A Case Study of Risk Management of Automotive Industry Projects Using RFMEA Method

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Article Info

Article history:
Received Aug 25\textsuperscript{th}, 2020
Revised Oct 5\textsuperscript{th}, 2020
Accepted Oct 26\textsuperscript{th}, 2020

Keyword:
Project Risk
Risk Detection
Automotive Industry
Risk Management
FMEA

Abstract

Considering the market need and customer attraction, automakers are always trying to define new projects and present products with new capabilities in the market. That is why a significant part of car companies' development research is focused on the definition of new projects. Principally, project risk management in car companies is essential and thus given special attention. There are different theories and methods of project risk control. However, since there is complete awareness of FMEA-related issues (Failure Mode and Effects Analysis) in automotive companies due to the establishment of the quality management system, the project's risk analysis using FMEA method to control the risk of automotive industry projects is presented in this paper by a real example. For this purpose, FMEA indicators tables are designed and presented proportionally to project risk management. Results of this research show that using failure mode and effects analysis for project risk management ensures the detection of project's weaknesses and provides a practical model for identification and reduction of project risks.

1. Introduction

Undeniably, the life of any business depends on profit and income. Otherwise, there will be no reason to participate in any economic movement. Car companies achieve success through the utilization of existing opportunities and resources for development and innovation in products and services [1]. For this purpose, new projects are set up and executed to use these opportunities to provide new products with more efficiency or lower prices [2]. The critical element in taking advantage of available opportunities is to make decisions which idealistically should be done based on complete information with a high degree of certainty regarding outputs. However, in the actual world, most decisions, especially those related to project schedules, are made based on incomplete information along with a level of uncertainty regarding outputs [3]. This uncertainty leads to risk in a project which itself increases costs and project execution time. Project planning is mixed with uncertainties and possibilities, and thus the risk is always an inherent part of project management [4].

In recent decades, researchers have done extensive work in the field of project risk management and provision of a systemic approach for designing, scheduling, project control and project risk analysis [5]. The risks of each project and the demand prediction during the project depend on various factors which include the project type, products which are utilized from various retailers, project timing, people related to the project and other internal and external factors [6]. Project risks can include different risks including executive, human, financial, economic, and environmental risks and lack of support [7, 8]. We can classify project risks as execution-related risks, time risk, cost risk, accumulation of minor risks, environmental risks and catastrophic risks. The goal of this paper is to review execution, time and cost risks [9, 10].

Designing a risk management information system in projects can significantly help in identifying risks. Planned indicators in this field are considered by the researchers to discover how high risk affects the quality of planning and the

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project's success. These indicators include managerial aspects such as costs management, human resources, purchase and quality and also organization support based on organizational maturity models.

Due to the vastness of the automobile industry, the enormous amount of capital and a large number of people working in these industries have been the focus of project risk control experts, and extensive efforts have been made to identify and control risks in the projects of this industry. If project risks are not identified and controlled, it will cause disruption in the process of these projects, which itself will lead to different problems in economy and history of the companies and will add to the problems resulting from other issues. Undoubtedly, this is a critical issue in high-capital industries such as automotive industry. In addition to increasing reliability, projects risk control system offers significant services in maintaining human resources and commercial activities of the automotive industry; this system also makes the decisions of senior managers purposeful in the framework of project control management and strengthens its strategic basis.

Many factors determine the success of a project, but the absence of a proper project risk management will increase the possibility of a failure in a project. It is essential and crucial to use an effective method of planning and project risk management that is easily understood by the project team. Due to the growth and complexity of the project, using a multi-disciplinary project management approach requires proper attention to project risk management. In this article, a practical and effective method is proposed for project risk control management which is a useful tool to be used in risk management of industrial projects, especially those related to the automotive industry.

In this paper, a practical model of risk management is presented along with an example in the automotive industry in which the failure mode and effects analysis (FMEA) has been used. FMEA technique is a useful tool in quality management systems, including ISO 9000 and QS-9000. Given that these standards are established in these companies, experts and managers of these companies are familiar with FMEA and can easily use this tool for project risk control.

2. Definition and stages of project risk management

Project risk management consists of all the processes that are related to identification, analysis and responsiveness to any uncertainty, which includes maximizing the positive results of opportunities and minimizing the negative results of threats. In some sources, risk management is introduced as one of the twelve primary levels of knowledge of project management, such that project risk management is divided into phases of risk identification, risk measurement, response to risk and risk control [10].

In different sources, other definitions are provided. According to Bohm, risk management is a process that includes two main phases; risk estimation phase which includes risk identification, analysis and prioritization and risk control phase which includes risk management planning, risk monitoring planning and corrective actions. According to Fairley, risk management includes seven phases: 1) identification of risk factors; 2) estimating the possibility of risk occurrence and its effect; 3) providing solutions to adjust identified risks; 4) monitoring risk factors; 5) providing a possible design; 6) crisis management; 7) reviving the organization after a crisis [11]. Chapman and Ward proposed a general project risk management process which is consisted of 9 phases: 1) Identifying the project's key aspects; 2) Focusing on a strategic approach in risk management; 3) Detecting the occurrence time of risks; 4) Estimating the risks and analyzing the relation between them; 5) Risks ownership allocation and providing a proper response; 6) Estimating the amount of uncertainty; 7) Estimating the importance of relations between different risks; 8) Designing responses and monitoring the risk mode and 9) Controlling the execution stages [12]. Risk is viewed from two perspectives; one is decision theory, and another is a managerial perspective. From the decision theory perspective, the risk is defined as deviations in the distribution of possible system outputs. According to this perspective, risk can be quantified and placed in formats such as probability theory.

In contrast, most managers do not accept this quantitative approach to risk. They consider the risk to be controllable and tend to talk about risk in qualitative terms. The two mentioned perspectives are practically separated from each other. Experience has shown that lack of success in many projects is the result of the unfamiliarity of managers with quantitative methodologies of risk management and consequently not implementing the related techniques. On the other hand, the managerial approach to risk is based on the simple tools of the Pareto chart. It means that most managers tend to focus on critical risks, and this is an advantage over the decision theory approach, which addresses all risks and is, therefore, time-consuming. One of the suggestions is to integrate the two mentioned approaches to enjoy the benefits of both of them using FMEA method [13].

Pritchard is the first person who used FMEA in 2000 as an advanced method that can identify project risks [14]. Thomas et al. (2004) then expanded this model for project risk management and introduced RFMEA. Using RFMEA greatly helps the engineering management, project manager and project's team members. The application of this method in one of the automotive industry projects is later presented. Using this method has been emphasized by various researchers in order to analyze project risks. In fact, RFMEA is a systematic approach to identify project risks, quantify
risks and then to estimate the most critical project risks. RFMEA method is not just a project risk analysis method, but it also help us better identify and plan for the project's critical conditions in the early stages [15].

3. FMEA method

During the 50s, the importance of safety issues and preventing predictable accidents in the aerospace industry led to the emergence of FMEA. After a while, this method was raised as the critical tool for increasing safety in chemical industry processes, and from them, the goal of its implementation is to prevent accidents. In February 1992, SAE-J-1739 Standard was introduced as the FMEA standard reference in the automotive industry. Following that, the development of quality assurance systems in the automotive industry, especially the establishment of standard QS-9000 in the US automotive industry made the use of FMEA more widespread [16]. FMEA is an analytic technique based on pre-occurrence prevention which is used for using failure mode and effects analysis. The focus of this technique is increasing safety coefficient and consequently, customer satisfaction through prevention before failure [10]. FMEA is a tool that is used with minimum risk to predict problems and defections during the stages of designing or development of processes and services in the organization. One of the factors in the success of FMEA is its execution time. When we face a problem in many of the cases, corrective measures might be defined and executed to eliminate that problem. These measures are a reaction against what has happened. In such cases, permanent elimination is difficult and requires enormous costs and resources, because moving from the current situation toward optimal conditions will have high inertia. However, during the implementation of FMEA and by predicting potential problems and calculating their risks, measures will be defined and executed to eliminate them or reduce their occurrence rate. There are two types of FMEA, one is PFMEA which is potential failure modes and effects analysis, and the other is DFMEA which is design failure modes and effects analysis. Here, we define RFMEA, which is project risks failure modes and effects analysis [17].

4. RFMEA preparation steps

RFMEA preparation requires teamwork. The number of team members depends on the project's complexity. However, more than six people are not recommended. If the project is complicated, it is better to form multiple committees with each sub-team taking on the part of the work. Teams consist of experts who have the most knowledge of the project. People such as engineers and design specialists, construction and assembly, quality, after-sales service, marketing and logistics. From the initial stages of work to the implementation of the proposed measures and review of their results and eventually completing the RFMEA, these teams are responsible for all the related activities. One of the advantages of this team approach is that any activity that is defined will always be agreed upon by all units of the organization, and therefore their implementation will not cause any problems or resistance. In this method, project risks are first identified, and values of risk indicators including risk intensity, I, occurrence probability, P, and risk identification are extracted from the related tables, and then the risk score, R, and RPN are calculated. The risk score is risk intensity multiplied by the probability of its occurrence, and RPN is a risk score multiplied by the recognition number, N.

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R = I \times P 
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RPN = R \times N
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Then, Pareto chart for risk score and RPN are separately prepared, and the critical risk score and critical RPN are determined based on the results of previous projects or the experience of experts. In the next step, the RPN graph is drawn based on the risk score for all the risks and lines of critical risk score and critical RPN are specified. After that, risks that lie both in the range of critical risk score and critical RPN are specified, and proper measures will be defined to reduce their risk score and RPN. Then in the next stage, given the defined measures, values of intensity, occurrence, extraction recognition, risk score and RPN are determined again. This operation continues until all the risks have a risk score and an RPN score lower than the critical values [14].

Nine executive steps of RFMEA are:

1. Risk identification
2. Determining the values of indicators of occurrence, intensity and recognition from Tables 1, 2, and 3
3. Calculating risk score and RPN value
4. Drawing the Pareto chart of risk score
5. Drawing RPN Pareto chart
6. Determining RPN values and critical risk score
7. Drawing the Pareto chart based on risk score
8. Preparing an action plan for critical risks
9. Recalculating RPN and risk score

Table 1. Suggested criteria to assess occurrence

| Occurrence Probability                               | Occurrence number |
|------------------------------------------------------|-------------------|
| It is definitely going to happen                      | 10                |
| It is very likely to happen                           | 9                 |
| The chance of occurrence is medium                    | 8                 |
| It might happen                                       | 7                 |
| The possibility of occurrence exists                  | 6                 |
| The probability of happening and not happening is the same | 5             |
| The probability of occurrence is low                  | 4                 |
| It is unlikely to happen                              | 3                 |
| It is extremely unlikely to happen                    | 2                 |
| It will not happen                                    | 1                 |

Table 2. Suggested criteria to assess intensity

| Risk type | Effect type                                                      | Criteria |
|-----------|------------------------------------------------------------------|----------|
| Time      | It is more than 20% effective in increasing the critical path    | 10       |
| Cost      | It is more than 20% effective in increasing the project's total cost |         |
| Executive | It will destroy the project's objective                          |          |
| Time      | It is 15% to 20% effective in increasing the critical path       | 9        |
| Cost      | It is 15% to 20% effective in increasing the project's total cost|          |
| Executive | It will destroy the project's objective                          |          |
| Time      | It is 10% to 15% effective in increasing the critical path       | 8        |
| Cost      | It is 10% to 15% effective in increasing the project's total cost|          |
| Executive | It will lead to intensive changes on the project's outcome, or the project's outcome may not be usable. | 7        |
| Time      | It is 8% to 10% effective in increasing the critical path         |          |
| Cost      | It is 8% to 10% effective in increasing the project's total cost  |          |
| Executive | It will lead to changes on the project's outcome, or the project's outcome may be usable with some modifications |     |
| Time      | It is 6% to 8% effective in increasing the critical path          | 6        |
| Cost      | It is 6% to 8% effective in increasing the project's total cost   |          |
| Executive | It will lead to changes in the project's outcome, or the project's outcome may need some modifications | 5        |
| Time      | It is 4% to 6% effective in increasing the critical path          |          |
| Cost      | It is 4% to 6% effective in increasing the project's total cost   |          |
| Executive | It will lead to minor changes on the project's outcome, or the project's outcome may need some minor modifications |     |
| Time      | It is 2% to 4% effective in increasing the critical path          | 4        |
| Cost      | It is 2% to 4% effective in increasing the project's total cost   |          |
| Executive | Its effect on the project's outcome is small, but it needs internal modifications | 3        |
| Time      | It is 1% to 2% effective in increasing the critical path          |          |
| Cost      | It is 1% to 2% effective in increasing the project's total cost   |          |
| Executive | Its effect on the project's outcome is minimal and will be solved with little modifications | 2        |
| Time      | It is less than 1 per cent effective in increasing the critical path |      |
| Cost      | It is less than 1 per cent effective in increasing the project's total cost |        |
| Executive | With minor adjustments, the changes are negligible                |          |
| Time      | It does not change the project's critical path                    |          |
| Cost      | It does not change the project's cost                             | 1        |
| Executive | Changes are negligible                                           |          |
Table 3. Suggested indicators to evaluate recognition

| Recognition Probability                                      | Recognition no. |
|--------------------------------------------------------------|-----------------|
| The risk is unrecognizable                                   | 10              |
| The probability of risk recognition is relatively unlikely   | 9               |
| Risk recognition is unlikely                                 | 8               |
| The probability of risk recognition is relatively low        | 7               |
| The probability of risk recognition is low                   | 6               |
| The probability of risk recognition is relatively medium     | 5               |
| The probability of risk recognition is medium                | 4               |
| The probability of risk recognition is relatively high       | 3               |
| The probability of risk recognition is high                  | 2               |
| Risk recognition is definite, and there is enough time to act| 1               |

Definition of recognition: recognition is a method or technique to discover risk when there is enough time to take necessary action.

5. A practical example of using RFMEA in the automotive industry

In this study, the project of setting up a manufacturing line of a car part has been studied and investigated. This project has more than 500 activities, and the project launch time is estimated to be 30 months. The total cost of the project is 30 billion Rials. The main activities of the project include designing the production line and processes, estimating, designing and creating buildings and facilities, purchasing, installing, commissioning and delivery of machinery, installation and commissioning of mechanical facilities of the project and purchase and delivery of project's additional equipment. Each of the above activities is divided into a large number of sub-activities, which are beyond the scope of this article, and only the following five main activities are sufficient as examples, and their risks are analyzed.

A- Installation of hydraulic press
B- Setting up the press
C- Producing the prototype with the press
D- Setting up the drilling machine
E- Setting up the overhead crane

Table 4 shows the risks of these activities along with the values of occurrence, intensity, recognition, risk score and RPN of risks. This table is prepared by teams and with the presence of 6 experts from related sections. For each item, experts have engaged in various discussions and values of indicators were agreed upon by all. In the case of disagreements between the experts regarding the values of the above indicators, a separate committee has been formed to further investigate to ensure the accuracy of the risk score.

After completing the RFMEA table, Pareto charts for risk score and RPN are provided as the following:

Figure 1. Pareto chart for risk score
Critical RPN and critical risk score should be selected according to the data so that we can identify the risks that are in critical condition. In this project and given the previous experiences of project team members, a critical risk score of 25 and critical RPN of 100 are selected. Based on the risk score and by placing the risk score and critical RPN, the RPN graph is as following.
Risks that are on the right edge of Figure 3 are in critical condition, and proper measures should be taken to reduce their RPN and risk score to less than critical values. These risks are six, which are shown in grey in RFMEA Table. Measures taken in project activities to reduce critical risks are presented in Table 5.

| Risk Number | Risk Description                                                                 | Taken Measures                                                                                     |
|-------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| 2           | If the main press does not work after installation, the hydraulic system has a   | The hydraulic system must be assembled and tested before installation                                |
|             | problem and needs to be redesigned and reinstalled                               |                                                                                                   |
| 5           | If the press does not work correctly after installation, then the assembly is    | For press assembly, we must use the help of experienced consultants in the hydraulic press industry |
|             | not done correctly, and the parts must be disassembled and reassembled          |                                                                                                   |
| 6           | If the press cannot be launched after installation, then the power required for  | Calculations related to the required electrical power of the press should also be calculated and    |
|             | the press is underestimated, and the substation must be strengthened             | announced by the project installation supervisor.                                                 |
| 10          | If the production part is broken, then the tonnage of the press is low, and the  | The required tonnage of the press to form the doors is recalculated separately by the product      |
|             | press must be strengthened                                                        | engineering and production engineering, and then the results are compared with each other to       |
|             |                                                                                 | ensure the amount of tonnage required by the press.                                              |
| 12          | If the produced part is broken, then the system software is not working correctly| System control software should be re-tested by the company's net unit before installation on the   |
|             | and needs to be repurchased and reinstalled                                      | press.                                                                                             |
| 14          | If the produced part is broken, then the device is not correctly set and must    | The opinion of experienced people from press companies should be used to set up the machine.     |
|             | be readjusted                                                                     |                                                                                                   |
After applying the above items, values of risk indicators for activities with critical risk are recalculated, which are shown in Table 6. As can be seen, all the risks have a risk control and a RON lower than the critical values. Therefore, there is no need for new measures to reduce the risk amount, and the project is in good condition in terms of risk management.

**Table 6. RFMEA Table after Taking Necessary Actions to Deal with Critical Risks**

| Plan number to respond to the action | Risk Number | Risk Description | Project time increase (month) | Reviewed project cost increase (Million Rial) | Reviewed possible time of occurrence | Reviewed occurrence probability number | Reviewed intensity number | Reviewed Risk number (multiplication of columns 7 and 8) | Reviewed Recognition probability | Reviewed RPN (multiplication of columns 9 and 8) |
|------------------------------------|-------------|-----------------|------------------------------|---------------------------------------------|------------------------------------|--------------------------------------|--------------------------|-----------------------------------------------|---------------------------------|-------------------------------------|
| A                                  | 2           | If the main press does not work after installation, the hydraulic system has a problem and needs to be redesigned and reinstalled | 3 10%                       | 1500 5%                                 | During launch                      | 3 8 24                           | 4                           | 96                                           |                                 |                                    |
| A                                  | 5           | If the press does not work correctly after installation, then the assembly is not done correctly, and the parts must be disassembled and reassembled | 3 10%                       | 1000 3%                                 | During launch                      | 2 8 16                         | 5                           | 80                                           |                                 |                                    |
| A                                  | 6           | If the press cannot be launched after installation, then the power required for the press is underestimated, and the substation must be strengthened | 2 7%                        | 400 1.3%                                | During launch                      | 3 6 18                         | 3                           | 54                                           |                                 |                                    |
| C                                  | 10          | If the production part is broken, then the tonnage of the press is low, and the press must be strengthened | 3 10%                       | 1200 4%                                 | During final testing               | 2 8 16                         | 4                           | 64                                           |                                 |                                    |
| C                                  | 12          | If the produced part is broken, then the system software is not working correctly and needs to be repurchased and reinstalled | 2 7%                        | 100 0.3%                                | During final testing               | 4 6 24                         | 3                           | 72                                           |                                 |                                    |
| C                                  | 14          | If the produced part is broken, then the device is not correctly set and must be readjusted | 1 3%                        | 10 0.03%                                | During final testing               | 6 4 24                         | 2                           | 48                                           |                                 |                                    |

6. Conclusions

Using RFMEA in risk management is a relatively simple and practical method. Given that the FMEA method is wholly known in automotive companies thus using it is more effective for project risk management. This method defines two indicators of risk score and RPN for all the risks, and in other words, it introduces project risks in quantitative terms. With this method, we can quickly identify critical risks and take proper actions to deal with them. Then, the values of numerical risk indicators are calculated, and we ensure that the risks are lower than the critical condition. Employing this method in automotive companies have had good results and has led to improvements in project management indicators such as time, deviation from the determined cost and technical quality of projects.

7. Acknowledgements

The authors would like to acknowledge of the cooperation of Dr Bashirnezhad, the assistant professor of the department of mechanical engineering of Azad University, for his tireless efforts; Mr Zabetnia, board member of Mashhad Ring Manufacturing Company and Prof. Razavi.

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