures and consideration of design changes
- Provide a basis for maintenance planning
- Provide a basis for quantitative reliability and availability analyses.
-

2 CASE STUDY

This case study, is a continuation of a previous research that had as a starting point the DMAIC methodology, performed in the same area of interest, underlining what can be improved and how, in order to diminish the delays or disruption occurrence during the production planning process.

With those take away` s, a new direction was established and will unfold more insights of a complete improvement plan set up.

Based on the previous research recommendation, a support tool for the sourcing process execution was developed, that integrates the required databases features and the knowledge needed to ensure the completion (Rus, Kifor, Zerbes, Grecu, Rus, 2014).

Furthermore, by using the FMECA analysis, the paper aim it is to identify the feasibility level of the proposed tool designed to improve and strengthen the current execution of the process, and concluding all nine steps of the analysis with a detailed overview over the current process, its flaws and malfunctions.

To prevent any deviation from the proposed course of action, a coordinating team was established, working together in order to overcome, any potential deviation from the current focus.

2.1 Product functions identification

Product functions identification are:

- Process guiding
- Training
- Proofing tool
- Process documentation index.

2.2 Failure mode identification

Once the functions of the proposed model have need identified, the paper will continue with an expanded view of the potential risks and failure identification, that might generate based on the above identified functions:

- Process guiding: misleading definition, of each step of the proofing tool, incomplete structure of the process, captured in the tool,
- Training: misinterpretation of the information, no option available for knowledge assessment testing.
- Proofing tool: no possibility of checking the reliability of the data/ attachments inserted by the user
- Process documentation indexation: incompatibility between the system interface and the various version of the used software's for the documents creation.

2.3 Identifying the failure modes effects

Once the functions of the tool, have been identified, the project team, continued with the next step that highlighted the failure modes that can occur during the usage of the tool.

1st Function - Process guiding

- *a) Misleading definition* – might drive to the accumulation of unclear knowledge that could generate incorrect actions during the process.

The same issue can be translated into extension of the established timeframe available for execution of the process, which will impact the post sourcing phases, and generate addition costs.

- *b) Incomplete structure of the process, captured in the tool* – for each commodity there are special requirements that can be easily overlooked if the process designer does not have the proper knowledge and understanding of those particularities. The effect of this potential failure/ risk will be reflected as an incomplete walk of the process. If the user has no experience in the area of activity where the model is implemented, can realize the mistake only at the end of the process, which will turn back the user to the overlooked step, generating delays from time perspective, cost impact on the current process and disruptions of the next stages that are planned after the completion of the sourcing process.

2nd Function Training:

- *c) Misinterpretation of the information* – the user does not have the proper knowledge and experience to assimilate the information given about the process execution step.
- *d) No option available for knowledge assessment testing* – the existent tool give the opportunity to take a training based on the information provided under each step, but doesn`t have the option to check the level of assimilated knowledge by the user.

3rd Function Proofing tool:

- *e) No possibility of checking the reliability of the data/ attachments inserted by the user* – the proposed tool does not have any option available to check the accuracy of the inserted document/ data where an input it is required. Therefore in the archiving stage that takes place after the process completion, there might be the risk of not having the proper data collected, which will drive to additional manual work in order to complete the documentation needed. This potential risk, won`t impact the post process activities from financial perspective, but will create additional workload on the user desk.

4th Function: Process documentation indexation

- *f.) Incompatibility between the system interface and the various version of the used software's for the documents creation* – can impact the post process activities, in which the archiving of the justifying documents it is mandatory. Due to the exchange of the programs version over the time, there is a possibility to upload incompatible documents/ versions that won`t be readable later on. This will impact the organization the future audit checks regardless if there are internal or external.
- But the biggest problem could be, if in the future, the user leaves the company, and the replacing person doesn`t have access to the contracting information due to the program/ versions incompatibility.

2.4 Severity determination (S)

To determinate the severity, it was used a parameter (S), that has the possibility to estimate the malfunction effect, perceived by the user. It is absolutely mandatory to define the severity of the flaws, and to establish the severity parameter, using a ranking system with numbers from 1 to 10, as can be shown in Table 1.

Table 1. Severity parameter rankings

Effect	Efficiency Criteria	S
Risky without prevention	Safe functioning of the product/piece/vehicle is affected and/or implies non-compliance with government regulations, without prevention.	10
Risky with prevention	Safe functioning of the product/piece/vehicle is affected and/or implies non-compliance with government regulations, with prevention.	9
Very high	Piece/product/vehicle (doesn't work) loses its primary function.	8
High	Piece/product/vehicle is functioning at low-level performance, unsatisfied user.	7
Moderated	Piece/product/vehicle is functioning, but comfort is not provided, unsatisfied user.	6
Low	Piece/product/vehicle is functioning, low-level comfort is provided. Several unsatisfactory user experiences.	5
Very low	Nonconformities and low software setup. Flaws identified by the majority of the users (more than 75% occurrence rate on user's side).	4
Minor	Nonconformities of the product. Flaws identified on user end in 50% cases.	3
Slightly	Flaws identified by some users (less than 25% users).	2
None	No defects.	1

2.5 Identifying the potential causes of the effects

Often the malfunction causes, can be driven by design deficiencies. To identify which are the causes that can lead to failures and negative effects, the team analyzed each single potential risk that interferes with the process for which the proposed model was designed. These causes are:

1st Function - Process guiding

- *a) Misleading definition* – there are several reasons that can generate the potential failure causes. Unclear definition can occur when the designer of the tool, does not capture in a clear and concise context the complete information offered to the user in order to enhance its knowledge and guide through the process flow. There are as well two opposite situations, in which either the designer of the process, has an extended knowledge over the area of activity, for which the tool was designed, either has too less knowledge. Either way, there is a risk that the information won`t be structured in accordance with user needs.
- *b) Incomplete structure of the process, captured in the tool* – can be generated by the frequent adjustments of a process, or by the lack of experience in the field of the designer.

2nd Function Training:

- *c) Misinterpretation of the information* – can occur when the user does not have the proper background or the basic knowledge related to the area of responsibility, or by the fact that the tool was designed in English language, due to the global usage within the organization, and the language barrier can influence the accuracy of the knowledge accumulation.
- *d) No option available for knowledge assessment testing* – the designed tool, has as purpose, a 1 to 1 training, shared in each step in order to support the execution of the process, by guiding the user from one step to another. However, this tool was not designed for further testing due to the fact that the trainings have no self-assessment option in more than 80% of the trainings offered by the organization.

3rd Function Proofing tool:

- *e) No possibility of checking the reliability of the data/ attachments inserted by the user*. The proposed tool aims to facilitate the execution of the sourcing process, by enhancing or presenting in a brief manner the process that unfolds. This tool will reduce the burden on the user end, by giving the opportunity of inserting step by step the post process documentation, required for the global archive, and by the audit rules. The main issue remains how the tool can overcome the potential wrong data insertion or incomplete data submission. Currently the model has no proofing option available, in order to prevent such situations.

4th Function: Process documentation indexation

- *f) Incompatibility between the system interface and the various version of the used software's for the documents creation* – the IT industry it is in a continuous expansion and development, regardless if we are analyzing the hardware or software area.
- This development led over the time to incompatibilities of the files, while working with new operating systems.

2.6 Determining the frequency

As shown above, the identified causes have been considered and analyzed by the project team. To continue with the next steps it was found suitable to estimate the risk of the product flaws occurrence, using the frequency parameter (F).

The causes were evaluated based on frequency appearance, considering that this parameter represents the probability that a certain cause can occur resulting a failure during the product lifecycle.

Table 2. Failure frequency

Failure probability		Failure frequency	F
Very high	Failure is almost inevitable; the construction concept is unusable, inappropriate.	≥100 to 1000	10
		50 to 1000	9
High	Repeated failure, problematic construction.	20 to 1000	8
		10 to 1000	7
Medium	Occasional failure, more advanced construction.	5 to 1000	6
		2 to 1000	5
		1 to 1000	4
Low	Rare failure, verified construction.	0,5 to 1000	3
		0,1 to 1000	2
Very low	Improbable failure.	≤ 0,010 to 1000	1

2.7 Failure detection probability (D)

On the previous step, the frequency of failure occurrence was established, therefore the current case study will continue with the calculation of the failure detection probability. This parameter estimates the probability as the effect driven by both potential cause and failure mode.

Table 3. Product control failure mode discovery probability

Discovery	Product control failure mode discovery probability	D
Absolutely uncertain	**Project verification will not or cannot detect** the potential cause/mechanism and the next detection mode or there is no project verification.	10

Discovery	Product control failure mode discovery probability	D
Very remote	**Very remote chance,** that the project verification will detect the cause/mechanism and the next detection mode.	9
Remote	**A remote chance,** that the project verification will detect the cause/mechanism and the next detection mode.	8
Very low	**Very low chance,** that the project verification will detect the cause/mechanism and the next detection mode.	7
Low	**Low chance,** that the project verification will detect the cause/mechanism and the next detection mode.	6
Moderate	**A moderate chance,** that the project verification will detect the cause/mechanism and the next detection mode.	5
Highly moderated	**A highly moderated chance,** that the project verification will detect the cause/mechanism and the next detection mode.	4
High	**A high chance,** that the project verification will detect the cause/mechanism and the next detection mode.	3
Very high	**A very high chance,** that the project verification will detect the cause/mechanism and the next detection mode.	2
Very sure	Project verification will almost sure discover the cause/mechanism and the next detection mode.	1

2.8 Criticality parameter identification (C)

The criticality parameter can take values between 1 and 1000, and can be determined with the usage of the formula:

$$C = S \times F \times D \quad (1)$$

Based on the generated value for the parameters C and S, there is a set of corrective items, that will be considered and applied in the following scenarios:

Table 4. Scenario for criticality index values

If	S = 9 ÷10	C ≤ 30
		C > 30 corrective action plan will be established
	S = 7 ÷ 8	C ≤ 50
		C > 50 corrective action plan will be established
	S = 1 ÷ 6	C ≤ 100
		C >100 corrective action plan will be established

2.9 Taking corrective actions and reduce risk

Summarizing the complete sequence of phases and based on the results shown in table 4, the cause that scored a value higher than 100 it is related with the training function, generated by the lack of a self-assessment option. Normally for such situations a corrective action plan should be created, but in this case the proposed tool was designed just with a training function that would support the training process, therefore this finding won't impact significantly the feasibility of the analyzed product.

For the next version of the proposed tool this corrective item will be taken into consideration as an improvement recommendation.

Table 5. Alternative FMECA worksheet

Failure modes	Failure modes effects	S	Potential cause	F	Verification mode	D	RPN
Misleading definition	- unclear definition - structure not in accordance with user needs	2	the designer of the tool does not capture in a clear and concise context the complete information offered	2	analyzing the current version of the training	9	36
Incomplete structure	- frequent adjustments- designer lack of experience	2	can be generated by the frequent adjustments of a process, or by the lack of experience in the field of the designer	2		10	40
Misinterpretation of information	- user does not have the proper background - language barrier	1	can occur when the user does not have the proper background or the basic knowledge related to the area of responsibility, or by the fact that the tool was designed in English language,	1	cross departments user trials	10	10

Failure modes	Failure modes effects	S	Potential cause	F	Verification mode	D	RPN
No knowledge assessment testing	- no self-assessment option	4	The designed tool, has as purpose, a 1 to 1 training, supporting the execution of the process, by guiding the user from one step to another. This tool was not designed for further testing. No self-assessment option in more than 80% of the trainings offered by the organization.	5	this cannot be verified, only 20% of the trainings use self-assessment	6	120
No possibility of checking the reliability of the data/ attachments	- wrong data insertion or incomplete data	3	The main issue remains how the tool can overcome the potential wrong data insertion or incomplete data submission. Currently the model has no proofing option available, in order to prevent such situations.	3		8	72
Incompatibility between the system interface and the various software	- files incompatibility	3	IT industry it is in a continuous expansion and development, regardless if we are analyzing the hardware or software area. This development led over the time to incompatibilities of the files, while working with new operating systems	2	regular software updates	8	48

3 CONCLUSIONS AND FUTURE RECOMMENDATIONS

3.1 Conclusions

FMECA is usually performed during the conceptual and initial design phases of the product in order to insure that all potential failure modes have been considered and the proper provisions have been made to eliminate these failures.

Based on the FMECA analysis, it was identified the feasibility level of the proposed tool designed to improve and strengthen the current execution of the sourcing process, and concluding all nine steps of the analysis with a detailed overview of the current process, its flaws and malfunctions.

The advantage of using this analysis was to get a sense of the potential failure causes which might occur during the execution of the process. Considering the results, future correction action can be implemented in order to reduce to 0 the potential failure.

3.2 Future recommendations:

The analyzed tool was designed to serve four main functions: to guide the user through the process, to overcome potential failures in the execution, to index the required documents and to train the user, based on the FMECA analysis results, a set of corrective items should be further developed, and improved. One of the recommendations is to have for the future version of the tool, that would allow also a self-assessment of the gained knowledge based on the product usage, which currently isn`t available since the tool was designed initially just to train, and not necessarily to evaluate the user.

4 ACKNOWLEDGEMENTS

This paper was published under the sponsorship of the project European Social Fund thru the “Integration of Romanian research in the context of European research – doctoral scholarship”, POSDRU/88/1.5/S/60370

5 REFERENCES

► Kifor, C., Oprean C., (2006), *Ingineria calităţii. Îmbunătăţirea 6 sigma,* Editura Universităţii „Lucian Blaga”, Sibiu, Romania, ISBN 973 – 739 – 035 – 2

► Rus, A.M, , ZERBES, M.V, Kifor, C., Rus, C.G., Grecu, V. (2014) – Process Improvement using DMAIC Methodology in automotive industry. Case study.

►Tracy P. Omdahl, *Reliability, Availability and Maintainability Dictionary*, ASQ Quality Press, 1988, ISBN-10: 0873890450

►SEMATECH, Failure Mode and Effects Analysis (FMEA): A Guide for Continuous Improvement for the Semiconductor Equipment Industry Technology, Transfer #92020963B-ENG, SEMATECH, September 30, 1992

►Rusand M., (2004) *System Reliability Theory*, Wiley