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Optimization of China EPC power project cost risk management in construction stage based on bayesian network diagram

Guiqin Zhang[1], Zheng Wang[1,2]

Abstract. In recent years, the application of EPC mode in China's power construction field has become more extensive, which is apparently improve the efficiency of construction, but meanwhile EPC mode put forward higher requirements of risk management and control capabilities for the EPC general contractor. As a key stage to form actual costs, optimize the risk construction stage has the profound significance. This paper firstly uses the form of interview to identify the type of construction risk and then constructs the logical structure between the risk factors, finally builds the Bayesian network model by MATLAB. By inputting the edge probability, the probability value of actual cost risk can be calculated under any condition. According to the results of calculation, this paper puts forward the difference management level of risk factors based on the process of risk transmission and the sensitivity of risk factors. It can help project management department enhance the risk management ability under the premise of limited resources and provide the power data support for risk management decision.

Key words. EPC power project, Bayesian network diagram, differentiation Management of risk.

1. Introduction

Nowadays, China is widely using the general contracting mode (EPC mode) , which has made outstanding contributions to China's power construction [1]. But at the same time it should be noted that under the mode of EPC, the contractors will take great losses if they don't identify risk accurately in time [2]. To solve this problem, we should start with the relationship between risk factors of each stage of EPC mode, and identify risk by combining the characteristics of EPC mode. Considering the suitability of the problem and the maturity of the model research,

[1]College of Economics and Management, North China Electric Power University, Changping District 102206, Beijing, China

[2]Corresponding Author, e-mail: 188104110787@163.com

this paper chooses Bayesian network model as the basic framework. Tugrul and Daim [3] who apply Bias network for analysis and estimation of the clean energy project investment risk, depict the probability of risks in the whole life cycle of clean energy project.Levent Koc [4] combines Bias network technology with network anti-invasion mechanism, and effectively estimate the probability of hacker attacks At present, the application of Bias network model in engineering risk research is quite limited, so it cannot meet the needs of practical engineering construction. Based on current situation, this article carries out the research of engineering risk by Bias network,

2. The bayesian model of epc power project cost risk in construction stage

2.1. The identification of cost risk

Construction stage is one of the important stages in the engineering projects. At this stage the contractor invests a lot of manpower, material resources and capital. If this stage of risk management is ignored, it may bring serious consequences to the project and cause a great loss [5], so as EPC project contractor, they must focus on the risk identification and control at this stage [6]. The general contractor at this stage is not mainly responsible for risk of equipment damage caused by the accident or personnel casualty risk, but also bear the risk due to design or procurement stage problems influenced by the time lag, poor quality and other unforeseen risks [7]. In addition, the contractor also needs to take risks of market price fluctuation, low management efficiency and social environment [8].

Table 1. The result of Delphi method

Risk categories	Risk name	Mention frequency
Subjective risk	Budget preparation	0.07
	Requirements of Quality and functional	0.13
	Construction technology	0.06
	Design	0.12
	Engineering investigation and survey	0.07
	Engineering quantity	0.12
	Construction organization	0.08
	Construction schedule	0.07
	Management	0.11
	Accident	0.1
Objective risk	Natural environment	0.19
	Market supply	0.18
	Social environment	0.17
	Price of labour, equipment and material	0.18

According to a large number of literature and construction experience [9, 10], we have figured out the most influential factors of cost as the basic elements of Bayesian network, meanwhile ignore the less mentioned factors, the results of the survey is shown in table 1.

According to the table 2, we combine the form of expert evaluation and case study to set up the Bayesian logical risk table. The result is shown in table 2.

Table 2. Main risks logic relationship at construction stage

Risk name	Parent logical point
Construction technology	Natural environment, Budget preparation, Requirements of Quality and functional
Engineering quantity	Construction technology, Design, Engineering investigation and survey
Market supply	Natural environment, Social environment
Accident	Social environment, Construction technology
Construction organization	Construction technology, Engineering quantity
Construction schedule	Construction organization, Design
Transaction cost	Market supply
Price of labour, equipment and material	Market supply, Construction technology
Management cost	Social environment, Accident, Construction schedule

2.2. Bayesian Network Model Of Cost Risk At Construction Stage

According to the logic table shown in table 2, the risks factor model are portrayed in Figure 1 by MATLAB.

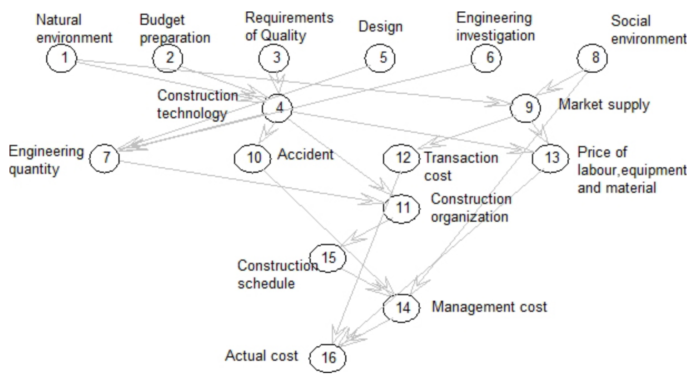

Fig. 1. Bayesian network model of cost risk at construction stage

After the Bayesian network diagram is completed, we can collect the EPC project data similar to the proposed project as a reference, and analyze the probability of each risk factor in Figure 1.Then the analysis probability values are introduced to the Bayesian network diagram, which can be dealt with MATLAB. The outcome of a program is the probability of the actual cost overrun caused by different risks, which is the basis of risk differentiation management. Through the analysis of the probability value, the general contractor can be more targeted to the differentiation risk management at construction stage.

Not only that, the EPC general contractor can analyze the sensitivity of a certain risk, they can adjust the probability of risk in the network, such as increased or decreased by 5%, then observe the change of probability value of actual cost risk after running the program. In this paper, the sensitivity is defined as formula 1.

$$S_i = \frac{C_p}{C_i} \tag{1}$$

S_i: The sensitivity of the risk factors i to risk of the actual construction cost.

C_p: The variation range of actual construction cost.

C_i: The variation range of the risk factors i.

Through the above analysis, EPC general contractor can make it clear in advance that which risks in this project has a more significant impact on actual cost risk. Thus they will pay more attention to these factors in order to help improve the efficiency of risk management. Detailed data analysis process will be given in case study.

3. case study

3.1. Data Collection

In order to ensure the validity of the data, with the aid of statistical experience, we believe the model can basically meet the requirements of the data when the sample size is greater than or equal to 30 and exclude abnormal data on the calculation results of interference.

This paper collects and studies 30 EPC project in China and interviews the project management staff in order to figure out the reason of the actual cost overruns, then calculates the average probability of each risk factor in Bayesian network graph. In a network diagram, there are three forms of probability: False, True, and Default. “False” indicates that the risk factor does not occur, while “True” means that the risk factor has occurred, the “Default” means that the risk factor occurs in accordance with the probability of the definition [11]. In this paper, that the actual index value exceeds 20% of the expected target value is defined as risks occurrence. At the same time, we revise the probability value slightly according to the situation. Summary table of Probability is shown in table 3.

Table 3. Summary of risk factors prior probability

Risk name	Prior probability
Natural environment	0.85, 0.15
Budget preparation	0.88, 0.12
Requirements of Quality and functional	0.87, 0.13
Design	0.81, 0.19
Engineering investigation and survey	0.83, 0.17
Social environment	0.95, 0.05
Transaction cost	0.94, 0.41, 0.06, 0.59
Construction schedule	0.82, 0.53, 0.18, 0.47
Market supply	0.86, 0.54, 0.71, 0.27, 0.14, 0.46, 0.29, 0.73
Accident	0.98, 0.82, 0.02, 0.18
Construction organization	0.96, 0.70, 0.84, 0.47, 0.04, 0.30, 0.16, 0.53
Price of labor, equipment and material	0.89, 0.72, 0.80, 0.32, 0.11, 0.38, 0.20, 0.68
Construction technology	0.90, 0.65, 0.81, 0.72, 0.68, 0.64, 0.67, 0.55, 0.10, 0.35, 0.19, 0.28, 0.32, 0.36, 0.33, 0.45
Engineering quantity	0.88, 0.62, 0.64, 0.59, 0.61, 0.55, 0.51, 0.22, 0.12, 0.38, 0.36, 0.41, 0.39, 0.45, 0.49, 0.78
Management cost	0.94, 0.67, 0.71, 0.84, 0.57, 0.62, 0.63, 0.42, 0.06, 0.33, 0.29, 0.16, 0.43, 0.38, 0.37, 0.58
Actual cost	0.90, 0.77, 0.72, 0.76, 0.71, 0.75, 0.70, 0.39, 0.10, 0.23, 0.28, 0.24, 0.29, 0.25, 0.30, 0.61

3.2. Model Test

In order to deepen the study of the relationship between the nodes in the Bayesian network and the risk probability of the actual cost, we calculate the shortest step distance from each risk factor node to the node of actual cost in the Bayesian network and arrange them in descending order. This arrangement can study more precisely of the influence on logical structure of factors to the actual cost. For the risks that have the same step distance, we arrange them in the order of occurrence.

In summary, we arrange the risk factors in accordance with above rules, and number them from 1 to 16, and switch state of the risk factor from “Default” to “True” one by one when operating the MATLAB. The result is listed in the table 4.

Table 4. Actual cost risk changes under risk factors transmission

Number	Risk name	Shortest step distance	The probability of the actual cost risk
1	None	–	0.2053
2	Design	5	0.2055
3	Engineering investigation and survey	5	0.2056
4	Engineering quantity	4	0.2130
5	Requirements of Quality and functional	3	0.2114
6	Budget preparation	3	0.2072
7	Natural environment	3	0.2278
8	Construction organization	3	0.2327
9	Construction technology	3	0.2439
10	Social environment	2	0.223
11	Accident	2	0.2338
12	Market supply	2	0.2492
13	Construction schedule	2	0.2589
14	Transaction cost	1	0.2713
15	Management cost	1	0.2986
16	Price of labor, equipment and material	1	0.3176

Then we input the above results into the software and draw the tendency chart which takes the risk serial number as abscissa, the probability of actual cost as the ordinate. The tendency is portrayed in figure 2.

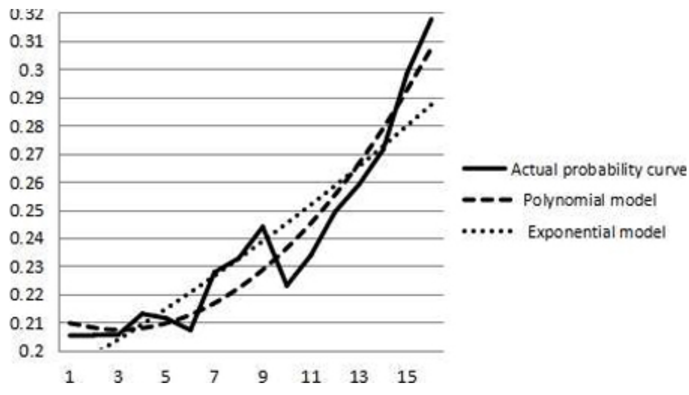

Fig. 2. Change of risk probability the actual cost risk

As what can be seen from Figure 2, if arranged according to the logical order, the later a single risk occurs in the process of risk transmission, the greater the risk of actual cost overrun will take, and the rate of increase is not linear. In order to accurately describe the practical situation of risk transmission progress in the network set up in paper, we perform a regression analysis, and the Polynomial model and Exponential model have the minimum error. The R2 of two models are 0.9342 and 0.8536, respectively.

Seen from Figure 2, the practical slope change of Polynomial model is more fitting than the Exponential model, so this paper chooses the Polynomial model as analysis object. The fitting Exponential function is 2 and then take the derivative, the result is shown in the formula 3.

$$y = 0.0006x^2 - 0.0035x + 0.2126 \tag{2}$$

$$y' = 0.0012x - 0.0035 \tag{3}$$

According to the derived function in 3, we calculate the average slope value of all step distance. The result is in table 5.

Table 5. Average slope value of all step distance

Shortest step distance	5	4	3	2	1
Average slope value	0	0.0013	0.0049	0.0103	0.0435

From table 5, it can be seen that the impact of the risk to the actual cost is rising rapidly in the process of risk transmission. The slope of the risk factor with the 5 steps is negligible, while the average slope of 1 step is 30 times more than that of the 4 steps. The results also prove that the later the logical position of risk is, the greater the cost to rectify the risk is, which will lead a sharp rise of the risks of exceeding the budget. Thus, the contractor can grade the risk management into different categories according to table 5. This article only gives management levels and does not involve the specific management measures. The general contractor should stipulate different levels of management measures based on the actual situation of enterprises and projects. In the network diagram used in this paper, managers can introduce the average slope of each distance as the management standard: the value of more than 0.1 can be set into first-level management, 0–0.1 into second-level management, while the factors value close to 0 can be set in to third-level management, so that all the different nodes will have a sub-level management correspondingly.

The above discussion is only for the risk transmission process, however, another kind risk is also one of the key points that the contractor needs to focus on, that is, the sensitivity of risk factors. Although some risks are at the front end of the logical order in the network diagram, their impact to the probability of the actual cost risk is much greater, so controlling this kind of the risk precisely is also of great significance. Therefore, this paper adopts sensitivity analysis on the basis of network model diagram. We can calculate the sensitivity of each risk factor by using the formula in 1.

Specifically, we increase the probability of each risk factor by 5% and input them into MATLAB, it should be noted that every factor remains “default” in each time the program runs (that is, the risk is occurring in probability). The result of the actual cost risk value is summarized in table 6.

Table 6. Sensitivity analysis of all risk factors

Number	Risk name (increase by5%)	The probability of the actual cost risk	Sensitivity
1	None	0.2053	–
2	Design	0.2055	0.004
3	Engineering investigation and survey	0.2054	0.002
4	Engineering quantity	0.2054	0.002
5	Requirements of Quality and functional	0.2057	0.008
6	Budget preparation	0.2054	0.002
7	Natural environment	0.2066	0.026
8	Construction organization	0.2061	0.016
9	Construction technology	0.2073	0.040
10	Social environment	0.2062	0.018
11	Accident	0.2058	0.010
12	Market supply	0.2079	0.052
13	Construction schedule	0.2068	0.030
14	Transaction cost	0.2072	0.038
15	Management cost	0.2059	0.012
16	Price of labor, equipment and material	0.2109	0.112

Table 6 shows that the sensitivity of risks is unrelated to the Bayesian network diagram constitution, and it is the unique attribute of each risk factor. So sensitivity analysis is another important work of cost risk management for a contractor. Similar to the construction of Bayesian network, the measurement of risk sensitive data should also be established on the continuous acquisition of engineering data, so that different sensitivity factors can be incorporated into differentiation management system. For example, in this paper, the contractor can set the sensitivity greater than 0.05, 0.01–0.05 and less than 0.01 to first, second and third-level management respectively. The management level set up in this article is extracted in table 7, but the specific control methods need to be carefully considered by the EPC general contractor.

EPC general contractor can consider the two aspects of management level comprehensively, and set reasonable management weight to develop a more scientific and accurate risk management system. Under the premise of limited management resources, the establishment of the management level system makes it possible for EPC general contractor to implement management more targeted and optimize the utilization of resources.

Table 7. Summary of risk factors differentiation management level

Number	Risk name	Management level	
		Logical order	Sensitivity
1	None	–	–
2	Design	3	3
3	Engineering investigation and survey	3	3
4	Engineering quantity	2	3
5	Requirements of Quality and functional	2	3
6	Budget preparation	2	3
7	Natural environment	2	2
8	Construction organization	2	2
9	Construction technology	2	2
10	Social environment	1	3
11	Accident	1	2
12	Market supply	1	1
13	Construction schedule	1	2
14	Transaction cost	1	2
15	Management cost	1	2
16	Price of labor, equipment and material	1	1

4. Conclusions

Through the Bayesian network modeling research study, this article analyzes the risk factors at construction stage from general contractor perspective, conclusions of this study are mainly the following three aspects:

(1) Based on network graph and the historical data, this paper constructs a polynomial regression mode derived from its derivative expressions, and the rise of the risk probability is not linear, instead, the speed of growth is increasing rapidly in the risks transmission process. This demonstrates that the later the risk occurs in the process of risk transmission, the greater the risk of actual cost overrun will take, the heavier the eventual losses that EPC general contractor s may suffer.That is to say, the loss caused by risk in the early period of construction is easy to make up.The general contractor should pay more attention to the preparative work of construction stage, such as repeatedly verifying the rationality of design and construction scheme, investigating the various conditions of the construction site more comprehensively so as to prevent risk probability in the network transmission process enlarging and reduce the occurrence probability of the risk factors at the end of network diagram.

(2) Different risk factors have different influence degree to the risk of actual cost. In this paper, the factors of market supply and price of labor, equipment and material are more sensitive to the actual cost. The general contractor shall provide preventive measures against these risks before construction stage.

(3) This paper discusses the importance of different factors in terms of the logical sequence of network diagram and risk factor itself, finally summarizes the risk control comprehensive level. Managers only need to weight these two aspects in accordance with the characteristics of the project. As a result, a complete set of risk prevention and control level will be built, making it easier for them to carry out a differentiation management. More money should be reserved for risk factors that have greater occurrence probability or more sensitive to the actual cost, otherwise the reserve funds of risks ought to be cut down.

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