Research on the Risk of TOT Hydropower Project Based on Fuzzy Fault Tree

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ABSTRACT

The transfer–operate–transfer (TOT) financing mode is a maturing project financing mode that is widely used in the construction and operation of domestic and foreign large-scale projects. The current theoretical research and practical applications of this mode are in the exploration and innovation process. On the basis of the case of the W hydropower project, this study uses the Hall 3D structural model to identify the project risks and the fuzzy fault tree method to quantitatively assess the risks. The measures of the major risks of TOT projects are also given to provide reference value proposals to the project manager.

KEYWORDS

Risk analysis, TOT, Financing mode, Hall 3D structural model, fuzzy fault tree

1 Introduction

Large and medium-sized project financing modes, which began in the 1970s, are mainly used in energy, utility, and infrastructure projects. Although this financing mode is relatively new compared with other modes, the production and application of project financing have practical significance in solving the problem of fund shortage. Therefore, the project financing mode has been widely developed and applied.

According to current research and the situation in China and abroad, the transfer–operate–transfer (TOT) model is a project financing mode that is applied to large construction projects. Examples of such projects are transportation projects (e.g., highways, railways, and aviation), energy construction projects (e.g., hydroelectric power stations), and resource exploitation projects (e.g., mineral, oil, and natural gas resource projects).

The W hydroelectric project is currently planning to use the TOT model in its operation. The main participants of this project will be the local government, investment companies, lenders, construction units, operation agencies, insurance institutions, raw material suppliers, users, and legal service agencies. One of the most important problems is raising or rapidly recovering construction funds, which can be solved by the project financing mode. From the view of project investors, this study analyzes the hydropower project risk management of the TOT financing mode.

2 TOT Financing Mode and Brief Introduction of the Case

2.1 Brief Introduction of the TOT Financing Model

TOT is a project financing mode that involves the transfer of ownership of an operating public infrastructure project from the owner to social investors for a price within a certain period of time. The investors will receive all revenues during the operating period. The project owners aim to increase the cash flow within the operating period. They also repatriate large sums of money at one time and use it as project loan payments or new project start-up capital. After the expiration of the concession, social investors transfer the operating public infrastructure projects to the project owners freely [1].

2.2 Introduction of the W Hydropower Station

The W Hydropower Station is located in the lower reaches of the Yunnan River in the Weiyuan (WY) Province. This station is the only key power plant in the WY River. The project area landform belongs to the medium cutting Zhongshan tectonic erosion landform. This area has folds and faults, and the basic earthquake intensity reaches 7.0 on the Richter scale. The climate belongs to subtropic monsoon, and the average annual temperature is 15.8 °C to 20.2 °C. The average annual rainfall is 1200 mm to 1600 mm. The drainage area over the dam of the W Hydropower Station is 3528 km2, the average annual flow is 71.1 m3/s, and the average annual runoff is 22.42 × 108 m3. The average annual sediment concentration is 1.594 kg/m3, the quantity of suspended sediment is 358 × 104 t, and the quantity of bedload transport is 35.8 × 104 t.

From the power grid planning of the W Hydropower Station in the region, the installed power capacity is approximately 750 MW in 2015, significantly higher than the current 241 MW installation. Thus, additional power should be generated to fill the gap of electric power systems and to ensure the sustained and stable development of the national economy of power supply areas. Most of the hydroelectric power stations in this region are riverbed power stations, which usually has an unreliable power structure and lacks peaking capacity systems. The W Hydropower Station has incomplete regulation capacity. The regulation capacity volume is 1.5986 × 108 m3. This station is a medium hydropower station and has the best power grid performance in the region. The W Hydropower Station can enhance the load capacity of regional power grids and provide significant benefits to the economic and safe grid operation. Thus, this station should be developed as soon as possible.

The W Hydropower Station has a solid basis of preliminary works. The pre-feasibility report passed the examination in 2001, and the original registered capital of the station is 10 million yuan. L Company invested 9 million yuan for a total equity of 90%. G Company invested 1 million yuan for a total equity of 10%. After financial restructuring, the registered capital becomes 90 million yuan, with L Company holding a total equity of 100%. The W Hydropower Station was built in the "Eleven-Five" period and started operations in 2010 to alleviate the power shortage in the region. This station is currently in the TOT operation of the feasibility study phase and is still operated by L Company.

3 Risk Identification Based on the Hall 3D Structure of the TOT Hydropower Project

3.1 TOT Hall 3D Structure

In 1969, Hall an American systems engineering expert, proposed a system engineering method called the Hall 3D structure. By fully considering all aspects involved in the system, he created a 3D structure with time dimension, logic dimension, and knowledge dimension [2].

Investors that use the TOT financing mode face various risks, such as policy, financing, and management problems. These risks influence project transfers and operations. The risk identification of TOT projects is the prerequisite and guarantee of project risk management. The purpose of risk identification is to know the objective existence of risks and to identify the causes and conditions of risks. Losses that occur may lead to serious consequences. Thus, risk identification should be conducted comprehensively. Profound risks directly affect the final achievement of TOT project risk management.

This study is based on the concept model of the Hall –3D structure, combined with the theory and practice of multiple TOT case studies. This study also proposes an integrated 3D structure of the risk factors in the TOT financing mode of hydropower stations (Figure 1).

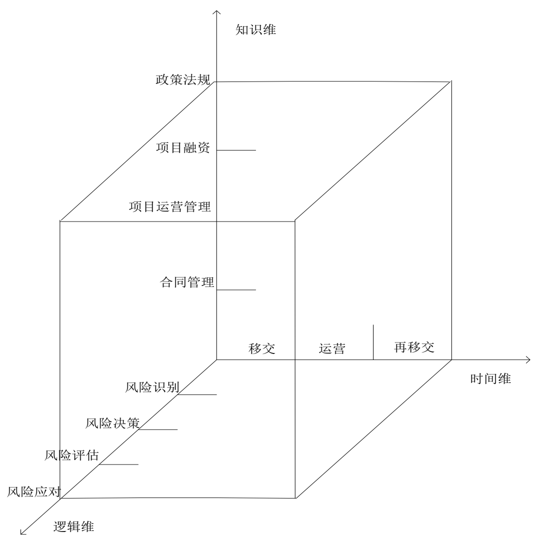

Figure 1. Integrated 3D structure of the risk factors of TOT financing mode

3.1.1 Time Dimension

The life cycle of a project encompasses all phases of the project from start to end. In this study, according to the project life cycle of the TOT financing mode, we divide the time dimension into three phases, namely, transfer, operation, and transfer. This study focuses on the analysis of the risk factors of the transfer phase.

3.1.2 Logic Dimension

In the logic dimension, according to the risk issues discussed in this thesis, we divide the entire process into four phases, namely, risk identification, risk decision, risk assessment, and risk response. The qualitative and quantitative analyses of risk factors are conducted according to this order, and helpful conclusions of risk prediction and avoidance are obtained.

3.1.3 Knowledge Dimension

In the knowledge dimension, we involve four major areas of risk factors, namely, policy and regulation risk, project financing risk, project operation management risk, and contract management risk.

3.2 Risk Identification of the W Hydropower Station Project

We believe that the risks faced by investors in the W hydroelectric project in TOT operation mode include the following aspects.

3.2.1 Policy and regulation risk

For investors, foreign capital is particularly important. Policy and regulation risk includes national or regional political risk, foreign exchange risk, and legal risk.

3.2.2 Project financing risk

The profits of investors are based on future cash flows. A short project financing time and substantial capital expenditures require investors to quickly raise large sums of money to participate in the bidding of power.

3.2.3 Project operation management risk

Given that the project operation time of TOT hydropower stations is long, a number of stakeholders are involved. The project management level directly affects the success of projects. Thus, the project operation management risk causes widespread concern in the community.

3.2.4 Contract management risk

Owing to a wide range of TOT hydropower projects involved in the transfer process, complicated transfer process procedures and contract terms lead to a certain degree of contract risk. Thus, investors should pay attention to these factors.

On the basis of the risk identification process and integrated 3D structure, we show the risk factors of the TOT financing mode of the W Hydropower Station. A good platform is provided for the quantitative analysis of the risk factors.

4 Case Analysis

4.1 Fuzzy Fault Tree Analysis Method

The fuzzy fault tree analysis method is the extension of fault tree theory. This method assesses system reliability by analyzing the logical relationship among the causes of system failure layer-by-layer. This method can identify system risks, determine the probability of risk occurrence, and provide risk management solutions. This method also has broad application prospects in operating public infrastructure projects.

4.1.1 Qualitative analysis process

The fuzzy fault tree analysis process generally includes three steps, namely, the determination of top events, the construction of a fault tree, and the qualitative analysis of the fault tree. A risk event that is identified as a top event has the characteristics of large probability and serious consequences. After determining the top events, we use the deductive analysis method to analyze such events. The direct causes of the events are identified step by step until all basic events are found. Logical relationships should be emphasized in this process and fault tree diagrams should be obtained. Finally, the resulting fault tree is simplified with the help of the Boolean algebra simplifying method to solve the minimum cut sets and minimum path sets of the fault tree.

4.1.2 Quantitative analysis process

Fuzzy number stands are used for the probability of basic events. The probability of the top event is calculated. The structure importance, probability importance, and critical importance coefficients of each basic event are obtained. The advantage of using fuzzy stands for event probability is that it can reduce the difficulty of obtaining the accurate values of occurrence probability and combine the practical experiences of experts to accurately describe project risks [3]. The detailed process is as follows:

(1) Determining the occurrence probability of basic events

Zadeh proposed fuzzy set theory to address the phenomenon of imprecise and vague problems in 1965. $\tilde{Y}$ is set as a map of domain X [0,1], i.e., $\tilde{Y}: X$,$x \mapsto \tilde{Y}(x)$. $\tilde{Y}$ is the fuzzy set of X , and $\tilde{Y}(x)$ is the membership function of fuzzy set $\tilde{Y}$. The membership functions of fuzzy numbers have many forms. This study uses triangular fuzzy numbers as an example.

(2) Determining the probability of top events

The probability of top events refers to the risks that occur during the operation of the entire project, i.e.,

$$P = 1 - \prod_{i=1}^{n}\left(1 - p_i\right).$$

On the basis of the algebraic algorithms of triangular fuzzy number, when the probability of the bottom event is a triangular fuzzy number (m, a, b), the result of the top events is also a fuzzy number and can be expressed as follows:

$$P_A = 1!\prod_{i=1}^{n}(1!\ P_i)$$

$$= 1!\prod_{i=1}^{n}(1!\ (m_i - a_i, m_i, m_i + b_i))$$

$$= ((1-\prod_{i=1}^{n}(1-m_i+a_i)),(1-\prod_{i=1}^{n}(1-m_i)),(1-\prod_{i=1}^{n}(1-m_i-b_i)))$$

(3) Determining the coefficient of structure importance

The structure importance of bottom event is based on observing the structure of the fault tree to determine the importance of the event location regardless of the occurrence probability during this process. The structure function of the fuzzy tree is defined as follows:

$$\phi = \phi(X) = (x_1, x_2, \cdots, x_n).$$

Considering that the state x_i of bottom event i evaluates 0 or 1, $i = 1, 2, \cdots, n$, the system state number that combines n events is called 2^{n-1}. Thus, the structure importance $I_\phi(i)$ of the bottom event i is defined as follows: $I_\phi(i) = \frac{1}{2^{n-1}} \sum_{(x/x_1=1)} \left[\phi(1_i, x) - \phi(0_i, x)\right]$.

(4) Determining the coefficient of probability importance

The coefficient of probability importance is used to analyze how the probability of basic event changes affects the probability of the occurrence of top events. The coefficient of probability importance is expressed as the top event probability P with partial derivatives of independent variables p_i, i.e., $I_{p(i)} = \frac{\partial P}{\partial p_i}$

(5) Determining the coefficient of critical impo-rtance

The analysis of critical importance is used to evaluate the basic events of importance. The effect of the probability of basic events on the probability of top events is considered. The coefficient of critical importance is expressed as follows:

$$_{g(i)} = \frac{\partial P / P}{\partial p_i / p_i} = \frac{p_i}{P} I_{p(i)} .$$

The coefficients of structure importance, probability importance, and critical importance are significant measures in the quantitative analysis of the fuzzy fault tree method. According to the basic meaning of measure, the coefficient of critical importance can fully reflect the importance of basic events from the sensitivity and probability of occurrence perspective.

4.2 Risk Analysis of the W Hydropower Station

4.2.1 Construction of fault tree

On the basis of the clustering analysis of the risk factors inherent in the TOT financing mode of the W Hydropower Project, 12 risk factors (Table 1) are obtained. The fault tree is built accordingly (Figure 2).

Table 1. Clustering analysis of risk factors

R	Risk category	Risk factor
TOT project financing Risk	R_1 Policy and regulation risk	x_1 The laws and regulations related to franchises are not perfect
		x_2 Policies are poorly continued
	R_2 Financing risk	x_3 The amount of funds used in plans are unreasonable
		x_4 The amount of funds exceeds the standard stage
		x_5 Interest rates change
		x_6 Inflation occurs
	R_3 Management risk	x_7 The technical conditions of operation management are not guaranteed
		x_8 Profit distribution is unreasonable
		x_9 Management procedures are complex
	R_4 Contract risk	x_{10} The concession period cannot be accurately determined
		x_{11} The rights and obligations of the main parties are not comprehensive
		x_{12} Contract changes

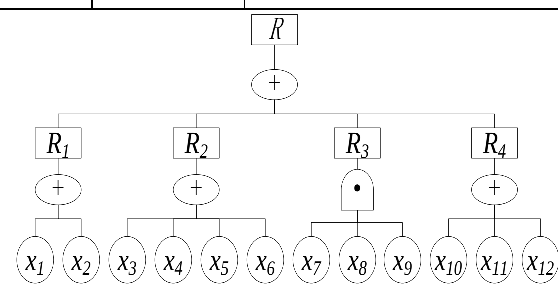

Figure 2. Fault tree logic structure of the financing risk accident of the W Hydropower Station.

4.2.2 Qualitative Analysis

The Boolean algebra method is used to solve the fuzzy fault tree, and the minimum cut set is obtained. The solving method is as follows. The fuzzy fault tree is first changed into a Boolean expression and then simplified by using the boolean algebra law. The simplest expression is the union of a number of intersections. each intersection is the minimum cut set of the fuzzy fault tree (Table 2).

$$R = R_1 + R_2 + R_3 + R_4$$
$$= x_1 + x_2 + x_3 + x_4 + x_5$$
$$+ x_6 + x_7 x_8 x_9 + x_{10} + x_{11} + x_{12}$$

The total of fault trees of the minimum cut sets is 10.

$R^1=\{x_1\}$; $R^2=\{x_2\}$; $R^3=\{x_3\}$; $R^4=\{x_4\}$;
$R^5=\{x_5\}$; $R^6=\{x_6\}$; $R^7=\{x_7x_8x_9\}$;
$R^8=\{x_{10}\}$; $R^9=\{x_{11}\}$; $R^{10}=\{x_{12}\}$

Table 2. Minimum cut sets of fault tree.

Minimum cut set	Risk factor
x_1	The laws and regulations related to franchises are not perfect
x_2	Policies are poorly continued
x_3 x_4 x_5 x_6	The funds used in plans are unreasonable, the amount of funds exceeds the standard stage, interest rates change, and inflation occurs
x_7 x_8 x_9	The technical conditions of operation management are not guaranteed, the profit distribution is unreasonable, and the management procedures are complex
x_{10}	The concession period cannot be accurately determined
x_{11}	The rights and obligations of the main parties are not comprehensive
x_{12}	Contracts change

According to the duality of minimum radius and cut sets, the success tree of dual fault tree is established. The fault tree operations are interchanged. The events that happened are changed into the events that did not occur. The method of Boolean algebra is used to generate the minimum cut sets of success number. The minimum radius sets of the original fault are obtained after the duality.

$$\begin{aligned}\overline{R} &= \overline{R}_1\overline{R}_2\overline{R}_3\overline{R}_4\\ &= \overline{x}_1\overline{x}_2\overline{x}_3\overline{x}_4\overline{x}_5\overline{x}_6(\overline{x}_7+\overline{x}_8+\overline{x}_9)\overline{x}_{10}\overline{x}_{11}\overline{x}_{12}\\ &= \overline{x}_1\overline{x}_2\overline{x}_3\overline{x}_4\overline{x}_5\overline{x}_6\overline{x}_7\overline{x}_{10}\overline{x}_{11}\overline{x}_{12}\\ &\quad+\overline{x}_1\overline{x}_2\overline{x}_3\overline{x}_4\overline{x}_5\overline{x}_6\overline{x}_8\overline{x}_{10}\overline{x}_{11}\overline{x}_{12}\\ &\quad+\overline{x}_1\overline{x}_2\overline{x}_3\overline{x}_4\overline{x}_5\overline{x}_6\overline{x}_9\overline{x}_{10}\overline{x}_{11}\overline{x}_{12}\end{aligned}$$

Minimum cut sets of success tree: $\overline{R}^1=\{\overline{x}_1,\overline{x}_2,\overline{x}_3,\overline{x}_4,\overline{x}_5,\overline{x}_6,\overline{x}_7,\overline{x}_{10},\overline{x}_{11},\overline{x}_{12}\}$;

$\overline{R}^2=\{\overline{x}_1,\overline{x}_2,\overline{x}_3,\overline{x}_4,\overline{x}_5,\overline{x}_6,\overline{x}_8,\overline{x}_{10},\overline{x}_{11},\overline{x}_{12}\}$;

$\overline{R}^3=\{\overline{x}_1,\overline{x}_2,\overline{x}_3,\overline{x}_4,\overline{x}_5,\overline{x}_6,\overline{x}_9,\overline{x}_{10},\overline{x}_{11},\overline{x}_{12}\}$

Minimum radius sets of fault tree: $R^1=\{x_1,x_2,x_3,x_4,x_5,x_6,x_7,x_{10},x_{11},x_{12}\}$;

$R^2=\{x_1,x_2,x_3,x_4,x_5,x_6,x_8,x_{10},x_{11},x_{12}\}$;

$R^3=\{x_1,x_2,x_3,x_4,x_5,x_6,x_9,x_{10},x_{11},x_{12}\}$

The minimum radius sets are obtained from the logical structure of the fault tree shown in Fig. 3, as indicated in Table 3.

Table3. Minimum radius sets of fault tree

Minimum radius set	Risk factor
x_1 x_2 x_3 x_4 x_5 x_6 x_7 x_{10} x_{11} x_{12}	The laws and regulations related to franchises are not perfect, policies are poorly continued, the funds used in plans are unreasonable, the amount of funds exceeds the standard stage, interest rates change, inflation occurs, the technical conditions of operation management are not guaranteed, the concession period cannot be accurately determined, the rights and obligations of the main parties are not comprehensive, and contracts change
x_1 x_2 x_3 x_4 x_5 x_6 x_8 x_{10} x_{11} x_{12}	The laws and regulations related to franchises are not perfect, policies are poorly continued, is the funds used in plans are unreasonable, the amount of funds exceeds the standard stage, interest rates change, inflation occurs, profit distribution is unreasonable, the concession period cannot be accurately determined, the rights and obligations of the main parties are not comprehensive, and contracts change
x_1 x_2 x_3 x_4 x_5 x_6 x_9 x_{10} x_{11} x_{12}	The laws and regulations related to franchises are not perfect, policies are poorly continued, the funds used in plans are unreasonable, the amount of funds exceeds the standard stage, interest rates change, inflation occurs, the management procedures are complex, the concession period cannot be accurately determined, the rights and obligations of the main parties are not comprehensive, and contracts change

4.2.3 Quantitative Analysis

By using the method of expert seminar hall, this study selects 5 experts from 4 aspects, namely, policies and regulations, project financing, project management, and contract management.

A total of 20 professionals who are familiar with the field and have high authority and representativeness are selected. In the risk assessment work, the expert scoring method is usually adopted to calculate the occurrence probability of an incident. However, experts find it difficult to indicate specific values to the probability of an event. Hence, they tend to use the language value set (small, smaller, medium, comparatively large, larger) to express “the failure probability.” Such a set is also used as an index to evaluate risks (Figure 2). After several rounds of public comment, feedback, and adjustment, various risks are analyzed.

This study uses the expert evaluation method to obtain the language variables of the probability of each risk given by all experts. The probability is transformed into fuzzy numbers according to Fig. 3. According to the weight coefficient given by each expert, fuzzy algebra algorithms are used to generate the weighted average fuzzy probability of any risk of accident given by all experts.

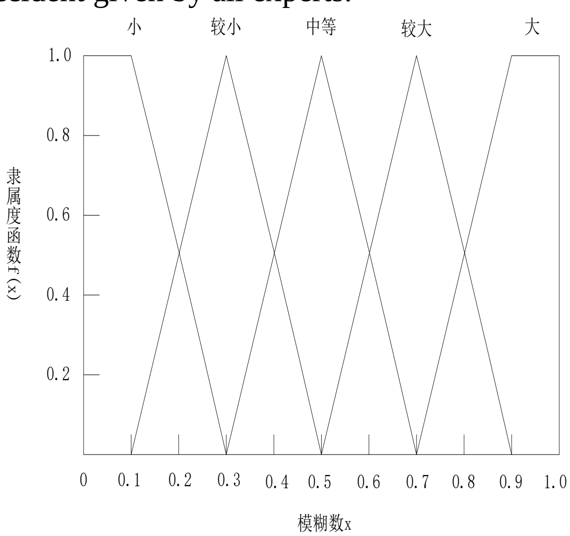

Figure 3. Natural fuzzy number.

The risk assessment index obtained from the experts is transformed into isosceles triangular fuzzy numbers. The median fuzzy number is the average of risk probability values. The fuzzy interval is ±10%, i.e., $a_i = b_i = 10\%$, and $n = 12$. The median probability of basic events is shown in Table 4.

Table 4. Median probability of basic events

Symbol	Risk factor	Event value	Median probability
x_1	The laws and regulations related to franchises are not perfect	Basic Event	0.0078
x_2	Policies are poorly continued	Basic Event	0.0099
x_3	The funds used in plans are unreasonable	Basic Event	0.0099
x_4	The amount of funds exceeds the standard stage	Basic Event	0.0099
x_5	Interest rates change	Basic Event	0.0099
x_6	Inflation occurs	Basic Event	0.0099
x_7	The technical conditions of operation management are not guaranteed	Basic Event	0.0099
x_8	Profit distribution is unreasonable	Basic Event	0.0099
x_9	Management procedures are complex	Basic Event	0.0000
x_{10}	The concession period cannot be accurately determined	Basic Event	0.0099
x_{11}	The rights and obligations of the main parties are not comprehensive	Basic Event	0.0099
x_{12}	Contracts change	Basic Event	0.0099

4.2.4 Risk Assessment

The coefficients of structure importance, probability importance, and critical importance are obtained by the quantitative analysis of the fault tree (Table 5) to evaluate the coefficients of TOT project risks.

Table 5. Coefficients of structure importance, probability importance, and critical importance

Minimum radius set	Coefficient of structure importance	Coefficient of probability importance	Coefficient of critical importance
x_1	0.08	0.16	1.0001
x_2	0.08	0.04	0.1268
x_3	0.04	0.03	0.1527
x_4	0.04	0.04	0.0445
x_5	0.04	0.02	0.0509
x_6	0.04	0.01	0.0445
x_7	0.18	0.15	0.2538
x_8	0.18	0.21	0.2545
x_9	0.18	0.12	0.0698
x_{10}	0.05	0.09	0.0191
x_{11}	0.05	0.08	0.0254
x_{12}	0.05	0.06	0.0254

The above results indicate the analysis of three important indicators, namely, the coefficients of structure importance, probability importance, and critical importance. The numerical coefficient of the structure importance of each basic event of the fault tree $I_\phi(i)$ is shown in the first column of Table 5. The comparative results of the coefficient of structure importance $I_\phi(i)$ are as follows:

$$I_\phi(7)=I_\phi(8)=I_\phi(9)>I_\phi(1)=I_\phi(2)>I_\phi(10)$$
$$=I_\phi(11)=I_\phi(12)>I_\phi(3)=I_\phi(4)=I_\phi(5)=I_\phi(6)$$

According to the comparative analysis of the coefficient of structure importance, the following factors need to be solved in TOT project financing: the technical conditions of operation management are not guaranteed, profit distribution is unreasonable, and management procedures are complex. The project company should also focus on management risks.

The numerical coefficient of probability importance of each basic event of the fault tree $I_{p(i)}$ is shown in the second column of Table 5. The comparative results of the coefficient of probability importance $I_{p(i)}$ are

$$I_p(8)>I_p(1)>I_p(7)>I_p(9)>I_p(10)>I_p(11)$$
$$>I_p(12)>I_p(2)=I_p(4)>I_p(3)>I_p(5)>I_p(6)$$

According to the comparative analysis of the coefficient of probability importance, the following factors are significant and should be given attention by the project company: profit distribution is unreasonable, the laws and regulations related to franchises are imperfect, the technical conditions of operation management are not guaranteed, and management procedures are complex.

The numerical coefficient of the critical importance of each basic event of the fault tree $I_{g(i)}$ is shown in the third column of Table 5. The comparative results of the coefficient of probability importance $I_{g(i)}$ are as follows:

$$I_g(1)>I_p(8)>I_p(7)>I_p(3)>I_p(2)>I_p(9)$$
$$>I_p(5)>I_p(6)=I_p(4)>I_p(11)=I_p(12)>I_p(10)$$

According to the comparative analysis of the coefficient of critical importance, the following factors should be focused on by the project company: the laws and regulations related to franchises are not perfect, profit distribution is unreasonable, the technical conditions of operation management are not guaranteed, the funds used in plans are unreasonable, and policies are poorly continued.

The final results regarding the coefficients of structure, probability, and critical importance of risk factors indicate that the W Hydropower Station should consider the following risks as the main risks: the laws and regulations related to franchises are not perfect, profit distribution is unreasonable, the technical conditions of operation management are not guaranteed, etc. Considering the properties of the four risk factors, investors should pay particular attention to policy and regulation risk and management risk; if the relevant policy and regulation risk is too large, it will have a significant effect on project financing, operation, management, and benefits [4]; if the project management risk is too large, it will lead to project internal control capability imbalance and will affect the success of the project.

4.2.5 Risk Response

According to the results of risk analysis and based on the 3D structure considering the time, knowledge, and logic dimensions of risk factors comprehensively, we propose the following measures according to the main risk of TOT financing mode of the W Hydropower Station:

(1) To seek written guarantee from the local government unit of Yunnan Province, the regional government, the central bank, and other departments of the organization, the project should meet the legal requirements of franchise policy in the host country or region in the handover procedures. If necessary, the relevant guarantee agreement with the host government should be signed to respond to the policy and regulation risk relevant to the project.

(2) In view of project financing and considering the large-scale infrastructure construction project properties of the W Hydropower Station, investors should utilize large-scale and multi-aspect financing modes to reduce the difficulty and complexity of financing and solve the financial problems of the entire project. The use of funds should also be reasonably planned and the normal procedures of the project transfer operation should be ensured to maximize revenues [5].

(3) Advanced and scientific management techniques and methods should be introduced in the W Hydropower Station. The project management should be divided into separate project units, and a reasonable management information system should be established. In terms of cost control, labor, material, and machine costs should be reasonably controlled to form a comprehensive and full-cycle project management system and to systematically operate the project.

5 Conclusion

This study introduces the Hall 3D structure of the theory of system engineering method to identify the risk factors of TOT financing mode. The risk factors are analyzed from three dimensions, namely, knowledge dimension, time dimension, and logic dimension. The major risk categories are also identified. The method of fuzzy fault tree is utilized for the quantitative analysis of the risk factors of TOT model in the application process. The minimum cut sets and minimum radius sets are determined. The importance degree of each risk factor is also determined. Through the preceding analysis process, we hope to provide sufficient reference values to help the W Hydropower Station avoid various risks in the operation of TOT mode, reduce the occurrence probability of the risks, and minimize the risk harms to ensure that the project operates reasonably, orderly, and efficiently.

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