Risk Evaluating of Chongqing Yangtze River Highway Tunnel Environment

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Abstract. The quantitative description on risk analysis is the assumption of risk management. Traditional risk assessment methods of engineering project are often affected by subjective factors. Fuzzy comprehensive evaluation by entropy weight model serve as a tool provide us a way to assess the risk. This new method could reduce or avoid the effect of subjective factors and fuzzy factors. This article introduce the basic theory of the method and analyze the risk of Chongqing Yangtze River Highway Tunnel environment, then calculates various risks factor using the entropy power the weight, and combines fuzzy mathematics method to establish evaluation model by combining qualitative analysis and quantificational computability, to evaluate the risk factor and to draw the conclusion. The practical analysis has proven that this method is preferable and feasible.

1. The entropy weight model theory
In the fuzzy risk evaluation, the design of the entropy weights is an important content, and it has significant impacts on the evaluation. Entropy is the concept of thermodynamics. Entropy is introduced in information theory by the Shannon (CE Shannon), and now it is widely used in the engineering, socio-economic etc, we have achieved good results by the theory[1-3]. The entropy weights as the weight, has a special meaning. This is under the circumstances that all of the evaluations, given evaluation objects set, to determine post-evaluation. The entropy is the target the relative intensity factor in a competitive sense. The values of the risk factors support the various indicators of evaluation has the big difference. The information entropy value is small, but the entropy weights is larger, indicating that the factor in the evaluation of the role of a larger. If all the values of the risk factors support the various indicators of evaluation set is same, that is, the information entropy reaches its maximum 1, and the entropy weights at this time is zero, then the factors is almost non-functional in a comprehensive evaluation[4].

If there are m evaluation factors, select s-reviewers to form a raw data matrix \( M = (m_{ij})_{m \times s} \), \( m_{ij} \) is the level of risk factors which j estimator to evaluate i index, \( i = 1,2,\cdots m; j = 1,2,\cdots s \) is the level of risk factors which j estimator to evaluate i index, the risk rating in the evaluation gather within the \( V = \{v_1, v_2, \cdots v_s\} \), and through the matrix of each index derived entropy value and entropy weight. In the Level of risk assessment problem, the i of the entropy factor evaluation index is defined as follow:

\[
H_i = -k \sum_{j=1}^{s} f_{ij} \ln f_{ij}, \quad i = 1,2,\cdots, m
\]
In formula, \( f_y = m_j \left/ \sum_{j=1}^{k} l_j \right. \), \( k = \frac{1}{\ln s} \); and assume that, when \( f_y = 0 \), \( f_y \ln f_y = 0 \).

The \( i \) evaluation index corresponding to the entropy weight of \( w_i \) is defined as:

\[
\begin{align*}
    w_i = (1 - H_i) \left( m - \sum_{i=1}^{m} H_i \right), \quad i = 1, 2, \ldots, m
\end{align*}
\]

Thus calculate the entropy weight of the right of all risk factors, from these entropy weight values to construct risk factors of the weight vector set: \( A = \{w_1, w_2, \ldots, w_m\} \).

2. Based fuzzy entropy of risk assessment model

The basis of the establish of Project Risk fuzzy entropy weight Evaluation Model, has determined the main factors that influence their evaluation, namely evaluation factor set, evaluation set and membership functions, and then obtain the weight of each factor and the membership degree, combining the two to be a comprehensive membership to determine the level of risk.[5]

If evaluation factor set is \( U = \{u_1, u_2, \ldots, u_m\} \), \( m \) is the number of risk factors; evaluation set is \( V = \{v_1, v_2, \ldots, v_n\} \), \( n \) is the risk level. Re-use of entropy weight method to calculate the weight of all evaluation factors, constitutes a weight vector \( A \), and then combine various risk factors, which is calculated by the membership function, to calculate degree of membership and the membership matrix \( R \) that accesses to comprehensive membership is constructed. Finally according to the principle of maximum membership, we can determine the level of risk[6].

In fuzzy mathematics, the fuzzy membership functions we commonly used in mainly are these two functions: one is the superior type function applicable to the issue of cost, and the other kind of superior type function applies to the problems the greater and the more benefits. Value at risk, taking the characteristics of the smaller the better into account, in this paper we adopt the former methods. According to the membership degree of all evaluation factors calculated by the membership functions, we can construct the membership degree matrix of risk factors \( u = (r_{ij})_{m \times n} \), Which \( r_{ij} \) \((i = 1, 2, \ldots, m; j = 1, 2, \ldots, n)\) is for the first \( i \) Kind of evaluation factors to evaluate the first place \( j \) Level risk probability values. Expression of the membership functions is:

\[
    r_{ij}(x_i) = \begin{cases}
    0 & x_i \geq v_{i(j+1)}, x_i \leq v_{i(j-1)} \\
    \frac{x_i - v_{i(j-1)}}{v_{i(j-1)} - v_{i(j+1)}} & v_{i(j-1)} < x_i \leq v_{i(j)} \\
    \frac{x_i - v_{i(j-1)}}{v_{i(j+1)} - v_{i(j-1)}} & v_{i(j)} < x_i \leq v_{i(j+1)} \\
    \frac{v_{i(j+1)} - x_i}{v_{i(j+1)} - v_{i(j+1)}} & v_{i(j+1)} - v_{i(j+1)} \leq x_i \\
    \frac{v_{i(j+1)} - x_i}{v_{i(j+1)} - v_{i(j+1)}} & x_i \leq v_{i(j+1)} - v_{i(j+1)}
\end{cases}
\]

\( x_i \) is the first \( i \) evaluation elements of the actual evaluation value in the formula(Actual evaluation value of the acquisition mode will be amplified in the below); In the first \( m \) evaluation factors, According to calculated the evaluation factors of membership, we can construct the membership degree matrix.

\[
    u = \begin{bmatrix}
    r_{11} & r_{12} & \cdots & r_{1m} \\
    r_{21} & r_{22} & \cdots & r_{2m} \\
    \vdots & \vdots & \ddots & \vdots \\
    r_{m1} & r_{m2} & \cdots & r_{mn}
\end{bmatrix}
\]

In general, we determine the value of membership function \( \mu(X) \) first, calculate various risks events using the entropy power the weight, then through integrated transformation the entropy fuzzy models, weight of evaluation factors will be set and attached to the matrix combination and it is the
Comprehensive membership $Y = A \times u$, Obtained that corresponding to the size of probability values for each risk level, take the greatest probability value, Corresponding risk level of the value is that the project risk level.

3. Case Study
Chongqing Yangtze River Highway Tunnel length of 3.63 kilometers, engineering, investment 2.05 billion budget for the two-lane dual carriageway designed driving speed of 50 kilometers, is China's Yangtze River to build the first highway tunnel environment, is currently the most complicated geological conditions in China, the highest levels of engineering, construction of the most difficult river at the end of tunnel environment project.

3.1. The determine of the evaluation factor set and evaluation set
This article analyze the risks faced by the project from the perspective of investors, and established the following risk factors index system., as shown in Table 1, we known the number of risk factors $m = 15$. In determining the evaluation set, usually take $n = 5$, and make evaluate the set defined as (Low risk, low risk, medium risk, high risk, the highest risk), and can be make its initialization assignment $V = \{1, 2, 3, 4, 5\}$, that $V_{11} = 1, V_{12} = 2, V_{13} = 3, V_{14} = 4, V_{15} = 5$.

3.2. Risk factors to determine the weight
Now select six experts, that $s = 6$, assigns separately to the 13 types of evaluation factors with their respective level of risk(Low risk is $1, 2$ risk is $2, 3$ risk is $3, 4$ risk is $4$, highest risk is $5$ ) and obtained the original data matrix $M = (m_{ij})_{13 \times 6}$. In which $m_{ij}$ is the $i$ kinds of evaluation factors in which the risk level believed by $j$ bits experts. that

\[
M = \begin{bmatrix}
2 & 3 & 1 & 1 & 2 & 4 & 2.16 \\
1 & 2 & 3 & 2 & 1 & 1 & 1.67 \\
3 & 4 & 2 & 1 & 1 & 3 & 2.33 \\
4 & 2 & 3 & 4 & 2 & 3 & 3.00 \\
2 & 1 & 4 & 2 & 3 & 1 & 2.16 \\
1 & 4 & 3 & 2 & 2 & 2 & 2.33 \\
5 & 2 & 4 & 4 & 3 & 5 & 3.83 \\
3 & 2 & 5 & 2 & 2 & 3 & 2.83 \\
2 & 1 & 2 & 3 & 1 & 1 & 1.67 \\
1 & 2 & 1 & 2 & 1 & 1 & 1.33 \\
3 & 4 & 4 & 2 & 2 & 3 & 3.00 \\
2 & 5 & 2 & 1 & 2 & 1 & 2.16 \\
3 & 2 & 4 & 2 & 2 & 1 & 2.33 \\
\end{bmatrix}
\]

Calculated entropy of the evaluation factors from the normalized data matrix obtained by the standard calculation, and then find the entropy. For an evaluation factor, if the evaluation of the evaluators of the factors are quite different, namely, the evaluators can provide less information about the factors, their opinions were not unanimous, so there is great uncertainty itself. According to the formula we can see that the corresponding entropy will be smaller, while the larger entropy, that is, the greater the weight of this factor, indicating the impact of its role in the whole project a larger, indicating entropy method to calculate the weights are derived Effectiv According to formula (1) and (2) Calculate the entropy of various risk factors and the entropy of the right, the calculation results as shown in Table 1, from the calculation results, the biggest is construction technology and technical solutions, design risk and program schedule risk in technical risk, it show that these three factors has played a larger role and have greater uncertainty, in the whole project, and the risk of these three factors is high
According to the original data can be obtained of the actual value of all evaluation factors, and here we definite it as the average of six expert evaluation: \( x_j = \frac{1}{6} \sum_{i=1}^{6} m_{ij} \), the actual evaluation of estimate correspond to the evaluation factors are see in the original data matrix.

| Primary risk | Lesser risk                     | Entropy | OEW (W) |
|--------------|---------------------------------|---------|---------|
| A1 Economic risk | B11 Risk policy framework | 0.9231  | 0.083   |
|               | B12 Financing risk              | 0.8532  | 0.065   |
|               | B13 Foreign Exchange Risk       | 0.8315  | 0.054   |
|               | B14 Bidding risk                | 0.9096  | 0.035   |
|               | B15 Inflation                   | 0.7973  | 0.041   |
| A2 Technical risk | B21 Design risk                | 0.8741  | 0.102   |
|               | B22 Program schedule risk       | 0.8326  | 0.125   |
|               | B23 Construction technology and technical solutions | 0.9155 | 0.114 |
|               | B24 Security Risk               | 0.8325  | 0.051   |
| A3 Natural risks | B31 Poor field conditions      | 0.8935  | 0.083   |
|               | B32 Harsh climate and environment | 0.8537 | 0.078   |
|               | B33 Geological disasters        | 0.9134  | 0.090   |
|               | B34 Geographically disadvantaged | 0.8810 | 0.079   |

3.3. Confirm of membership degree matrix of risk factors
The results of five kinds of risk level correspond to the evaluation factors are known and defined in the Chinese language \( v_i = 1, v_2 = 2, v_3 = 3, v_4 = 4, v_5 = 5 \), then the membership function calculated degree of membership have a total of five expressions. Then according to the actual value of the various evaluation factors, Select the corresponding interval formula to calculate the risk probability of the wake of this five kinds of grades separately, that is membership grade, calculated as shown in Table 2. after calculating the risk level of membership grade corresponding to the various risk factors, we arranged it in a 13 \( \times \) 5 matrix, \( u = (r_{ij})_{13 \times 5} \), that is membership degree matrix.

| Number | Actual value | Risk level (matrix \( R = (r_{ij})_{13 \times 5} \)) |
|--------|-------------|------------------------------------------------|
| 1      | 2.16        | \( r_{i1} \) 0.75 0.25 0 0 |
| 2      | 1.67        | \( r_{i2} \) 0.375 0.625 0 0 0 |
| 3      | 2.33        | \( r_{i3} \) 0.50 0.50 0 0 0 |
| 4      | 3.00        | \( r_{i4} \) 0 0.375 0.625 0 0 0 |
| 5      | 2.16        | \( r_{i5} \) 0 0 0.75 0.25 0 0 0 |
| 6      | 2.33        | \( r_{i6} \) 0 0.375 0.625 0 0 0 |
| 7      | 3.83        | \( r_{i7} \) 0 0 0 0 0 0 0 0 0 |
| 8      | 2.83        | \( r_{i8} \) 0 0 0 0 0.25 0.75 |
| 9      | 1.67        | \( r_{i9} \) 0 0.75 0.25 0 0 0 |
| 10     | 1.33        | \( r_{i10} \) 0 0 0 0 0.875 0.125 |
| 11     | 3.00        | \( r_{i11} \) 0 0 0.25 0.75 0 0 0 |
| 12     | 2.16        | \( r_{i12} \) 0 0 0 0.375 0.625 0 0 0 |
| 13     | 2.33        | \( r_{i13} \) 0 0 0 0 0.5 0.5 0 0 0 |

Table 2 Five risk level of membership grade corresponding to the various risk factors
3.4. The comprehensive evaluation of the project

From the previous chapter on the project to determine the risk rating methodology we can calculate the project's comprehensive membership, we will combine the weight set with 15 types of evaluation factors and then it become a Membership degree matrix. that 

\[ A = W \times u = \]

\[ \begin{bmatrix} 0.083 & 0.065 & 0.054 & 0.035 & 0.041 & 0.102 & 0.125 & 0.114 & 0.051 & 0.083 & 0.078 & 0.09 & 0.079 \end{bmatrix} \]

\[ = (0.05, 0.32, 0.42, 0.15, 0.06) \]

From the results we can see that 5 kinds of the size of the risk level of probability of occurrence (namely, the risk level of membership degree), Shown in Table 3, According to the principle of maximum degree of membership we can see that Medium-low probability of occurrence is maximum, so there is a lower risk of Chongqing Yangtze River Highway Tunnel environment.

| Risk Level | Minimum | Lower | Medium | Higher | Top |
|------------|---------|-------|--------|--------|-----|
| Level      | 0.05    | 0.32  | 0.42   | 0.15   | 0.06 |

4. Conclusion

For Chongqing Yangtze River Highway Tunnel environment projects requires large investment and long construction period, the construction is very difficult, but taking into account the technical conditions for the construction and construction process in all aspects of system integrity, the overall risks faced by the project is relatively low.

In this paper, by combining entropy weight and fuzzy math, we had established a risk assessment model, and Risk assessment of the project results is in line with the actual situation, it shows that this Combining method is effective. This methods which is combined with quantitative and qualitative, it is linked with decision-makers subjective judgments and reasoning. Quantitative description of policymakers description can avoid policymakers logic errors in the complex structure. As can be seen, this method have a high use, so strengthening its research has a dual significance of theory and practice.

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