Construction project risk evaluation based on FMEA

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Abstract. FMEA (Failure Mode & Effects Analysis) is a preventive risk analysis technique, which purpose is to make the prevention in advance, rather than correct afterwards. Its core is to evaluate the failure mode from three dimensions: S (Severity), O (Occurrence) and D (Detection). The risk is reduced to an acceptable level by quantifying the failure mode of the risk and the cause of the key failure, and developing preventive measures to control it. Fuzzy comprehensive evaluation is a combination of qualitative and quantitative analysis, which combines the advantages of qualitative and quantitative. Combining FMEA with the Fuzzy comprehensive evaluation method, using the advantages of FMEA’s pre-existing control and full-process participation, it can make up for the shortcomings of the Ex-post control higher than Ex-ante control in the current risk management, and make the risk evaluation method more perfect. It is necessary and meaningful to reduce the losses caused by the risk of projects by making effective and reasonable analysis and control of the risks that may occur in the construction project.

1. Introduction
Risk assessment is a very important part of the risk management system. It is mainly to determine what kind of standard can be used to evaluate the potential risk, and whether the risk can be accepted. In each of the proposed or under construction projects, where always hid a variety and different types risks. Whether the project can be success, the key is whether the project decision-makers can be able to identify and evaluate all possible risks of the project life cycle, and whether is able to use of reasonable and effective risk response measures and strategies based on the evaluated results. In view of the real engineering project risk, making effective identification, prediction, evaluation and decision can avoid and reduce the risk, and achieve the maximum benefit under the given risk.

2. FMEA Relevant Overview
FMEA is a reliability analysis technology have a preventive, "feed forward control" greater than "feed back control" characteristic. It is based on the method of the structured system, as early as possible to find out the possible failure modes or risk factors, and analyze the causes of these failure modes and the possible impacts on the sub-systems, subsystems and the entire system of the previous layer after the failure mode occurs. On this basis, reasonable and effective prevention and improvement measures are taken to develop appropriate prevention and improvement programs.

Through making the thorough and detailed analysis to the possible risk of the subsystems and components of the whole system, and dividing the failure mode according to the degree of it’s harm,
classifying with the size of the severity. Appropriate to the proposed reasonable effective prevention or improvement measures, in order to reduce the possibility of the entire system failure.

Risk priority number method is the commonly used measure in risk assessment of FMEA. This method sorts the risk factors with using risk priority number, and concludes the order of all risk factors. To get the RPN of various factors, the perpetrators must be clear that:

① The severity of the impact of each failure mode (S)
② The emergence probability of each reason caused failure mode (O)
③ The difficulty of detection of each reasons caused the failure mode (D)

RPN is calculated by these three factors:

\[ RPN = S \times O \times D \]

The larger the RPN value, the larger the failure mode or risk, and the greater the impact of a specific failure mode or risk on the project. For different projects, it is necessary to develop a response plan and improvement plan.

S, O, D is the three main factors of FMEA. S is the severity of the failure mode. O is the probability of the failure. D is the probability of not detecting the failure. For obtaining the RPN of a potential failure mode, the three risk factors are evaluated using the 10-point scale described in Tables 1.

The relationship between RPN and S, O, D is expressed using the tabular form in Figure 1.

It expresses that the failure mode is controlled, and cannot pay attention or consideration, when the value of RPN (generally < 50) is very low. But appropriate precautions and improvement measures must be taken, if the value of S is high, regardless of the value of RPN is high or low.

| Score | S | O | D |
|-------|---|---|---|
| 10    | serious harm of no warning | Very high, Almost inevitable | ≥ 1/2 | Absolutely not sure |
| 9     | serious harm of warning    | Very high, Almost inevitable | 1/3 | Very rarely |
| 8     | Very serious               | High, Recurrent             | 1/8  | Rarely |
| 7     | More serious               | High, Recurrent             | 1/20 | Seldom |
| 6     | General serious            | Moderate, Occasional occur  | 1/80 | Few |
| 5     | General                    | Moderate, Occasional occur  | 1/400| Moderate |
| 4     | Minor slight               | Low, Relatively few happen  | 1/2000| Upper middle |
| 3     | Slight                     | Low, Relatively few happen  | 1/15000| Much |
| 2     | Very slight                | Low, Relatively few happen  | 1/150000| Very much |
| 1     | Nix                        | Very low, hardly occur      | ≤ 1/1500000| Almost certain |

Table 1. The 10-point scale described

| Sort | S                  | O                   | D                  | RPN               |
|------|--------------------|---------------------|--------------------|-------------------|
| 1    | No effect          | Hardly occurs       | Easy to find       | Low (good)        |
| 2    |                    |                     |                    |                   |
| 3    |                    |                     |                    |                   |
| 4    |                    |                     |                    |                   |
| 5    |                    |                     |                    |                   |
| 6    |                    |                     |                    |                   |
| 7    |                    |                     |                    |                   |
| 8    |                    |                     |                    |                   |
| 9    |                    |                     |                    |                   |
| 10   | Very dangerous or serious | High probability of occurrence | Hardly find | High (bad) |

Figure 1. The relationship between RPN and S, O, D
3. FMEA feasibility analysis in the construction project risk assessment

Based on the theoretical knowledge of risk assessment, we can easily get that the successful risk assessment must run through the whole life cycle of one project. The environment of construction maybe change at any time, and risk is ever-present, so the required risk management plan must be dynamic, and timely. Risk management is a very strong processed work, FMEA also is a more strong processed work. At the same time, timeliness is the most important for the successful implementation of FMEA. Also only to be able to judge and predict the possible risks, it is able to make the possible losses to minimum, and can be named the successful risk management plan.

Secondly, the management process of the constriction project risk management correspond with the implement process of FMEA. The failure mode is corresponding to the risk identification process, the assessment of S, O and D to the risk assessment process of the constriction project risk management. They all take the appropriate measures to the failure modes or risks after risk assessment. Therefore, the method-FMEA can be applied in the construction project risk management.

Specially, it is a necessary step making the assessment of the influence degree to the failure mode in the whole system for the FMEA implementation. Such as the risk priority method, its core formula is: .The effects caused by the sub-systems and each components of the whole system are the formula assessment contents. This is similar with the WBS which assesses the possible risk from top to down used in the construction project risk management.

It can be obtain that FMEA and construction project risk management in the implementation process and the risk assessment method and ways have the similarities through the above comparison. These similarities indicate that the FMEA applied to the construction project risk management is feasible. Meanwhile, the characteristic of FMEA-“feed forwards control” is higher than “feed back control” will enable construction project risk management more effective. So, making plenty understanding and appropriate using in project risk management to FMEA, which will reduce the project losses caused by risk and minimize the losses.

4. The Establish of Project Risk Assessment System Based on FMEA

Many preparatory works need to be finished before carrying the risk assessment. The first thing to do in risk management is to determine the scope of the project to be carried out, and then identify the risk factors that may cause losses within the scope of the project. These factors are analyzed, then risk assessment is conducted to determine the degree of risk, and finally, based on the results of the risk assessment, effective response is made.

When building a project using FMEA for risk management, the first thing to do is to set up an FMEA risk management team. The team members should include all relevant stages of the entire construction project and the participants of the process as much as possible. Then it is to determine the scope of management. The next step is to analyze the risk factors that may occur, record them in the FMEA form, and use them as a factor. This paper uses the risk priority number method in the assessment, and evaluate the risk factors by the experts.

As present in table 2, in the FMEA expert evaluation table, each expert evaluates each of the factors listed in table based on the full consideration in the severity(S), the occurrence possibility(O) and the detectable degree(D) of every risk factors in the project.

Table 2. The FMEA expert evaluation table

| number | Failure mode | S    | O    | D    | RPN | explanation |
|--------|--------------|------|------|------|-----|-------------|
| Factor | Sub-factor   |      |      |      |     |             |
| 1      | U1           | U_{11}|      |      |     |             |
| 2      |              | U_{12}|      |      |     |             |
| 3      | U2           | U_{21}|      |      |     |             |
| 4      |              | U_{22}|      |      |     |             |
| 5      | U3           | U_{31}|      |      |     |             |
Evaluation factors in the table need to develop the corresponding evaluation standards, and then calculate the values of the risk coefficient RPN:

\[ RPN = S \times O \times D \]

After calculating the RPN, it is then applied to the fuzzy comprehensive evaluation method, and the risk factors are evaluated by the combination of the two.

5. Conclusion
Risk assessment occupies an important position in risk management. Only analysis the risks correctly, the best response plans could be made. Most of the previous risk assessment methods mostly focuses on afterwards events. Introducing FMEA into risk assessment can combine the feature of FMEA-feed forwards control is higher than feedback control. At the same time, since the FMEA is a method of reliability analysis that can be used throughout the life cycle, the evaluation of the risk in the project can also be carried out throughout the life cycle without causing a disjointed information.

Fuzzy comprehensive evaluation is the method combining qualitative and quantitative analysis. It combines their advantages and improves the risk assessment method. Making effective and reasonable analysis and control before the event, it is necessary and meaningful for reducing project risk losses.

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