

# The method of Network Risk Assessment based on the Extension Engineering

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**Abstract.** With the fast paced development of the network planning techniques, its application in the project management area is gaining momentum. The practice of network planning in real life projects is affected by a variety of risk factors. In order to better estimate project status with network planning techniques, the article proposes a methodology to quantify the degrees of risks and to take precautions during project execution to minimize the risk related costs and to achieve the project objectives. This methodology performs an overall evaluation of the risk factors through the extension engineering method, considering the unpredictability nature of the continuing effect of the risk factors on Program Evaluation and Review Technique (PERT)

## 1. Introduction

Project management is a series of activities, including decision-making and planning, organizing and monitoring, controlling and coordination, training and motivating, to achieve the success of project under some specific constraints. The task of project management includes the whole process of project management activities to fulfill the objectives of the cost, schedule and quality under certain conditions. However, the complicated engineering project environment introduces a lot of risks on cost, schedule, and quality control. It is a significant challenge for managers to qualify and quantify the influence of the uncertainty upon all aspects of the project engineering. Article [1] aims at non-busy periods of PERT network plan, redistribute the time of the non-busy periods to formulate the PERT network with effective process arrangement. This method is not practical with real life projects, taking account the risk factors within project environment. Article [2] is based on PERT, but also conducts project risk analysis and assessment. However, it only performs probability calculation, without utilizing any effective approach to do qualitative and quantitative evaluation for the risk factors. Article [3] combines the application of the fuzzy theory and PERT network plan to reveal the critical path of the project. This approach has demonstrated positive result, however, it fails to include consideration of the influence of the risk factors. Article [4] builds a general model for the transition of risk elements in the GERT network plan, but it focuses on the nodes immediately before a GERT node for the completion of the node. instead of the whole project work. In real life project environment, the application of this model has also proved to be limited.

Therefore, the current research about network planning technique has two problems. One is the lack of consideration of the risk factors; the other one is the absence of an effective algorithm. This thesis proposes an approach, which is based on the project schedule management and the randomness of PERT continuing to be affected by the actual risk factors, and uses extension engineering method to comprehensively evaluate the risk factors and determine the risk level, and to promptly take



precautions in the project execution to reduce the risk related costs, so that the project may accomplish the anticipated objectives.

## 2. Risk management

Engineering project risk management is the process to identify project risks, evaluate risks, and plan responds to project risks. Project risk management is to realize positive risks to benefit the project, and to reduce or avoid the negative risks minimize the impact to the project. The primary task of the risk management is to recognize the risk of possible loss caused by a potential event, and then to analyze and evaluate the identified risk. The main measure of the risk is by the equation  $R = \sum (P_i C_i)$ , where  $P_i$  is the probability of  $i$ th failure event, while  $C_i$  is the impact caused by the  $i$ th failure event.

A common method of risk presentation is risk probability and impact matrix method, the figure 1 shows an example of such a risk matrix.

|          |                | Likelihood  |              |                 |              |              |
|----------|----------------|-------------|--------------|-----------------|--------------|--------------|
|          |                | I<br>Remote | II<br>Unlike | III<br>Possible | IV<br>Likely | V<br>Certain |
| Severity | 1<br>Trivial   |             |              |                 |              |              |
|          | 2<br>Minor     |             |              |                 |              |              |
|          | 3<br>Lost time |             |              |                 |              |              |
|          | 4<br>Major     |             |              |                 |              |              |
|          | 5<br>Fatal     |             |              |                 |              |              |

Figure1. Risk matrix

The risk matrix divides the severity of evaluation into five levels, respectively 1, 2, 3, 4, 5, or not serious, not very serious, general serious, serious and very serious. It divides likelihood into five levels based on the size of the failure of numerical, I, II, III, IV, V, of which I means possibility is very low, while V means possibility is very high.

## 3. The extension engineering methods

### 3.1. Introduction

In project risk evaluation and prediction, we frequently encounter comprehensive analysis with multi factors, which often are expressed in different forms, such as percentage, dimensional values, or scores. Extension engineering method tends to combine these different forms of expression into a comprehensive factor, combine the quantitative and qualitative research, studies the quantity relation and its changes and the relationships between things and change.

### 3.2. Correlation function and correlation function algorithm

Give the domain  $U$  and a set in the  $U$ . Use a number in the  $(-\infty, +\infty)$  to describe the degree of the element  $u$  in the  $U$  belongs to or doesn't belong to  $A$ , denoted by  $K(U)$ ,  $-\infty < K(u) < +\infty$ ,  $K(u) > 0$  shows the degree of  $u$  belongs to  $A$ ,  $K(u) < 0$  shows the degree of  $u$  not belongs to  $A$ ,  $K(u) = 0$  shows the degree of  $u$  belongs to or not belongs to  $A$ ,  $K(u)$  is called correlation function.

**3.2.1. Distance.** If  $x$  is one point in real domain  $(-\infty, +\infty)$ ,  $(x, y)$  and  $X_0 = \langle a, b \rangle$  are two intervals in the real domain. so  $\rho(x, X_0) = \left| x - \frac{a+b}{2} \right| - \frac{1}{2}(b-a)$  is called the distance between point  $x$  and interval  $X_0$ .

3.2.2. *Place value.* If  $X_0 = \langle a, b \rangle$ ,  $X = \langle c, d \rangle$ , and  $X_0 \subset X$ , so the place value of the point  $x$  about

the two intervals  $X_0$  and  $X$  is

$$D(x, X_0, X) = \begin{cases} \rho(x, X) - \rho(x, X_0), & x \notin X_0 \\ -1, & x \in X_0 \end{cases} \quad (1)$$

3.2.3. *Correlation function.* The correlation function of point  $x$  about intervals  $X_0, X$  is

$$K(x) = \frac{\rho(x, X_0)}{D(x, X_0, X)} \quad (2)$$

### 3.3. The computing of extension engineering method (extensional method)

- Determine the measurement conditions
- Determine evaluation index of the object that is to evaluate
- Determine the Amount of domain and the limit Amount of domain of every evaluation index that Correspond to evaluation degree
- Calculate qualified level
- Standardize the qualified level
- Determine the weight coefficient
- Calculate priority degree

### 3.4. The application of extension engineering method

In PERT network, pessimistic time is time when risk occurs. Due to the occurrence of risk, the three major objective, namely cost, schedule, and quality of the project are affected, especially for the critical path. In the points of cost, schedule, quality, project managers may use the method of extension engineering to evaluate the degree of risk according to the corresponding risk matrix, and to determine the risk area, so that the she may take corresponding preventive measures to ensure the completion of the project targets.

## 4. Case analysis

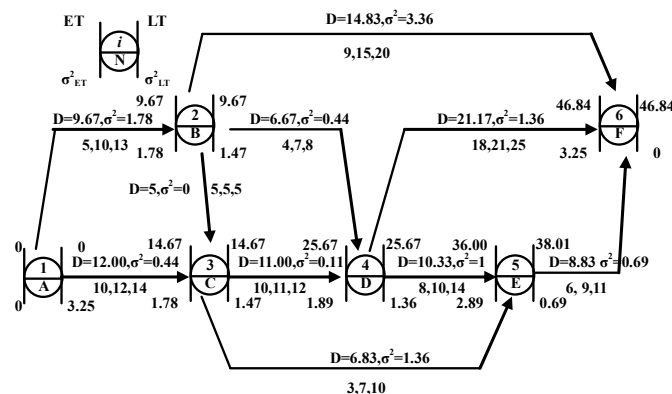


Figure2. Network planning

After calculating, we can obtain the key nodes are ①②③④⑥, and the key path is ①→②→③→④→⑥. In addition, we assume that delaying one day the compensation for loss is 0.5% of the total cost.

#### 4.1. Determine the measurement conditions

Assume that the risk factors can be expressed like this: C1-cost increases, C2- schedule delays, C3-quality standard. Their classification is in the table, respectively, range  $\langle 0,0.2 \rangle$ ,  $\langle 0.2, 0.4 \rangle$ ,  $\langle 0.4,0.6 \rangle$ ,  $\langle 0.6,0.8 \rangle$ ,  $\langle 0.8,1.0 \rangle$  express  $I \sim V$  in turn.

Table 1. The classification of factors.

| Factors  | The level of factor |          |                    |            |           |
|----------|---------------------|----------|--------------------|------------|-----------|
|          | I                   | II       | III                | IV         | V         |
| cost     | Not Apparent        | under3%  | 3%~6%              | 6%~9%      | Exceed 9% |
| schedule | Not Apparent        | under3%  | 3%~6%              | 6%~9%      | Exceed 9% |
| quality  | Not Apparent        | A little | Accept reluctantly | Not accept | useless   |

4.2. *Determine evaluation index of the object that is to evaluate (The severity of failure consequences)*  
 The consequences of failure are divided into 5 levels, each corresponds with I, II, III, IV, V levels after the failure in the risk matrix The element that to be evaluate as follows:

$$R = \begin{bmatrix} H & c_1 & V_1 \\ & c_2 & V_2 \\ & c_3 & V_3 \end{bmatrix}$$

V1, V2, V3, each represents the level of evaluation. Assume that the risk factors occur in the critical path ① → ②, resulting in the actual construction duration 13 days. After the calculation, the total extensive duration is  $13 - 9.67 = 3.33$  days, the costs incurred for the  $C * 0.5\% * 3.33 = 1.665\% C$ , no significant quality reduced. From the table, we can see that "loss cost" is class II, "delayed schedule" is level IV, "substandard quality" is I. Then

$$R = \begin{bmatrix} H & c_1 & V_1 \\ & c_2 & V_2 \\ & c_3 & V_3 \end{bmatrix} = \begin{bmatrix} H & c_1 & \langle 0.2 & 0.4 \rangle \\ & c_2 & \langle 0.6 & 0.8 \rangle \\ & c_3 & \langle 0 & 0.2 \rangle \end{bmatrix}$$

4.3. *Determine the amount of domain and the limit amount of domain of every evaluation index that Correspond to evaluation degree*

4.3.1. *Divide the consequences of failure into five degrees*. They are H1, H2, H3, H4, H5 (not serious, not too serious, seriousness of the general, more serious, very serious), so the amount of domains are described as  $V_{ij}$  as follows:

$$\begin{aligned}
 R &= \begin{bmatrix} H & H_1 & H_2 & H_3 & H_4 & H_5 \\ c_1 & V_{11} & V_{12} & V_{13} & V_{14} & V_{15} \\ c_2 & V_{21} & V_{22} & V_{23} & V_{24} & V_{25} \\ c_3 & V_{31} & V_{32} & V_{33} & V_{34} & V_{35} \end{bmatrix} \\
 &= \begin{bmatrix} H & H_1 & H_2 & H_3 & H_4 & H_5 \\ c_1 & \langle a_{11}, b_{11} \rangle & \langle a_{11}, b_{11} \rangle & \langle a_{11}, b_{11} \rangle & \langle a_{11}, b_{11} \rangle & \langle a_{11}, b_{11} \rangle \\ c_2 & \langle a_{11}, b_{11} \rangle & \langle a_{11}, b_{11} \rangle & \langle a_{11}, b_{11} \rangle & \langle a_{11}, b_{11} \rangle & \langle a_{11}, b_{11} \rangle \\ c_3 & \langle a_{11}, b_{11} \rangle & \langle a_{11}, b_{11} \rangle & \langle a_{11}, b_{11} \rangle & \langle a_{11}, b_{11} \rangle & \langle a_{11}, b_{11} \rangle \end{bmatrix} \\
 &= \begin{bmatrix} H & H_1 & H_2 & H_3 & H_4 & H_5 \\ c_1 & \langle 0.0, 0.2 \rangle & \langle 0.2, 0.4 \rangle & \langle 0.4, 0.6 \rangle & \langle 0.6, 0.8 \rangle & \langle 0.8, 1.0 \rangle \\ c_2 & \langle 0.0, 0.2 \rangle & \langle 0.2, 0.4 \rangle & \langle 0.4, 0.6 \rangle & \langle 0.6, 0.8 \rangle & \langle 0.8, 1.0 \rangle \\ c_3 & \langle 0.0, 0.2 \rangle & \langle 0.2, 0.4 \rangle & \langle 0.4, 0.6 \rangle & \langle 0.6, 0.8 \rangle & \langle 0.8, 1.0 \rangle \end{bmatrix}
 \end{aligned}$$

4.3.2. According to 4.3.1, we can see that the limit amount of domains are

$$c_1: \langle 0, 1.0 \rangle; c_2: \langle 0, 1.0 \rangle; c_3: \langle 0, 1.0 \rangle, \text{ then: } R = \begin{bmatrix} H & c_1 & V_{10} \\ & c_2 & V_{20} \\ & c_3 & V_{30} \end{bmatrix} = \begin{bmatrix} N_0 & c_1 & \langle 0, 1.0 \rangle \\ & c_2 & \langle 0, 1.0 \rangle \\ & c_3 & \langle 0, 1.0 \rangle \end{bmatrix}$$

#### 4.4. Calculate qualified level

Using correlation function can calculate the qualified level

$$K_j(V_i) = \frac{\rho(V_i, V_{ij})}{D(V_i, V_{ij}, V_{i0})}$$

$$K_1(V_1) = \frac{\rho(V_1, V_{11})}{D(V_1, V_{11}, V_{10})} = \frac{\rho(V_1, \langle a_{11}, b_{11} \rangle)}{D(V_1, \langle a_{11}, b_{11} \rangle, \langle a_{10}, b_{10} \rangle)} = \frac{\rho(\langle 0.2, 0.4 \rangle, \langle 0, 0.2 \rangle)}{D(\langle 0.2, 0.4 \rangle, \langle 0, 0.2 \rangle, \langle 0, 1.0 \rangle)}$$

$$D(\langle 0.2, 0.4 \rangle, \langle 0, 0.2 \rangle, \langle 0, 1.0 \rangle) = \rho(\langle 0.2, 0.4 \rangle, \langle 0, 1.0 \rangle) - \rho(\langle 0.2, 0.4 \rangle, \langle 0, 0.2 \rangle)$$

$$\rho(\langle 0.2, 0.4 \rangle, \langle 0, 1.0 \rangle) = \frac{1}{2} [\rho(0.2, \langle 0, 1.0 \rangle) + \rho(0.4, \langle 0, 1.0 \rangle)] = -0.3$$

$$\rho(\langle 0.2, 0.4 \rangle, \langle 0, 0.2 \rangle) = \frac{1}{2} [\rho(0.2, \langle 0, 0.2 \rangle) + \rho(0.4, \langle 0, 0.2 \rangle)] = 0.1$$

$$K_1(V_1) = \frac{0.1}{-0.3 - 0.1} = -0.25$$

Similarly, we can calculate other qualified level values as follows:

$$\begin{aligned} K_1(V_1) &= -0.25 & K_2(V_1) &= 0 & K_3(V_1) &= -0.25 & K_4(V_1) &= -0.5 & K_5(V_1) &= -0.625 \\ K_1(V_2) &= -0.625 & K_2(V_2) &= -0.5 & K_3(V_2) &= -0.25 & K_4(V_2) &= 0 & K_5(V_2) &= -0.25 \\ K_1(V_3) &= 0 & K_2(V_3) &= -0.5 & K_3(V_3) &= -0.75 & K_4(V_3) &= -0.833 & K_5(V_3) &= -0.625 \end{aligned}$$

#### 4.5. Standardize the qualified level

Use the formula ( ) to standardize the qualified level

$$k_I = \begin{cases} \frac{K(I)}{\max_{x \in X_0} K(x)} & K(I) > 0 \\ \frac{K(I)}{\max_{x \in X_0} |K(x)|} & K(I) < 0 \end{cases}$$

According to the formula above we standardize the qualified level as follows:

$$\begin{aligned} K_1(V_1) &= -0.25 & K_2(V_1) &= 0 & K_3(V_1) &= -0.25 & K_4(V_1) &= -0.5 & K_5(V_1) &= -0.625 \\ K_1(V_2) &= -0.625 & K_2(V_2) &= -0.5 & K_3(V_2) &= -0.25 & K_4(V_2) &= 0 & K_5(V_2) &= -0.25 \\ K_1(V_3) &= 0 & K_2(V_3) &= -0.5 & K_3(V_3) &= -0.75 & K_4(V_3) &= -0.833 & K_5(V_3) &= -0.625 \end{aligned}$$

#### 4.6. Determine the weight coefficient

Use AHP to determine the weight, establish the

$$A = \begin{bmatrix} c_1 & c_2 & c_3 \end{bmatrix}$$

$$\text{judgments matrix} = \begin{bmatrix} 1 & 2 & 2 \\ 1/2 & 1 & 1 \\ 1/2 & 1 & 1 \end{bmatrix},$$

$c_1, c_2, c_3$  Separately express cost, schedule and quality. According to the judgments matrix we can calculate the weight  $A = (0.5, 0.25, 0.25)$

#### 4.7. Calculate priority degree

The priority degree of H1 is

$$C(H_1) = A \circ K(H_1) = (A_1, A_2, A_3) \circ \begin{bmatrix} k_{11} \\ k_{21} \\ k_{31} \end{bmatrix} = (0.5, 0.25, 0.25) \circ \begin{bmatrix} -0.25 \\ -0.625 \\ 0 \end{bmatrix} = -0.281$$

Similarly,

$$C(H_2) = -0.25$$

$$C(H_3) = -0.625$$

$$C(H_4) = -0.458$$

$$C(H_5) = -0.594$$

Compare  $H_j$ , the maximum is  $C(H_2) = A \circ K(H_2) = -0.25$ . Then the risk of failure consequences is grade II, that the consequence of failure is "not serious". Corresponding to the project management risk matrix can be aware of this risk level in the low-risk areas, indicates that the main indicators of project are impacted to a lesser extent, will not cause a temporary loss. But risk measures should be prepared all the same.

## 5. Conclusion

In this paper, we exams the risk factors of the critical path in PERT from three angles, namely cost, schedule, and quality, then use the extension engineering method to comprehensively evaluate, and determine the level of risk for project managers so that decision making is based on good data collected.

Project management includes more concerns than cost, schedule, and quality. Other concerns like safety, environmental protection will also be impacted by project risk factors. Therefore, application of extension engineering methods to evaluate the risk factors should consider more aspects of the project, so that the risk assessment will produce more accurate and valuable information for project decision making.

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