Study on Risk Management of EPC General Contractor Based on F-AHP Model

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Abstract: The risk management is an important part of the Engineering Procurement Construction (EPC) general contractor’s project management. This article combined with the characteristics of EPC models, systematically analyzes the risks that general contractor facing under EPC models, and established a fuzzy comprehensive evaluation model based on triangular fuzzy number complementary judgment matrix. Finally, proposed risk management countermeasures in the different implementation stages of the project.

Keywords: EPC general contract project, F-AHP, Fuzzy complementary judgment matrix, Risk management

1 Introduction

EPC general contracting mode is a kind of typical engineering general contracting mode, which is being widely used in the current international engineering contracting and actively advocated in the current domestic construction market. Risk and profit always coexist. In this mode, the profit space of the general contractor is larger, but the responsibility and risk he or she undertakes is bigger. In this case, the general contractor need have a higher level of risk management.

How to form a scientific and effective risk management mechanism is crucial for general contractor. And it can attract more contractors to enter the engineering general contracting market, promote Chinese construction market contracted by the traditional mode to the new contract model, and speed up the development process of the construction industry. Past researches often need a consistency check to the judgment matrix when determined the weights by using the APH, and exist a certain difficulty and some significant differences. Use the AHP which is based on triangular fuzzy number complementary judgment matrix, and establishes a fuzzy comprehensive evaluation model, avoids the problems such as the significant difference due to subjective thinking and makes the evaluation results more accurate (1).

2 EPC General Contracting Project Risk Analysis

2.1 The features of the EPC general contracting project model

Engineering Procurement Construction (EPC) general contracting is also called the project general contracting. It refers to a general contractor or the association composed of several contractors which is entrusted by the owner practices a comprehensive “turnkey” contract through the whole process to the whole project design, materials, equipment procurement in accordance with the contract, and it is entirely responsible for the quality, cost, safety and schedule management of the contracted projects (2).

The EPC mode has the following features: the contract structure is relatively simple and the organization and coordination work of the owner is less, but the contract management is difficult; the management of the general contractor span large; the owner will fewer risks; the different stages can be make a better link and shorten project construction period; the general contractors, need to have a wealth of practical experience and a higher level of management since the responsibility and risk they took is big; owing to it requires a great deal of coordination, information sharing mechanism and integrated management need to be established, and that will be conducive to the modernization of project management.
2.2 EPC general contracting project risk factors identification
Identification of risk factors is the first step of risk management. Only by making the risk evaluation on the basis of risk identification can we predict how much damage that all kinds of risk factors do and thus control the risk factors pointedly. Through literature research and the review of related data, classifies and summarizes the risks in EPC general contracting project concluded that the main risks that EPC general contractor faced in EPC mode are as follows [3-4]:

1. Political risk, refers to the domestic political environment of the host country or the political relations between the host countries and other countries change, the possibility of economic loss will be brought to foreign enterprise or investors.
2. Economic risk, refers to the possibility of loss to the EPC contractors when the economic situation, economic strength, economic stability and the market demand of the country or region changes.
3. Technical risk, mainly includes design risk, engineering change risk and special engineering construction technology risk.
4. Management risk, refers to the risk caused by a lack of experience or the limited management level in the project management team.
5. Organization risk, refers to whether the organization of the project design can meet the needs of practical engineering, and how to handle the relationship between stakeholders, the level of company leadership's support to the project department and the team spirit of project group.
6. Natural risk, refers to the risk which is harmful to economic activity, material production or life safety, caused by the phenomenon of irregular change due to the forces of nature.

The main risks to the general contractor in EPC mode are as shown in Table 1.

<table>
<thead>
<tr>
<th>Number</th>
<th>Risk category</th>
<th>Risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Political risk</td>
<td>Political instability and shifting government policies, etc.</td>
</tr>
<tr>
<td>2</td>
<td>Economic risk</td>
<td>Exchange rate changes, the rise in prices of material, the owners ability to pay, etc.</td>
</tr>
<tr>
<td>3</td>
<td>Technical risk</td>
<td>The difficult design, difficult special engineering construction, design change, etc.</td>
</tr>
<tr>
<td>4</td>
<td>Management risk</td>
<td>Bidding risk, subcontract management, supplier management, the management in the process of implementation, etc.</td>
</tr>
<tr>
<td>5</td>
<td>Organization risk</td>
<td>The handling of the relationship between stakeholders, the level of company leadership’s support in the project, the team spirit of project group, etc.</td>
</tr>
<tr>
<td>6</td>
<td>Natural risk</td>
<td>Adverse climatic conditions, geological conditions, etc.</td>
</tr>
</tbody>
</table>

3 Risk Assessment Modeling

3.1 The analytic hierarchy model of risk on fuzzy
The analytic hierarchy process (AHP) is a decision method combining qualitative with quantitative, and it is widely used in recent years. But there are following problems: it’s difficult to test whether the comparison judgment matrix has consistency; it is complex to modify the comparison judgment matrix; and how to solve more effectively the remarkable difference problem in consistency of the comparison judgment matrix and human thinking. Now we can determine the risk factor weights and sorting by using of the fuzzy analytic hierarchy process (F-AHP) which based on triangular fuzzy number complementary judgment matrix.

3.1.1 Establish the model of risk factor hierarchy structure
According to the risk factors of the EPC general contractor identified in Table 1, establish the structure of risk factor analytic hierarchy as shown in Table 2. The first stage contains 1 indicator, second level contains 6 indicators, and the third includes 17 indicators.

3.1.2 Construct fuzzy risk judgment matrix
Because the expert judgment information is fuzzy, after the establishment of analysis hierarchy structure,
consulting experts’ judging information by the triangular fuzzy number, we can obtain the triangular fuzzy number complementary judgment matrix combined with the method of fuzzy scale. Among them, fuzzy scale and its meaning are shown in Table 3.

If a risk factor on a level has association with N risk factors in the next level, according to the multiple comparison of experts carry on the N risk factors, triangular fuzzy complementary judgment matrix can be given: \( A = (a_{ij})_{n \times n} \), where \( i, j \in N \). Among them, \( a_{ij} = (l_{ij}, m_{ij}, u_{ij}) \), which is a triangular fuzzy number, and \( l_{ij} + u_{ji} = m_{ij} + m_{ji} = u_{ij} + l_{ji} = 1 \). \( l_{ij}, m_{ij}, u_{ij} \) represent the most pessimistic estimates, the most likely estimate and the most optimistic estimate about the important degree of risk factor \( i \) compared with risk factor \( j \) from experts, when compared risk factors \( i \) and risk factors \( j \) in the next layer with the risk factors in the upper layer.

### Table 2 The hierarchical model of EPC project general contractor’s risk factors

<table>
<thead>
<tr>
<th>Schedule the risk factors of the EPC project general contractor A</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Political risk B₁</strong></td>
<td>Policy instability C₁</td>
</tr>
<tr>
<td></td>
<td>Policy change C₂</td>
</tr>
<tr>
<td><strong>Economic risk B₂</strong></td>
<td>Exchange rate changes C₃</td>
</tr>
<tr>
<td></td>
<td>Material prices grow higher C₄</td>
</tr>
<tr>
<td></td>
<td>Owner payment ability C₅</td>
</tr>
<tr>
<td><strong>Technical risk B₃</strong></td>
<td>Big design difficulty C₆</td>
</tr>
<tr>
<td></td>
<td>Large difficulty of special engineering construction C₇</td>
</tr>
<tr>
<td><strong>Management risk B₄</strong></td>
<td>Engineering change C₈</td>
</tr>
<tr>
<td></td>
<td>Risk of bidding C₉</td>
</tr>
<tr>
<td></td>
<td>Subcontract management C₁₀</td>
</tr>
<tr>
<td></td>
<td>Supplier management C₁₁</td>
</tr>
<tr>
<td><strong>Organizational risk B₅</strong></td>
<td>Management in the implementation process C₁₂</td>
</tr>
<tr>
<td></td>
<td>Relationship deal between the parties C₁₃</td>
</tr>
<tr>
<td></td>
<td>Project support of the leadership C₁₄</td>
</tr>
<tr>
<td></td>
<td>The team spirit of unity C₁₅</td>
</tr>
<tr>
<td><strong>Natural risk B₆</strong></td>
<td>The climate and environment C₁₆</td>
</tr>
<tr>
<td></td>
<td>Geological conditions C₁₇</td>
</tr>
</tbody>
</table>

### Table 3 Fuzzy scale and its meaning

<table>
<thead>
<tr>
<th>Scale</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>Comparing two elements, the latter is extremely important than the former</td>
</tr>
<tr>
<td>0.2</td>
<td>Comparing two elements, the latter is strongly important than the former</td>
</tr>
<tr>
<td>0.3</td>
<td>Comparing two elements, the latter is obviously important than the former</td>
</tr>
<tr>
<td>0.4</td>
<td>Comparing two elements, the latter is slightly important than the former</td>
</tr>
<tr>
<td>0.5</td>
<td>Comparing two elements, the latter is equally important than the former</td>
</tr>
<tr>
<td>0.6</td>
<td>Comparing two elements, the former is slightly important than the former</td>
</tr>
<tr>
<td>0.7</td>
<td>Comparing two elements, the former is obviously important than the former</td>
</tr>
<tr>
<td>0.8</td>
<td>Comparing two elements, the former is strongly important than the former</td>
</tr>
<tr>
<td>0.9</td>
<td>Comparing two elements, the former is extremely important than the former</td>
</tr>
</tbody>
</table>

### 3.1.3 Calculate the weight vector

The first, introduce the concept of possibility degree, designing \( a = (a_1, a_2, a_3) \), \( b = (b_1, b_2, b_3) \).

\[
p(a \geq b) = \lambda \max \left\{ 1 - \max \left[ \frac{b_1 - a_1}{a_3 - a_1 + b_3 - b_1}, 0 \right], (1 - \lambda) \right\} \left\{ 1 - \max \left[ \frac{b_2 - a_2}{a_3 - a_2 + b_3 - b_2}, 0 \right] \right\} \tag{1}
\]
So we said the \( p \) is the possibility degree of \( a \geq b \); similarly,

\[
p(b \geq a) = \lambda \max \left\{ 1 - \max \left[ \frac{a_m - b_l}{a_n - a_l + b_m - b_l}, 0 \right], 1 - \max \left[ \frac{a_s - b_m}{a_n - a_s + b_s - b_m}, 0 \right] \right\}
\]

We said the \( p \) is the possibility degree of \( b \geq a \). Among Them, \( \lambda \in [0, 1] \), the value of \( \lambda \) is depended on the decision maker’s attitude towards risk. When \( \lambda > 0.5 \) we said that decision makers are risk seeking; When \( \lambda = 0.5 \) we said that decision makers are risk neutral; When \( \lambda < 0.5 \) we said that decision makers are risk averse individuals.

Using formula (3) to calculate the rows of triangular fuzzy number complementary judgment matrix \( A \) and normalize them, we can obtain the triangular fuzzy number weight vector \( \omega (= \omega_1, \omega_2, \ldots, \omega_m) \).

Carrying out multiple comparisons with triangular fuzzy number \( \omega_i \) using formula (1) (2) we can obtain the relative possibility degree \( \chi(\omega_i \geq \omega_j) \) named \( \chi_{ij} \), \( i, j \in N \), and then we can get the possibility degree matrix \( \chi = (\chi_{ij})_{n \times n} \). Using the formula (4) we can obtain the weight vector of possibility degree matrix.

\[
w = \frac{1}{n} \left( \sum_{j=1}^{n} \omega_j + 1 - \frac{n}{2} \right), i \in N
\]

3.1.4 The total order of risk factors level

To calculate the relative importance weights of each factor in the index layer compared to the target layer, is called the level of total order. The process is calculated layer by layer from the highest to the lowest. Design a middle layer \( B \) contains \( m \) factors \( B_1, B_2, \ldots, B_m \), whose weights is \( b_1, b_2, \ldots, b_m \) about the target layer \( A \); their next layer \( C \) contains \( n \) factors \( C_1, C_2, \ldots, C_n \), whose weights is \( c_{i1}, c_{i2}, \ldots, c_{in} \) about the target layer \( B_i \); so the weights of \( C_1, C_2, \ldots, C_n \) is \( c_1, c_2, \ldots, c_n \) about \( A \), among them,

\[
c_j = \sum_{i=1}^{m} b_i c_{ij}, j = 1, 2, \ldots, n.
\]

3.2 Fuzzy comprehensive evaluation of EPC project risk model

3.2.1 Establish factor set

Design factor set \( U_1 = \{U_1, U_2, \ldots, U_m\} \) refers to the corresponding risk factors in the first level among the hierarchical structure. \( U_i = \{u_{i1}, u_{i2}, \ldots, u_{ik}\} \) refers to the corresponding risk factors in the second level, and \( i = 1, 2, \ldots, m; k \) is the factor number in the next layer about \( U_i \).

3.2.2 Establish evaluation set

Design evaluation set \( V = \{v_1, v_2, \ldots, v_s\} \) refers to \( s \) kinds of evaluations for factors. In the risk management of engineering project, usually divide risk into five grades which is high risk, higher risk, general risk, lower risk, low risks. So risk evaluation set is generally set to \( V = \{ \text{high, higher, general, lower, low} \} \).

3.2.3 Determine the membership degree matrix

Asking the experts familiar with the EPC project, using expert scoring or voting method, we can get the degree of the second level factor \( U_i \) belongs to each comment, and the single factor evaluation matrix can be obtained:

\[
R = \begin{bmatrix}
r_{i1} & r_{i2} & \cdots & r_{i5} \\
r_{i2} & r_{i2} & \cdots & r_{i5} \\
\vdots & \vdots & \ddots & \vdots \\
r_{i5} & r_{i5} & \cdots & r_{i5}
\end{bmatrix}
\]

3.2.4 Evaluate the second level factor \( U_i \) comprehensively
Designing the weights of \( U_i = \{u_{i1}, u_{i2}, \ldots, u_{ik}\} \) calculated, through the method of the F-AHP is \( W_B = \{c_{1i}, c_{i2}, \ldots, c_{ik}\} \), we can get the comprehensive evaluation: \( \hat{B}_i = W_B \circ R_i \), \( i=1,2,\ldots,5 \).

3.2.5 Evaluate the first level factor \( U = \{U_1, U_2, \ldots, U_m\} \) comprehensively.

Design the weights of \( U = \{U_1, U_2, \ldots, U_m\} = \{B_1, B_2, \ldots, B_6\} \) calculated above is \( W_B = \{b_1, b_2, \ldots, b_6\} \). The total evaluation matrix is \( R = [\tilde{B}_1 \ \tilde{B}_2 \ \ldots \ \tilde{B}_6]^T \). The fuzzy comprehensive evaluation of project risk is \( \hat{B} = W_B \circ R \).

Finally, according to the principle of maximum membership degree, we can determine the risk level of EPC general contract project.

3.3 Application of evaluation model

3.3.1 After the calculation of risk fuzzy and hierarchy analysis model, we can get the important degree of each factor which is at the bottom of the hierarchical structure model for the entire project risks, and find out the main risk of the project facing. It’s good for the general contractor to monitor each risk factor and to put forward appropriate emergency response plan.

3.3.2 Via fuzzy comprehensive evaluation for the risk of EPC project, the general contractor can understand total risk level of the project current status, and it can provide the basis for the general contractor management decision.

3.3.3 Because the EPC general contract projects are often quite complex, the construction cycle is longer, the contract amount is larger, many risk factors are faced, so the risk assessment should be a dynamic evaluation process. The general contractor should establish a dynamic management system of the project risk, control the project from time to time, appraise the project risk regularly, find out the main risk at different implementation stages of the project, and finally realize the dynamic management for risk.

4 The Measures to the Risk of the EPC General Contracting Project

The key to the risk management of the general contractor is identifying and evaluating the risk, and establish a dynamic risk management system. In order to have a better risk management, it also needs to have a real-time monitoring to the risk and formulate the corresponding control measures. According to the risks of project in different stages, EPC general contractor should take corresponding measures [6].

4.1 The process of bid quotation

Before bid quotations, the general contractor should have a detailed investigation to the bidding project, evaluate the overall risk of the project to provide the basis for the bid decision: (1) Investigate the social, political, legal, economic and financial environment the project located in detail; (2) Read the tender documents and contract documents carefully, avoid losses caused by the ambiguous and vague situations exists in the file; (3) Insight into the local culture and the standard of using, to avoid the risk caused by the culture gaps or different standards, reduce the losses due to the subjective views; (4) Have a detailed on-site investigation and exploration; (5) Pay a further investigation to the owners credit and ability; (6) Choice the supplier of materials and equipment reasonably.

4.2 The process of contract

The general contractor should determine the share about the risk to the both side of the contract as follows: (1) Clear the terms of the contract, and reach an agreement to the understanding of the contract, to avoid the general contractor losses caused by the misunderstanding on some clauses; (2) Take an reasonable settlement way to the price of the installation engineering, so as to minimize capital advances; (3) Take an appropriate way of contract pricing, with the appropriate pricing formula, to reduce the losses caused by the inflation, rising prices, exchange rate changes and other factors.
4.3 The process of implementation

The implementation includes three stages: design, procurement and construction. It’s often tending to overlap between these three works, so the general contractor should pay attention to the coordination between these works. Especially the following works: (1) Pay attention to the design work, to evade the risks as a result of the factors such as design flaws; (2) To control the purchasing work strictly, and strengthen the management of the supplier; (3) Have a well preparation to start, and review whether it is complete of the relevant formalities; (4) Check the foundation construction material that provided by the landlord, and seriously examine whether it is accurate; (5) Strengthen the management of the subcontractor and service team; (6) Strengthen the control of the time limit for a project, cost, quality, etc.

5 Conclusion

Risk management is one of the most important contents of project management, also is the key to the success of projects. Establish an effective risk assessment and prevention mechanism is the important content of general contractor for effective risk management. General contractor only to establish a scientific and effective risk management mechanism, will attract more contractors enter into the general contracting field, and promote the development of construction industry more quickly.

References