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Analysis of risk control for engineering cost

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ABSTRACT

There are uncertainties in engineering cost activities for engineering project management. Risks in engineering cost surely bring forth risks in engineering cost control. Only when the risk factors in engineering cost activities are scientifically analyzed the "three excess" phenomena can be avoided. By comprehensively using risk management and mathematical statistics theory, the author sets random sampling functions for the probability distributions of the uncertain factors impacting engineering cost, inputs the random samples into the cost-computing equations, simulates the uncertain factors impacting cost in specific projects using Monte Carlo simulation and the Crystal Ball software, and then obtains simulation results for cost. Next the author performs statistics analysis on the simulation results and obtains a risk value for cost. By analyzing this value the author provides reference comments for risk management of project cost, so as to elevate the accuracy for cost control.

Key words: Engineering Cost, Risk Control, Monte Carlo

INTRODUCTION

Engineering cost evaluation is an important part in engineering project management activities. When engineering project activities are performed, all the projects need cost budgeting and control. The costs worked out in the rough budgeting and budgeting stage are forecasted costs. Because there are many uncertainties existing in the external and internal environmental factors, it is relatively difficult to accurately forecast the engineering project cost. There are three phenomena named "three excess" in our country's engineering project construction, which are: final accounting exceeds budgeting; budgeting exceeds rough budgeting; rough budgeting exceeds estimation. A final reason for the "three excess" phenomena is that the estimation of risk in the implementation process of constructional projects is not sufficient and risk management awareness is lacked for the cost management of constructional projects[1]. Therefore, doing research about engineering project's cost can make engineering cost more real and exact, and provide scientific evidences for engineering project activities as well.

1 Risks in engineering project's cost

1.1 Definition of risks in engineering project's cost

Engineering cost has two implications: one is the total expected and practical investment in the fixed assets for building a project, namely the sum of the one-time costs needed by the corresponding fixed assets and intangible assets formed through the building of a project; another refers to the expected and practical prices of the installation projects and the total prices of the building projects formed from the transaction activities in land market, device market, technology and labor market and contract market until the completion of a project. It can be seen that the former definition refers to project's investment fees while the latter refers to market's project prices. This paper adopts the former definition.

The definition of engineering project's risk is: losses or disadvantageous outcomes contradicting with expected benefits, namely potential losses, or damages to participants of a construction project arisen from various uncertainties[2]. It can be seen from definition that the main features of risk are uncertainty and possibility of damages.

Combining features of project risk and the basic definition of engineering cost, this paper defines risks in engineering project's cost as the set of uncertain factors affecting the investments during all the stages of project construction to gain expected benefits.

1.2 Risk factors in engineering project's cost

Main factors causing risks in engineering project's cost to happen include the following several types.

(1)Survey and design factors: incomplete understanding of geological conditions when doing survey, incomplete design contents, unreasonable planning, neglecting of the hardness the construction process.

(2) Construction factors: technological level being unable to meet requirements, management of construction spot not being in place, insufficiency of safety precaution work.

(3) Transaction factors: statement error of contract, missing of term, contract implementation being not in place.

(4) Natural environment factors: force majeure such as storm, blizzard, hurricane, flood and mud avalanche.

(5) Sociological environment factors: happening of inflation, currency variation, material and labor cost rise, adjustment of industry policies by the country, or adoption of new requirement or higher technological standards.

1.3 Risk management for engineering project's cost

From the above definition of risk in engineering cost, the work of risk management for engineering project's cost is a work that contains the whole construction process and needs collaboration of various participants, exhibiting uncertainty and unpredictability[3]. The risk management work for engineering cost mainly contains the following content.

(1)Forecasting work. Because real engineering activity has not occurred during the designing and bidding stage, all project activities are predictive. Cost work also belongs to predictive works during rough estimation, estimation and budgeting stage. Among them investor's forecasting work is intent on providing basis for the project's decision making while contractor's forecasting work is intent on providing basis for transactional and operational activities.

(2) Evaluation work. Engineering cost is one important basis for evaluating total project investment and an important index for a project's economic feasibility. Enterprise's quota in engineering cost is also an important basis for evaluating the contracting enterprise's management level and operational achievement.

(3) Regulation and control work. Engineering cost is an important index to control in project activities. Its function mainly rests on that the country regulates and controls projects utilizing the cost's economic leverage effect, the investing party performs investment control during every investment stage and the contractor and subcontractor performs control on the enterprise's cost running.

2 The risk analysis model for project cost

The currently used cost computation and analysis is insufficient in evaluating the probability that risks occur in engineering activities. Generally speaking, uncertain factors are simply corrected, which lacks necessary confidence level. In addition, emphasis of cost risk management is put on aspects such as checking working plan budget and reasonably settling accounts during construction stage and there is no detailed method for cost risk management during the preparing stage of construction[4-5]. The cost risk analysis model proposed in this paper is able to provide a quantitative analysis method for cost risk management. It is mainly composed of three parts: engineering project's cost risk identification, cost risk confirmation and cost risk evaluation.

2.1 Cost risk identification

The main job of cost risk identification is to identify which cost risks exist in a project's whole process, sub-process until the specific activities of the project and make sure the probabilities of the risky events relevant to the project's cost[6]. The sources of risks in engineering cost mainly include the purchasing cost risk of device, tools, appliances and productive furniture, the project cost risk of building and installation, and other project cost risks.

2.2 Cost risk confirmation

Confirmation of engineering cost risk is mainly intent on confirming the impact the uncertainty of every specific project activity imposes on the quantification of engineering cost and its impacting level on the whole project's cost[7]. This paper mainly utilizes the above-mentioned probability function of every risk factor to confirm the impact a risky event imposes on project cost, and then confirms how much the risks impact an engineering project's cost through the Monte Carlo simulation method[8-9].

The fundamental principle of the Monte Carlo simulation method is that, suppose a function Y = f(X1, X2, …, Xn), where the probability distributions of the variables(X1, X2, …, Xn)are known, the Monte Carlo method then directly or indirectly draws a set of sample values (X1i, X2i, …, Xni) of the random variables (X1, X2, …, Xn), and then confirms the function value Yi =(X1i, X2i, …, Xni)according to the functional relation between Y and(X_1, X_2, …, X_n). By repeatedly and independently drawing samples several times, a set of sample values Y1, Y2, …Ym of function Y are obtained. When there are sufficiently enough simulation times, a probability distribution and digital characteristics near the true ones of function Y can be obtained.

The risky factors in project cost have uncertainties and they have different probability distributions. After several times of sample drawing experiment for the risky factors, the probability distribution of the engineering cost's function and its digital characteristics can be simulated. After that, perform cost risk analysis with the data obtained utilizing Monte Carlo simulation. The cost risk is computed as follows.

(1) get a value of the random variable (X_1, X_2, …, X_n) by the random sampling method;

(2) simulate engineering cost, whose functional form is listed in Equation (1), using the Monte Carlo method;

$$Z = g_1(X1) + g2(X2) + \ldots + gn(Xn) \quad (1)$$

(3) Calculate the probability of cost risk, which is calculated by Equation (2).

$$P = n /N \quad (2)$$

Where n is the time the simulated value of Z exceeds a prescribed interval, N is the sample capacity, whose value should not be less than 50.

2.3 Cost risk evaluation

Let the value of Z be simulated N times. When the jth simulated value of Z goes beyond the acceptable range of the mean value $Z = \frac{1}{n}\sum Zj$, it can be seen that the acceptable value of cost is exceeded and risky event has occurred. Let the value of n be increased by 1. According to statistics theory, when P's value is less than 0.25, the probability of risky event is relatively small; the engineering cost for this project can be regarded as having no risk, and meets normal requirement. When P's value is larger than 0.25 and smaller than 0.75 risky event is regarded as being possible to happen and it is needed to perform adjustment and control on the cost of this project. When P's value is greater than 0.75 the probability of risky event is relatively large, the engineering cost risk of this project is regarded as being too large and it is needed to reconsider the project's feasibility.

3 Case study of project cost risk

3.1 Random number function of cost risk factor

Purchase cost of device, tools and appliances, and productive furniture belongs to asset category, which is depreciated according to certain depreciating rate and has linear relation with time axis. The distribution of its value can be assumed to be uniformly distributed in the interval ［a, b］ when being sampled. The sample function of its random number is shown by Equation (3).

$$x = R(b - a) + a \quad (3)$$

The cost of construction and installation projects is calculated by doing statistics for the market price of manpower, machine and material in recent years. The statistical sample should have normal distribution. When doing random sampling, its value can be assumed to have a normal distribution with parameter (μ, σ). The sample function of random number is shown by Equation (4), where Rk is a random number uniformly distributed in interval ［0, 1］.

$$f(x) = \sigma Rk + \mu \quad (4)$$

Other project costs are recorded according to certain rates, and are related to the computed purchase cost of device, tools and appliances, and productive furniture, as well as the cost of construction and installation project. Their value can be assumed to have triangular distribution in interval [a, c] , as listed in Equation (5).

$$\begin{cases} x = c - \sqrt{(1-R)(c-b)(c-a)} & R > \dfrac{b-a}{c-a} \\ x = a + \sqrt{R(b-a)(c-a)} & R \le \dfrac{b-a}{c-a} \end{cases} \quad (5)$$

3.2 Project's cost risk simulation

In order to verify the feasibility of the cost risk model, take a city's municipal engineering project to perform simulation and estimation. When doing simulation and analysis for the engineering project cost, mainly search price variation and rate change of manpower, material and machine in the recent several years, then perform simulation according to their respective random sampling function, and finally get the simulated result of project cost. In sampling function (3) a takes the value of 356 355, b takes the value of 365 234; in sampling function (4) μ takes the value of 3323 623, σ takes the value of 1323; in sampling function (5) a takes the value of 23652, b takes the value of 21321, and c takes the value of 16 000.

Table 1 is the result of doing 100 times' simulation using Crystal Ball. Suppose the prescribed interval range of Z is [(1－0.07), (1 + 0.05)] , and the time that the range is exceeded is recorded as the risky frequency number.

Table 1 Simulation result of engineering project cost

Simulation result	Simulation result	Simulation result	Simulation result	Simulation result
3 713 851	3 708 414	3 693 716	3 710 622	3 694 203
3 713 591	3 702 096	3 695 774	3 710 720	3 709 235
3 698 316	3 693 077	3 701 179	3 694 711	3 689 888
3 691 801	3 695 602	3 710 325	3 705 459	3 693 934
3 695 626	3 692 192	3 699 808	3 698 989	3 691 087
3 697 566	3 699 082	3 709 482	3 699 879	3 699 147
3 695 691	3 694 127	3 694 315	3 707 742	3 698 268
3 694 510	3 694 963	3 707 124	3 694 434	3 689 293
3 717 683	3 698 506	3 697 688	3 694 888	3 695 798
3 709 746	3 691 812	3 698 403	3 713 335	3 709 249
3 696 058	3 689 792	3 707 604	3 697 115	3 704 204
3 709 361	3 714 116	3 703 608	3 709 798	3 695 596
3 697 157	3 691 775	3 710 134	3 706 024	3 707 376
3 706 694	3 687 498	3 699 755	3 690 978	3 711 506
3 692 873	3 713 793	3 699 686	3 696 404	3 696 434
3 695 166	3 695 840	3 707 832	3 710 781	3 699 370
3 708 947	3 696 241	3 705 021	3 694 886	3 689 272
3 698 237	3 711 093	3 694 351	3 696 673	3 700 944
3 707 962	3 691 879	3 697 465	3 706 033	3 713 757
3 696 857	3 695 285	3 695 952	3 711 147	3 696 505

3.3 Risk evaluation of project cost

It can be counted from Table 1 the time the simulated value of Z exceeds the prescribed interval range. Here the prescribed interval of Z's value takes mean value. The mean value of the simulation result is 3 700 598 and the sample capacity is 100. It can be obtained from Equation (2) for computing cost risk probability that the risky probability of cost 0.61, implying that risky event is possible to happen, and the cost of this project needs to be adjusted and controlled.

CONCLUSION

Risk management of engineering project's cost is one of the important jobs in project management activities. In the past the emphasis of managing cost risk in practice activities were put on construction stage and cost risk management in construction preparation stage were usually neglected. This paper studied engineering cost risk, took risky factors impacting engineering cost into account, proposed a cost analysis model by utilizing Monte Carlo simulation method, simulated the uncertain variables in cost, obtained the confidence interval of cost, and makes the work of cost risk management be settled on a sound basis.

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