Research on Quality Risk Assessment of EPC Projects for Transmission and Distribution Engineering Based on Design Enterprises

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Abstract. Among EPC general contractors, design companies often dominate by virtue of their design advantages. However, due to the complex risks of power transmission and transformation projects throughout their life cycle, quality management is the weak point of the EPC general contractor with design as the leader, and the problems caused by quality risks are directly related to the contractor’s Economic interests and credibility. Therefore, this paper will analyze the potential quality risks in the whole process of the project, establish a risk identification list, and use the fuzzy comprehensive evaluation method to evaluate the quality risk of the EPC project of the power transmission and transformation project led by the design enterprise based on the principle of maximum membership degree.

1. Introduction
The power transmission and transformation project requires a large amount of capital investment, a long construction period, and many uncertainties. It is necessary to use the advantages of the EPC model to save money, improve efficiency, reduce differences, and ensure the smooth progress of the project. At present, EPC general contractors generally take the design unit as the leader and actively play the key role of design in the project. Although there is generally a supervision business, its concept is still based on the supervision management mode thinking. Most of the quality management of the whole process is only in written articles, and it is not very specific to each point. Therefore, in order to maximize the role of the EPC general contractor, which is led by the design enterprise, in the power transmission and transformation project, it is necessary to strengthen its ability to control quality risks.

In recent years, China has attached great importance to the control of the quality of construction projects, and many scholars have conducted in-depth research on this. Yin Bin used project risk management theory and method to make a scientific identification of the main risks that may be faced in the pre-development phase, construction implementation phase and production operation phase of the 1000kV AC transmission and transformation project in Linyi Substation [1]. Li Baolin explored the quality of supervision and control of safety in current power transmission and transformation projects, and gave a rough range of quality risks [2]. According to the defects of the supervision enterprise itself, Yin Xueqin proposed on how to improve the quality control of power transmission and transformation engineering on the principle of “three control, two management, one coordination
and one performance” [3]. Li Zhihong introduced the quality influencing factors of power transmission and transformation engineering from the aspects of personnel, machinery, materials, methods and environment [4]. Wu Ying evaluates a power transmission and transformation project based on fuzzy evaluation and proposes risk countermeasures [5]. Wang Dazhao selected the most influential indicators to establish a quality risk assessment system, and evaluated the primary and secondary indicators separately through the fuzzy comprehensive method [6]. Zhang Canjiang analyzed the specific defects of EPC implementation from eight aspects by analyzing the defects of EPC mode in power transmission and transformation engineering [7]. However, in the quality risk research of various types of power transmission and transformation projects, the quality risk research of the EPC general contracting model led by the design unit is still scarce and needs further improvement.

This paper considers that there are too many uncertainties in the quality and safety of the general contracting with the design enterprise as the main body in the whole process, which makes it easy for the contractor to be in a passive position in the completion acceptance stage. Therefore, this paper will use the analytic hierarchy process to establish a risk identification system, and use fuzzy comprehensive evaluation to quantitatively analyze the uncertainty of risk, and provide reference for the subsequent research work.

2. Analysis of EPC general contract quality risk factors in power transmission and transformation engineering

2.1. Construction of a Quality Risk List

In view of the cumbersome process at each stage of the power transmission and transformation project, it is necessary to comprehensively analyze the quality risk factors of the EPC power transmission and transformation project led by the design enterprise under various possible conditions. According to the analytic hierarchy process and the characteristics of the power transmission and transformation project, The following list of quality risks is shown in Table 1.

| Serial number | Evaluation target | Primary evaluation index \((U_i)\) | Secondary evaluation index \((U_{i2})\) |
|---------------|-------------------|--------------------------------|---------------------------------|
| 1             | Design quality risk \(U_1\)                             | Designer connection risk \(U_{11}\) | Construction drawing design rationality risk \(U_{12}\) |
|               |                   | Construction drawing design rationality risk \(U_{12}\) | Design cycle risk \(U_{13}\) |
|               |                   | Design cycle risk \(U_{13}\) | Lack of risk in basic data \(U_{14}\) |
|               |                   | Lack of risk in basic data \(U_{14}\) | Material equipment price rise risk \(U_{21}\) |
| 2             | EPC power transmission and transformation engineering quality risk \(U_2\) | Contract risk \(U_{22}\) | Material quality inspection risk \(U_{23}\) |
|               | Procurement quality risk \(U_2\)                    | Material quality inspection risk \(U_{23}\) | Equipment safety risk \(U_{24}\) |
|               |                   | Equipment safety risk \(U_{24}\) | Equipment safety risk \(U_{31}\) |
| 3             | Construction quality risk \(U_3\)                   | Construction personnel quality risk \(U_{32}\) | Construction environment risk \(U_{33}\) |
|               |                   | Construction environment risk \(U_{33}\) | Supervision risk \(U_{34}\) |
| 4             | Management risk \(U_4\)                             | Functional overlap risk \(U_{41}\) | Talent risk \(U_{42}\) |
|               |                   | Talent risk \(U_{42}\) | Coordinating risk \(U_{43}\) |

2.2. Risk list factor analysis

2.2.1. Design quality risk

- Designer connection risk. Power transmission and transformation projects are a huge comprehensive work, mainly the construction and installation of overhead lines and transformers. Due
to the technical barriers, the professionals responsible for the specific division of engineering design are prone to deviations due to different standards.

- Reasonable risk of construction drawing design. In the engineering project, the construction drawing is the basic document to guide the construction. During the design process, the designer may have a design that does not fully consider the current level of technical application or lack of similar engineering design experience, and exceeds the capabilities of the construction party. The quality of the construction drawings is guaranteed to a certain extent to ensure the quality of construction.
- Design cycle risk. Many design institutes simply pursue high efficiency, and rely on a large amount to win more profits and artificially compress the normal design cycle, which reduces the design quality and brings hidden dangers for subsequent work.
- Lack of risk in basic data. In the preliminary work of the project design, if the design basic data is lacking and it is difficult to meet the depth expected by the owner, the construction drawing design will be rushed, and the design will leave more doubts and the risk is very uncontrollable.

2.2.2. Quality of purchase risk
- Risk of rising prices of materials and equipment. Since most EPC engineering contracts are total price contracts, this limits the general contractor's expenditure on materials and equipment procurement. The price of equipment procurement from project bidding, cost analysis, winning bid, contract signing to project implementation will fluctuate with market changes, which will lead to the pursuit of quality neglect quality in procurement.
- Contract risk. If the bidder's inquiry made during the bidding period is not comprehensive enough, and there is no comprehensive understanding of the market information of the place of purchase, if the sensitive material equipment does not obtain a looser contractual requirement, the actual purchase price will be higher than the contracted price.
- Material quality inspection risk. In the procurement process, quality inspection of material samples should be carried out in accordance with national standards and industry standards, and resolutely eliminate the use of inferior products to shoddy, which is the most basic guarantee for the quality of the project.
- Equipment safety risk. Equipment safety is related to the personal safety of the operators. It must be carried out in accordance with the specifications during the procurement and commissioning of the equipment to avoid the risks caused by blindly believing in experience.

2.2.3. Construction quality risk
- “Four new” technology application risks. The application of “four new” technologies can improve the average level of society, but if it is not handled properly, it will bring huge hidden dangers to the project. As a designer, we must fully consider the technical characteristics of the project. The first consideration is the reliability of the new technology, so that the technology is new but fully grasped.
- Quality risk of construction workers. In the construction process, the professional quality of the construction personnel plays a decisive role in the construction quality. The professional construction personnel can identify the risks during the construction process and communicate with the designers to ensure the quality of the project.
- Construction environmental risk. The geological conditions, hydrological conditions and weather conditions of the construction site have a great impact on the quality of the project. Therefore, in the design stage, the collection of such information at the construction site must be taken into consideration to avoid unnecessary losses caused by rework in the future.
- Supervision risk. Since the current stage does not improve the supervision system of the EPC model, the composition of the supervision team may not meet the requirements of the EPC general contracting model, so the requirements for project quality will be different from the general contractor and the owner, which is unfavorable to the construction progress.
2.2.4. Management risk
- Functional overlap risk. Although the EPC general contracting model is the responsibility of the general contracting enterprise, the five parties’ main responsibilities remain unchanged. The functions of the supervisory party and the general contractor will overlap, which requires internal control and coordination of the duties of each department.
- Talent risk. EPC general contracting is often suitable for the management of large and medium-sized projects. It requires a large number of high-quality compound talents who understand project management. In actual operation, it can discover potential quality risks in time and feedback to relevant responsible parties in time, so as to avoid professional barriers. Unnecessary loss
- Coordinating risks. Communication problems arising from differences in opinions, responsibilities, and resource allocations occur at work, and these problems are accompanied by the entire project. The contractor needs to fully consider the design function, analyze the specific problem and create a good communication environment.

3. Establishment of fuzzy comprehensive evaluation model for quality risk
The fuzzy comprehensive evaluation method is a comprehensive evaluation of the research objects affected by many factors. The analytic hierarchy process is used to weight each factor. Based on the principle of maximum membership degree, the fuzzy mathematical model is used for quantitative calculation to objectively evaluate the current project quality level.

3.1. Applying AHP to empower various quality risk factors
- Construct a judgment matrix for each risk factor and sub-factor. This step requires a nine-point scoring method to compare the relative importance of the two factors, giving an assessment and assignment.
- Calculate the largest eigenvalue of the judgment matrix and its corresponding eigenvector. This article takes the square root method for calculation.

3.2. Establishment of fuzzy comprehensive risk assessment model based on the principle of maximum membership degree

3.2.1. Set evaluation factor set and sub-evaluation factor set:
Let $U = (U_1, U_2, \ldots, U_n)$
$U_i = (U_{i1}, U_{i2}, \ldots, U_{jn})$, $i = 1,2,\ldots,n; j = 1,2,\ldots,t$

3.2.2. Conducting a first-level evaluation
A comprehensive evaluation process for the sub-evaluation factor set: $V = (V_1, V_2, V_3, V_4, V_5) = (\text{Low, low, medium, significant, high})$

The total evaluation matrix consists of $m$ indicators of $n$ scenarios, and the total evaluation matrix is $R = (r_{ij})_{m \times n}$.

$$
R = \begin{pmatrix}
    r_{11} & r_{11} & \cdots & r_{11} \\
    r_{11} & r_{11} & \cdots & r_{11} \\
    \vdots & \vdots & \ddots & \vdots \\
    r_{11} & r_{11} & \cdots & r_{11}
\end{pmatrix}
$$
For this quality risk assessment, \( n=5, m=15 \). \( R_{ij} \) refers to the degree of membership, from the degree of membership of \( U_i \) to the comment \( V_j \). First, the experts are invited to grade the evaluation objects, and the scores are counted and the index membership is calculated \( r_{ij} \).

\[
r_{ij} = \frac{m_{ij}}{f} \tag{5}
\]

Where \( m_{ij} \) represents the frequency at which \( U_i \) belongs to \( V_j \) and \( f \) represents the number of people participating in the evaluation. In turn, the single factor fuzzy evaluation set of the index \( U_i \) can be obtained, \( R_i = (r_{i1}, r_{i2}, r_{i3}, r_{i4}, r_{i5}) \).

The comprehensive evaluation vector of \( U_i \) is calculated \( B_i \).

\[
B_i = W^{(1)}_k \cdot R_i = (b_{i1}, b_{i2}, ..., b_{i5}) \tag{6}
\]

3.2.3. Conducting secondary evaluation

Determination of weight distribution under analytic hierarchy process:

\[
W^2 = (w_1, w_2, ..., w_f) \tag{7}
\]

Secondary comprehensive evaluation:

\[
B = W^{(2)} \cdot R = (b_1, b_2, ..., b_5) \tag{8}
\]

According to the principle of maximum membership degree, the fuzzy comprehensive evaluation is \( V_k \).

4. Case analysis

A power transmission and transformation project is approved by a design institute-led contractor using the EPC model. According to the quality risk list established in 2.1, we will analyze the whole process quality risk as follows:

4.1. Determination of weight

The judgment matrix \( A \) and \( A_i \) of the project-level risk and the second-level risk weight can be obtained by the nine-degree comparison method, as shown in Table 2–6.

| Table 2. Risk indicator weight calculation. | Table 3. Risk indicator weight calculation. |
| A | U₁ | U₂ | U₃ | U₄ | W | A₁ | U₁₁ | U₁₂ | U₁₃ | U₁₄ | W⁽¹⁾ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| U₁ | 1 | 2 | 3 | 4 | 0.4565 | U₁₁ | 1 | 2 | 4 | 3 | 0.4717 |
| U₂ | 1/2 | 1 | 2 | 3 | 0.2707 | U₁₂ | 1/2 | 1 | 2 | 2 | 0.2562 |
| U₃ | 1/3 | 1/2 | 1 | 4 | 0.1927 | U₁₃ | 1/4 | 1/2 | 1 | 1/2 | 0.1078 |
| U₄ | 1/4 | 1/3 | 1/4 | 1 | 0.0801 | U₁₄ | 1/3 | 1/2 | 2 | 1 | 0.1644 |

| Table 4. Risk indicator weight calculation. | Table 5. Risk indicator weight calculation. |
| A₂ | U₂₁ | U₂₂ | U₂₃ | U₂₄ | W⁽²⁾ | A₃ | U₃₁ | U₃₂ | U₃₃ | U₃₄ | W⁽³⁾ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| U₂₁ | 1 | 3 | 2 | 3 | 0.444 | U₃₁ | 1 | 1/2 | 4 | 3 | 0.3309 |
| U₂₂ | 1/3 | 1 | 2 | 3 | 0.255 | U₃₂ | 2 | 1 | 3 | 3 | 0.4105 |
| U₂₃ | 1/2 | 1/2 | 1 | 4 | 0.213 | U₃₃ | 1/4 | 1/3 | 1 | 5 | 0.1779 |
| U₂₄ | 1/3 | 1/3 | 1/4 | 1 | 0.088 | U₃₄ | 1/3 | 1/3 | 1/5 | 1 | 0.0807 |
Table 6. Risk Indicator weight calculation.

| Indicator | $U_{41}$ | $U_{42}$ | $U_{43}$ | $W^{(4)}$ |
|-----------|---------|---------|---------|---------|
| $A_1$     | 1       | 1/2     | 3       | 0.348   |
| $A_2$     | 2       | 1       | 2       | 0.484   |
| $A_3$     | 1/3     | 1/2     | 1       | 0.168   |

The consistency test CR value is less than the specified value, indicating that there is no problem with the consistency test.

4.2. Conduct a first-level evaluation

Twelve experts were invited to evaluate the risk of quality risk of the power transmission and transformation project. The comment set: $V = \{\text{low, lower, medium, significant, high}\}$, the results are shown in Table 7.

Table 7. Risk assessment.

| Evaluation index                                      | low | lower | medium | significant | high |
|------------------------------------------------------|-----|-------|--------|-------------|------|
| Designer connection risk                              | 2   | 3     | 5      | 2           | 0    |
| Construction drawing design rationality risk          | 3   | 5     | 3      | 1           | 0    |
| Design cycle risk                                     | 5   | 4     | 3      | 1           | 0    |
| Lack of risk in basic data                           | 4   | 4     | 2      | 2           | 0    |
| Material equipment price rise risk                    | 3   | 5     | 3      | 1           | 0    |
| Contract risk                                         | 5   | 4     | 1      | 2           | 0    |
| Material quality inspection risk                      | 3   | 6     | 2      | 1           | 0    |
| Equipment safety risk                                 | 7   | 4     | 1      | 0           | 0    |
| "Four new" technology application risks              | 7   | 3     | 2      | 0           | 0    |
| Construction personnel quality risk                   | 8   | 3     | 1      | 0           | 0    |
| Construction environment risk                         | 1   | 4     | 4      | 3           | 0    |
| Supervision risk                                      | 3   | 6     | 1      | 2           | 0    |
| Functional overlap risk                               | 5   | 3     | 2      | 0           | 0    |
| Talent risk                                           | 4   | 3     | 4      | 1           | 0    |
| Coordinating risk                                     | 4   | 2     | 3      | 3           | 0    |

The first-level fuzzy comprehensive evaluation matrix of the quality risk of the project can be obtained by normalizing the evaluation results $R_1$:

$$R_1 = \begin{pmatrix} 0.1667 & 0.25 & 0.4167 & 0.1667 & 0 \\ 0.25 & 0.4167 & 0.25 & 0.0833 & 0 \\ 0.4167 & 0.3333 & 0.25 & 0.0833 & 0 \\ 0.3333 & 0.3333 & 0.1667 & 0.1667 & 0 \\ 0.5833 & 0.25 & 0.1667 & 0 & 0 \end{pmatrix}, \quad R_2 = \begin{pmatrix} 0.25 & 0.4167 & 0.25 & 0.0833 & 0 \\ 0.4167 & 0.3333 & 0.0833 & 0.1667 & 0 \\ 0.25 & 0.5 & 0.1667 & 0.0833 & 0 \\ 0.5833 & 0.3333 & 0.0833 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$R_3 = \begin{pmatrix} 0.1667 & 0.25 & 0.4167 & 0.1667 & 0 \\ 0.25 & 0.4167 & 0.25 & 0.0833 & 0 \\ 0.4167 & 0.3333 & 0.25 & 0.0833 & 0 \\ 0.1667 & 0.25 & 0.1667 & 0.1667 & 0 \\ 0.25 & 0.5 & 0.0833 & 0.1667 & 0 \end{pmatrix}, \quad R_4 = \begin{pmatrix} 0.25 & 0.4167 & 0.25 & 0.0833 & 0 \\ 0.4167 & 0.3333 & 0.25 & 0.0833 & 0 \\ 0.3333 & 0.1667 & 0.25 & 0.25 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$B_1 = W_1^{(1)} \cdot R_1 = \begin{pmatrix} 0.4717 & 0.2562 & 0.1078 & 0.1644 \end{pmatrix}, \quad B_2 = \begin{pmatrix} 0.2424 & 0.3154 & 0.3140 & 0.1364 & 0 \end{pmatrix}$$

Similarly, it is available: $B_2 = (0.3218 \ 0.4058 \ 0.1751 \ 0.0972 \ 0), \quad B_3 = (0.5017 \ 0.2850 \ 0.1554 \ 0.0579 \ 0), \quad B_4 = (0.3623 \ 0.2360 \ 0.2613 \ 0.5033 \ 0)$. 

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4.3. Perform secondary evaluation

According to the first-level evaluation results, the second-level fuzzy evaluation matrix can be obtained:

\[ B = W(2) \cdot R = (0.4565 \ 0.2707 \ 0.1927 \ 0.0801) \cdot \begin{pmatrix}
0.2424 & 0.3154 & 0.3140 & 0.1364 & 0 \\
0.3218 & 0.4058 & 0.1751 & 0.0972 & 0 \\
0.5017 & 0.2850 & 0.1554 & 0.0579 & 0 \\
0.3623 & 0.2360 & 0.2613 & 0.5033 & 0 \\
\end{pmatrix}
\]

\[ = (0.3235 \ 0.3277 \ 0.2416 \ 0.1401 \ 0) \]

According to the principle of maximum membership, the quality risk level of the power transmission and transformation project is lower, but to achieve the best level. This shows that the quality supervision of the project needs to be improved.

5. Conclusion

This paper analyzes the quality risk factors of the EPC power transmission and transformation project led by the design enterprise in the whole process, and builds a list of risk factors. Based on the principle of maximum membership degree, the fuzzy comprehensive evaluation principle is used to analyze the risk. I hope that the general contracting mode with design as the leader will play a certain enlightenment in the follow-up research in the field of power transmission and transformation.

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