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RISK ASSESSMENT TECHNICAL REPORT

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Table of Contents

Introduction	1
Literature Review.....	2
Methodology process of the FMEA	6
Initial FMEA.....	8
Post-Mitigation FMEA.....	11
Conclusion.....	12
References	13

Introduction

The main topic of this technical report is to investigate risk management which is a fundamental element from an engineer's perspective. Also, the object of this report is to investigate the assembly line process with the Failure Mode and Effect Analysis (FMEA) procedure to analyse the vulnerability elements and the potential area of failure.

The primary aspect of this analysis is to improve the investigation on the FMEA for the vehicle components.

In the last 30 years, the quality of the products has become essential in the Automotive sector. Indeed, companies have made products with higher quality standard, as a consequence of the increment of the customer demand related to authenticity and preservation of the product, while, if the company does not meet customer's expectations, they may receive negative feedback, that could cause an effect on the manufacturer image (Renu, et al., 2016). The priority aspect that engineers should be looking at is the circumstances that are happening in their territory. Also, they should consider and carry out their knowledge and remain updated with the present project with studies. Also, the essential part is to achieve the demand of the customer or the company that the engineer is working with. They have to look through documents, journals, that are plentiful of information which will help the engineer in the decision-making process (Van Emden, 2005). The Institute of Healthcare Improvement determines that the FMEA is an efficient and, dedicated method to analyse where a project could fail and determine which elements of the plan need to be modified (Reid, 2005). Besides, risk analysis in the FMEA style encourages quality control to assess the graduation of effective preventive measures to lead to higher levels of performance (Mecca & Masera, 1999).

In the first paragraph, this technical report will illustrate the Literature Review and Methodology process of the FMEA. Then the Initial FMEA will be evaluated with the respective mitigate actions. Finally, Post FMEA will explain the fundamental actions to prevent the failure of the process, and a conclusive section will highlight the key findings.

Literature Review

In the transportation sector, risk management is vital for the success of projects, to face strong competition. Nevertheless, a large number of projects show suspension and modification in their scope or failure. These problems began as a consequence of incompetence and inefficiency of the management which rise the risk of the project. Also, there could be other causes for which the project is at risk and they are divided into categories and groups as Segismundo et al. (2008) have indicated.

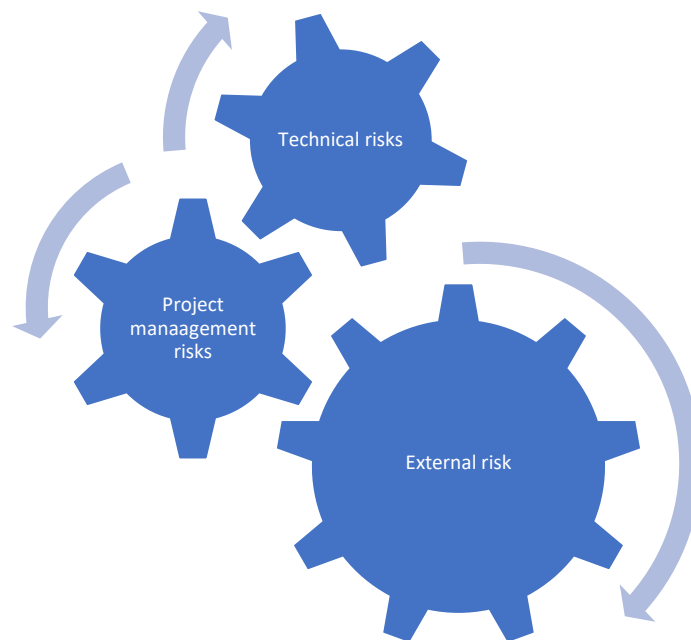


Figure 1. Risk categories (Segismundo, et al., 2008)

Technical risks are the focal point, and they relate to complicated technologies used during the project. Then project management risks derive from the source materials as a result of the low quality of the strategy. Finally, external risks arise when some of the legislation has been modified or when there is a change in customer needs (Segismundo, et al., 2008).

Nowadays, the fundamental tool to understand and prevent the risk of a project is labeled as Failure Mode & Effect Analysis (FMEA) (Segismundo, et al., 2008). According to the Code of Conduct, the main aspect that engineers needed to be aware of are as follow (IMECHE, 2018):

- Pick up professional knowledge and continue to improve their skills.
- Guarantee competence and professional work.
- Evaluate and reduce the risk in every single professional work.

This is an entire brief of engineers conduct, that a member of the Institutional of Mechanical Engineers can adopt when utilizing their judgment (IMECHE, 2018).

The primary subject that the IMECHE considers is to be motivated by innovation and research. Indeed, carry meeting with reading and debate communications around the subject that belong to Mechanical Engineering is essential (IMECHE, 2014).

Additionally, the FMEA can be used for risk management, that is relevant to the entire potential risk (Kumar & Kumar, 2016). It is decisive to remove the engineer and manufacture failures during the process, to ensure that the vehicle is safe. Furthermore, the Risk Priority Number (RPN) is utilized to identify the high potential failure of the project. The simple formula to calculate the RPN is (Aized, et al., 2020):

$$RPN = Severity * Occurence * Detectability$$

On the other hand, the main law that the entire business must apply is Health and Safety. The employer and the self-employed are in charge to take responsibility for the Health and Safety of their business, taking the right decision to maintain a secure working environment. Also, the essential law in the United Kingdom is to “do what is ‘reasonably practicable” to assure Health and Safety (HSE,2014, p.6).

Nowadays, many projects present cancellations, delays, and failures in their plan. PMBOK (cited in Segismundo, et al.,2008, p.900) observed that a project is at risk when ambiguous events appear, which generates a negative or positive event that can affect the plan, such as extra expenses and quality of the product. In addition, the risk can be categorized within exterior risk, technical risks, and a lower budget for the project. For this reason, a company to prevent all these complications for the plan, use the FMEA (Segismundo, et al., 2008).

The FMEA is a process that sketches the possible failure mode, effects, and sources of the technical system (Peeters, et al., 2018). The primary method that the FMEA adopts is the RPN. This method is utilized to care and find out the powerless of the project, for that reason, that will give the confidence to utilize the RPN. Proposed strategy and administering new merchandise are categorized as complicated decision-making, further, it is crucial to look at the risk of every alternative when companies make decisions (Segismundo, et al., 2008).

On the other hand, the FMEA can have some critical points (Segismundo, et al., 2008) :

- From the evaluation of the RPN, Severity, Occurrence, and Detectability could be distorted, in other words, they are not always precise.
- The RPN is not a constant intention of improvements.

Consequently, there are five crucial questions that FMAE investigates:

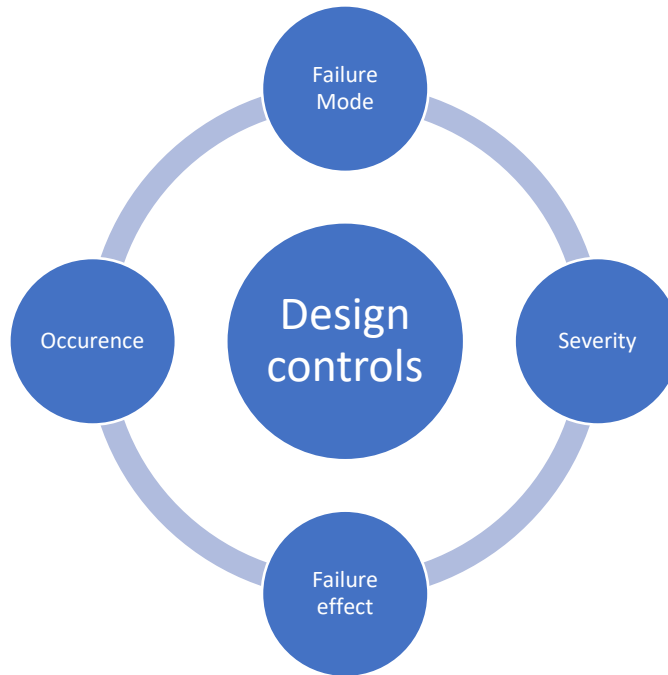


Figure 2. Main questions of the FMEA

Regularly, the FMEA will only be presented after the design project is concluded. Therefore, the team of the FMEA will debate and consider the possible errors and the potential failure. Subsequently, the team can be divided as small, for an individual engineer, and large, if related to the multidisciplinary team. However, for a development product, the operation is required to start with a surrogate FMEA, and then the updated product is compared to the original. Differently, the new product starts from the beginning and the team establish a list of potential failure. The challenging part for the team is to recognize the effects of the failure and to authorize individual value of severity, detection and, occurrence into the RPN (Bradley, et al., 2006).

On the other hand, the risk analysis has decisive questions to answer such as what could go wrong, what are the probability of the failure to occur, and what would be the consequence for the company.

The FMEA has the capability of adopting the engineering observation, authenticity, and progress in new techniques. However, as Stamatis and Diomidis point out, four procedures are essential and need attention (Stamatis & Diomidis, 2003).

All the issues are not equals.	This is an essential element that the FMEA is aware of. Likewise, it is required that employees understand and believe the concept of the essential few.
The customer must be recognized	For the FMEA is essential that the customer is analysed. For instance, the customer is classified as: external and intermediate that cannot be developed with no surprise consequence.
The action must be recognized	The action that some workers are doing must have a knowledge and understanding of it, otherwise, the results are only a waste of time.
“One must be prevention-oriented” (Stamatis & Diomidis, 2003, p.26)	In fact, FMEA relates to customer gratification and market condition.

Table 1. Important aspects of the FMEA (Stamatis & Diomidis, 2003)

The reason for conducting the FMEA is to reduce the risk in a certain organization, process, design, and to determine the risk on any occasion when is achievable. Differently, manufacturing problems are treated as failure results. However, customer requests heavily affect the performance of the FMEA, even before the international standards of all major automotive firms in their supplier certification standards acted (Stamatis & Diomidis, 2003).

Methodology process of the FMEA

The priority rule that employers must look at is to measure and control the risk in a company, to look after staff members, and ensure they are working in a safe environment. The employer should consider how to prevent the risk of injuries that could happen, the more likely and most unlikely. The most important element of the risk assessment is to classify the high potential risk in a workshop. The primary aspect that engineers should be looking at is to try to listen to every single employee or contractor that the company is working with and analyse who is at a high risk of potential injuries. After identifying the potential hazard, the immediate question will be, how likely or unlikely it can occur. However, it is not predicted that the employer can delete or prevent the risks, while the risk is an element of workday life (HSE, 2014).

On the other hand, with the increase of technology and with the rise of production, companies face a critical issue: The Health and Safety of the workers. For this reason, the FMEA has improved on the analysis of the Analytic Hierarchy Process, which is an adequate system to prevent or reduce the issue (Bao, et al., 2017).

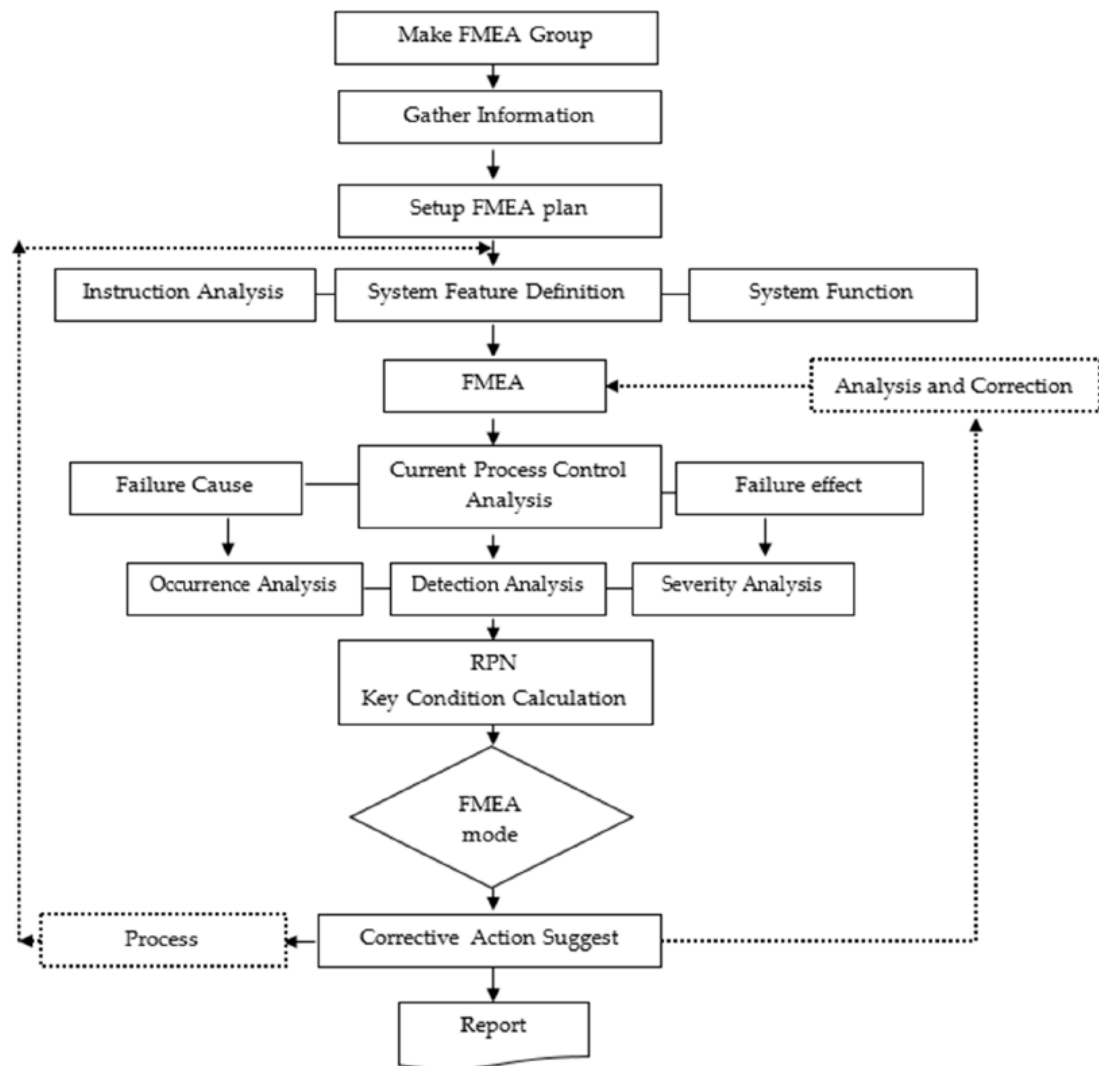


Figure 3: FMEA methods (Bao, et al.,2017, p.3)

As illustrated in Figure 3, the process is to arrange and advise for a risk management agreement, generally used in the Automotive sector. As mentioned before, the common method of the FMEA is to consider the RPN in various aspect such as S (severity), O (occurrence), and D(detection), which are the three risk factors that the FMEA is considering to have the same attention (Bao, et al., 2017).

Each year more than one million people are murdered, and around 50 million had disturbed by traffic accidents, further, following forecasted predictions, the number of traffic accidents could rise by 65%. Consequently, the most important goal for automotive companies is to manufacture much safer vehicles. The critical elements in the vehicle are the brake, which is located in a wheel brake, and these elements turn the control force into a brake torque, that is active to a wheel from a brake gear (Tretsiak, 2012).

Initial FMEA

Potential Failure Mode	A) Likelihood of Occurrence Rate 1:10 10 Most likely occur	B) Severity Rate 1:10 10 High-Severy	C) Likelihood of Detection 10 Lower probability	Risk Priority Number (RPN) AxBxC	Mitigating Actions Recommended Process to Reduce the risk of the probability
Brake calliper mounting bolts not torqued to correct level	5	6	8	240	Complete the task and ensure with a supervisor or with an expert technician that the caliper is at the correct torque.
Incorrect brake disc size installed	6	5	6	180	Before mounting the new brake disc, double-check the size of it and secure that the middle center is fitted properly otherwise could cause noise
Brake pads installed in wrong orientation, with friction material not contacting disc surface	6	6	9	324	It is crucial that before any technician install the brake pads follows the indications for the correct installation
Brake line fitting not fully tightened	8	6	8	384	The technician once have completed the task assures along with a supervisor the job has been done accurately
Inacurate colour of the Seat belt	5	6	4	120	It is required to have the Seat belt on the car all the same colour.

Table 2. Initial FMEA, with the RPN Calculated and the Mitigation action in the Process

In a workshop is mandatory to maintain the vehicle into a good repair, especially the brake system, the tyres and, lights, to achieve a good safety system (HSE, 2014).

Table 2 was able to discuss, after accurate research were conducted, the Likelihood of Occurrence, Severity Number, Likelihood of Detection and, strict rules of the FMEA were adopted. Those three elements have been investigated and mitigate actions must be followed by employers or employees, to avoid any errors in production that could cause a massive waste of time. At this moment, it is very important to act before the inaccuracy is delivered at the wrong time. Subsequently, the Severity Number has been observed, which is critical to follow as it can have a huge influence on the business expectation. For Instance, the brake pads fitted in the wrong direction could cause a delay in the production, while the technician has to remove some other parts of the vehicle to assure the brake pads are fitted to the right orientation and create the correct friction.

The likelihood of Detection has been evaluated. It is another important aspect that engineers must look at before the items go into production such: the right size of the disk, the right colour for the seat belts, and the correct torque to tight the brake caliper, before all these problems are into the production. Finally, the RPN has been calculated which represents the overall risk (Noble,2021).

The main aspects that contribute to the Commercial Motor Vehicle (CMV) safety related to the brake systems are operation, inspection, and maintenance. In 1936, was published the first legislation on the CMV brakes, linked to safety problems. However, between 1993 and

2003, motor vehicle standard and motor car safety go through review and joined specific regulations such as (Freund, 2007):

- Obligation to introduce an anti-block braking system in a vehicle.
- The necessity of automatic switch brakes and brake indicators.
- Training is required for a person that is working with inspecting, maintain, repair, or service CMV brake systems.

The primary actions that the FMEA recommends are to cut down and eliminate the risk of potential failure acting as cost and the efficacy of doing specific actions (Carlson, 2012).

Process Step/Function	Requirement	Failure Mode	Cause	Prevention Controls	Detection Controls	Recommended Actions
Op. 20 (attach seat cushion to track using a torque gun). Select four screws	Four screws	Less than four screws	Too few screws inadvertently installed	Visual aids illustrating correct quantity Operator training	Visual Inspection in station	In-station torque monitoring; line lockout if less than four
	Specified screws	Wrong screw used (larger dia)	Similar screws available at station	Visual aids illustrating correct screw Operator training	Visual inspection in station	In-station torque angle monitoring; line lockout if angle not met Error proof by design: use one type screw for station/product
Op. 20 (attach seat cushion to track using a torque gun). Beginning with right front hole, torque each screw to the required torque	Assembly sequence: First screw in right front hole	Screw placed in any other hole	More than one hole available to operator	Visual aids identifying location of first screw Operator training	Visual inspection in station	Add position sensor to nut runner, not allowing tool to operate unless runner is aligned with correct hole

Table 3. Recommended action linked to the FMEA actions (Carlson,2012, p.48)

Table 3 explains the fundamental process and the critical actions that are acted on an element to mitigate the risk. Also, the seat belts are determined to secure the health and safety of the driver and prevent injuries in case of a potential accident (Peter & Goddard, 2009). A comparison with a similar process solidly clamps the tube to ensure no items will be loose or damaged. The FMEA acts when the tube is not clamped secured, in other words, the tube is loose. In addition, the primary effect will be that the tube is not in the correct position. Finally, once the tube is out with abnormal circumstances, the entire body could collapse cause serious injuries to the rider. The crucial actions that are highly recommended are to use a

daily routine to schedule the clamping tool as long as it shows a comfortable graph (Carlson, 2012).

As shown in Table 2, five failures have been identified. However, the most at risk are the Brake pads installed in the wrong orientation and Brake line fitting not fully tight. Firstly, the risk that the brake line is not tight is high because the likelihood of detection is low and the likelihood of occurrence is high. For this reason, to reduce the risk, the task should be checked by a supervisor before moving into the next task. The brake pads were installed in the wrong direction, and the Likelihood of Detection is low, Likely of occurrence is high. According to Freund (2007), the technician must identify what are doing and have the right knowledge to complete the task (Freund,2007).

Post-Mitigation FMEA

Failure Mode & Effect Analysis (FMEA) - Braking Component Installation Process					
Potential Failure Mode	A) Likelihood of Occurrence 10 Most likely occur	B) Severity 10 High-Severy	C) Likelihood of Detection 10 Lower probability	Risk Priority Number (RPN) A*B*C	Potential Risk Remaining Process to Reduce the risk of the probability
Brake calliper mounting bolts not torqued to correct level	4	5	4	80	Once the bolts are regulated at a specific amount of torque, the risk of the brake calliper to collapse is unreal.
Incorrect brake disc size installed	4	4	6	96	The brake disc is fundamental parts of the vehicle, when the size is correct the risk of failure is immaterial.
Brake pads installed in wrong orientation, with friction material not contacting disc surface	5	6	8	240	Just after the technician has ensured the task is done correctly, it is required to have a safe drive before to move on to a different task.
Brake line fitting not fully tightened	5	4	5	100	At the time that the bolts are correctly fitted with the right amount of torque required, it will not be any risk of failure.
Inacurate colour of the Seat belt	5	7	4	140	As a result, the seat belt should be all the same colour to do not confuse the driver and the passangers.

Table 4. Post-Mitigation FMEA

After accurate testing, as mentioned in the Initial FMEA, the brake needs to finalize special testing before the task is completed (Pawar, 2016). After meticulous research and accurate actions have been considered, the highest is the RPN number, the highest is the risk of the manifestation. The primary aspect that has been examined in both tables, was the possibility of Occurrence. In table 4 the highest number of the RPN was brake line fitting not fully tightened and brake pads were not fitted into the right orientation. Following accurate studying and research, those two priority risks were examined, and mitigate actions were determined. For this reason, in the Post FMEA, a massive improvement has been obtained, as the number of RPN has decreased. Although the number of the RPN has reduced, brake pads installed in the wrong direction have still the highest number, since there is a part of the risk that cannot be avoided with mitigating actions. One of the reasons is that it is easy to make a simple mistake, and as mentioned in Renu et al. (2016) that can cause a massive delay for a company and may receive inappropriate feedback from the customer. However, the fundamental role of the FMEA is to treat every single element as a possible failure, in other words, the other elements have been considered into equal aspects (Tretsiak, 2012).

Conclusion

To conclude, the main judgment of the FMEA has been discovered. As the quality of the product become exclusive, at the same time, the demand of the consumer increase.

This aspect has incredibly changed the way of how companies work, since the interest of the company to find a unique product has risen. Also, the research on the Health and Safety of workers to ensure that are working in a safe environment has become fundamental for a company. In addition, the FMEA is a successful process that with their team, are constantly working hard to find the best result and to avoid possible failure in a design, assembly process, and manufacturing. For this reason, the RPN is used to reduce the high potential failure of the project.

On the other hand, the Severity, Occurrence, and Detectability values are not constantly accurate and do not always show a constant improvement. As a result, some of the mitigating actions have been evaluating into an Initial and Post FMEA. At the same time, some results show higher RPN on the Initial FMEA, but the mitigating actions illustrate a massive decline in the Post FMEA. Besides, some actions cannot be reduced totally as the risk of failure is high and workers still need to pay particular attention, otherwise failures could affect the production. Finally, the entire potential failure, in the Initial and post-FMEA has been treated all in the same way, as the FMEA requires.

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