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Risk Assessment of Chemical Project Cost Control Based on Principal Component Analysis

Xiangpeng Kong

Zibo vocational institute, Zibo 255000, China

djdqddrb@163.com

Objective: To assess the risk of cost control of chemical projects based on principal component analysis. Methods: The principal component analysis method is used to analyze the risk points of cost control and to assess the risk of chemical projects in combination with the features of the projects themselves. Results: The principal component analysis is used to assess the risk of cost control of chemical projects and conclude in the study that the key points on the cost control of chemical projects are as follows: first, strictly control the cost of materials; second, control the cost of power and fuel. Conclusion: It's concluded that the principal component analysis is an effective method on evaluating the risk of cost control of chemical projects with some reasonable suggestions proposed.

1. Introduction

China witnesses the rapid development of its market economy. In the process of reform, chemical enterprises often face more complex risk. The chemical projects are large in construction scale and long in construction time, so it is easy to generate financial risks in cost control, and once out of control, it will inevitably cause large economic losses. Financial risk itself has the characteristics of loss and objectivity. Once the cost control fails, the whole budget of the chemical project will be out of control. Therefore, chemical enterprises should do well in financial risk assessment, so as to effectively mitigate risks, avoid risks and reduce losses. If we fail to pay attention to the impact of financial risk on the entire chemical project, it is easy to cause the failure or delay of the chemical project, and even the whole design and construction shall be re-planned. In the whole chemical project, any link from plan, design, construction and completion may have uncontrollable factors, which may cause financial risk and affect the cost of the whole chemical project. However, at present, many chemical enterprises in China have not correctly learned about the management of financial risks, especially, failure to comprehensively and systematically analyze and evaluate all kinds of financial risk factors in the whole process of chemical project, which will bring great adverse impacts on chemical projects and even make the cost out of control. Therefore, based on principal component analysis, this study assesses the risk of cost control of chemical projects and puts forward some suggestions.

2. Literature review

In the 1980s, the modern project cost control theory was born gradually. In the 1990s, China's engineering management community proposed the idea of cost management throughout the project. At the current stage, domestic and international research on project cost control has been carried out at various levels and from various perspectives. The cost control methods include net value method, activity cost method, and value engineering. In the implementation of cost control, the cost dynamic control is mainly achieved through the combination of engineering project cost and modern information technology.

In 2004, the US COSO organization formally released the "Enterprise Risk Management Framework" to guide the company's risk management activities. More and more companies are beginning to focus on risk management. Risk management includes risk identification, risk analysis, risk response and risk monitoring. Risk management, strategic management and business management have become the three major management activities of modern companies. There are many ways to identify risks. In practical applications,

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the method usually needs to be determined according to the actual situation. In a project, it is generally necessary to use a variety of methods in order to receive good results.

The realization of net value requires accurate cost and schedule data. The fuzzy net value model can develop and analyze the net value index, completion time and cost uncertainty. The case was used to illustrate how the model was implemented in practice (An et al., 2016). Although the net-value method enables project managers to know whether the cost is overspending, it cannot know when the cost deviated too much and needs to take timely measures. Based on the theory of net value, an integrated cost-schedule-risk graphical approach was constructed to determine whether the cost was out of control or within the expected range (Acebes et al., 2013). Factor analysis was introduced into the analysis of net value bias. The analysis of the causes of deviations was refined to determine the degree of influence of changes in various factors on cost deviations. Although the net value method achieves a comprehensive control of the cost-to-progress, it does not reflect the true cause of the project cost or schedule deviation, just like the traditional cost control method.

In most cases, during the implementation phase of the project, it is difficult for the project to be completed within the specified time and budget. The reason has also been explored by scholars. Chan et al. conducted surveys on Hong Kong contractors through 400 questionnaires. It is pointed out that the first 10 factors that affect the progress of the project are delays in design information, low efficiency in drawings, poor on-site management and supervision, and conflict of documents. Some scholars analyzed the 161 completed construction projects in South Korea. The influencing factors of cost control are attributed to changes in project scope, construction delays, irrational project cost estimates, and lack of a net value management system. Although there are many control technologies and project control software, project cost and schedule control are still not optimistic. Through the investigation of 250 construction projects in the UK, the key factors affecting cost overruns and schedule delays were identified. The first five factors are design changes, uncertainty of risk, inaccuracy of cost and time estimates, complexity, and subcontractor default. In Australia, by investigating the importance of 48 cost-influencing factors to contractors, owners and consultants respectively, it was found that schedule planning and implementation problems have the greatest impact on costs. Further verification of systematic control processes, efficient design and site management are key factors affecting cost control (Doloi, 2013). Cheng identified 16 key factors influencing cost control from 42 factors through two questionnaire surveys in China. The most influential factors are clear contract scope, cost control and contract disputes (Cheng, 2013).

Project risk management does not mean pursuing the elimination of all risks. It is not feasible to eliminate all risks. In addition, it may bring a very high price. Therefore, many scholars believe that as long as the project risk is controlled within an acceptable range, it is the most successful project risk management method. For risks of low frequency and low intensity, such risks rarely occur. Even if the risk occurs, the consequences are not great. Therefore, it is entirely possible to minimize the risk through its own power. In the current fierce market competition, proper risk management of the project will be a winning weapon for the success of the project. Based on this concept, guidance on establishing a risk management plan is given in a large-scale natural gas project. Maintaining risk at an acceptable level is a key point in performance management. Risk assessment is a dynamic and iterative process. Before a major decision is made and after major news is received, a reassessment is required (Hnottavange-Telleen, 2015).

Sources of risk are classified. The complex source of risk becomes a distinct trapezoidal structure. It provides a clear path for subsequent risk analysis and response measures. In response to the cooperative design model, possible sources of risk are proposed. The risk sources were classified and a project risk management method adapted to the cooperative design model was proposed. In the energy management contract, the combination of qualitative analysis and quantitative analysis is also used for risk control. In the ion-exchange membrane caustic soda project, a full-process risk factor model was established. Qualitative and quantitative methods are used to assess the level of risk. As a result, an effective risk management approach and emergency response plan have been established. Hong et al. applied AHP to risk management of a global safety assessment project (Hong et al., 2014).

To sum up, the above-mentioned research work mainly focuses on the study of cost control of process projects. Effective cost control is emphasized. From the exploration of a simple project cost control method to the combination of new technologies and methods, researchers have never stopped their steps. However, in terms of cost control, there are few studies that integrate cost control processes, methods, and means to form an effective cost control model. Therefore, based on the above research status, the cost dynamics of the project construction phase are controlled. Based on the features and advantages of BIM technology, the cost control mode is improved. A dynamic cost control model integrating BIM technology, two-level net value method and dynamic control flow was constructed.

3. Methods

3.1 Risk control and assessment

This study assesses the risks in the cost control of chemical projects based on principal component analysis, with the flow of risk management shown in Figure 1, and constructs the project risk management team, with its organizational structure shown in Figure 2.

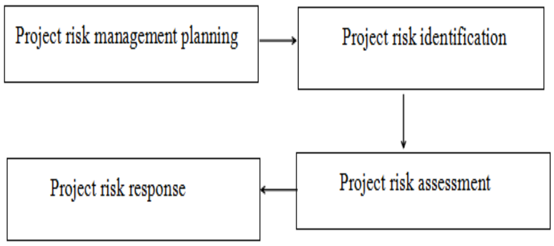

Figure 1: Chinese project risk management flow

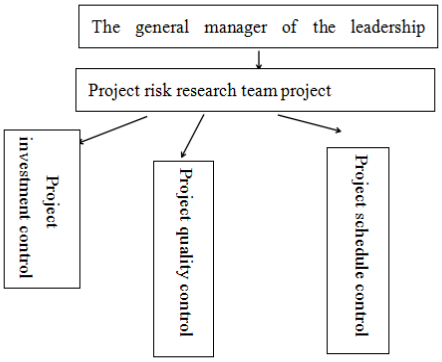

Figure 2: Project risk management team organization

The risk factors that affect cost control of chemical projects are shown in Table 1.

Table 1: Risk factors that affect cost control

Indexes	Major risk variables
Technical risk factors	Design the possibility of construction without consideration V1
	Design defects and errors V2
	Design indicators / specifications use unreasonable V3
	Unreliable construction technology V4
	Wrong construction technology V5
	Quality level requires V6
Organizational risk factors	Poor owner's ability to pay V7
	The level of construction managers is short of V8
	The quality of labor service is too poor V9
	Unreasonable bid quotation V10
	Chaos in construction site V11
	Participation of parties in unsuitable or undue V12
	Poor safety measures V13
	Imperfect supervision and incentive measures V14
	Inadequate demonstration of new materials V15
	Poor quality of material and equipment V16
	Material shortage or delay in supply V17
Environmental risk factors	Major adjustment of national related policies V18
	Inflation (people， machines， material prices rise) V19
	Force majeure factor V20
	Geological conditions and reconnaissance have different V21
	Unidentified groundwater level V22
	Environmental pollution V23

3.2 Principle of principal component analysis

Principal component analysis is an attempt to recombine many indicators with certain correlation into a new set of comprehensive indicators that are not related to each other. Generally, the processing in mathematics is to make the linear combination of the original P indicators as the new comprehensive indicators. The most classical approach is to express with the variance of F1 (the first linear combination selected, i.e. the first comprehensive indicator), that's, the larger Var (F1) is, the more information F1 contains. Therefore, F1 selected in all linear combinations should have the largest variance, so F1 is called the first principal component. If the first principal component is insufficient to represent the information of original P indicators, and F2 is selected as the second linear combination. In order to effectively reflect the original information, the existing information of F1 does not need to appear in F2 again, and Cov (F1, F2) = 0 is required in a mathematical language expression, then F2 is called the second principal component. In the same way, the third, fourth ..., Pth principal component can be constructed.

2.2 Mathematical model of principal component analysis

$$F_1 = a_{11}ZX_1 + a_{21}ZX_2 + \ldots + a_{p1}ZX_P$$

$$F_2 = a_{12}ZX_1 + a_{22}ZX_2 + \ldots + a_{p2}zx_p$$

…

$$F_p = a_{1m}ZX_1 + a_{2m}ZX_2 + \ldots + a_{pm}ZX_P$$

Where, a1i, a2i, …, api (i = 1, …, m) is a feature vector corresponding to a plurality of eigenvalues of the covariance matrix ∑ of x, ZX_1, ZX2, …, ZX_p is the value of the original variable through the standardized processing. Because there are often indicators of different dimensions in practical applications, the impact of the dimensions must be eliminated first before the calculation to standardize the original data. The data used in this article has a dimensional effect (the data standardization referred to in this article refers to Z standardization). The data used in this study has a dimensional effect (the data standardization referred to in this study refers to Z standardization).

$$A = (a_{ij})_{pxm} = (a_1, a_2, \ldots, a_m), R_{a_i} = \lambda_i a_i$$

R is correlation coefficient matrix, λi and ai are the corresponding eigenvalues and unit eigenvectors, λ1≥ λ2≥ … ≥ λp≥0.

The main steps of principal component analysis are as follows: (1) Standardize indicator data (SPSS software automatically executes); (2) Determine correlation among indicators; (3) Determine the number of principal components m; (4) Fi expression of principal component Fi; (5) Naming of principal component Fi; (6) Value of principal component and comprehensive principal component (evaluation).

3.3 Principal component analysis of oil production cost in Sinopec Shengli Oilfield

Principal component analysis of oil production cost

There are many classification ways of oil production cost in oilfield. This study designs 10 indicators such as material cost, direct wage and additional cost, depreciation, underground operation cost, other exploitation cost, oilfield maintenance cost, reserve use cost, power cost, overhaul fee and fuel cost through widely consulting the information and hearing the opinions of the experts to evaluate the oil production cost in Sinopec Shengli Oilfield according to objective, scientific, comparable, quantitative and qualitative principles. This study takes the oil production cost of each oil well of Sinopec Shengli Oilfield in 2008 as the original data, which almost cover the oil production cost of the whole Sinopec Shengli Oilfield. The data are reliable and accurate (since there are too many data items in this study, it starts with the coefficient matrix processed by SPSS).

It can be seen from Table 2 that the correlation coefficients of direct wage and additional cost, oilfield maintenance cost and material cost are all greater than 0.9, indicating that the three costs have strong correlation. In addition, the correlation coefficient of other several indicators is above 0.7, which indicates that there is overlap of information, and it is suitable for principal component analysis. The principle of extracting the number of principal components is the first m principal components with eigenvalues greater than 1 corresponding to the principal components. To some extent, the eigenvalues can be regarded as indicators indicating the influence force of the principal components. If the eigenvalue is less than 1, the explanation force of the principal component is not as great as the average explanation force of directly introducing an original variable. Therefore, it is generally acceptable to use eigenvalues greater than 1 as an inclusion criterion. As can be seen from Table 3 (interpretation of total variance), three principal components, m = 3, are extracted. The contribution rate of the three principal components is 44.481%, 26.185%, and 15.303%, respectively, and the cumulative contribution rate is 85.970%.

The cumulative contribution rate is greater than 80%, which shows that the three principal components basically retain the variance information of the original data. The eigenvalue of three principal components is λ 1 = 4.448, λ 2 = 2.619 and λ 3 = 1.530.

Table 2: Correlation coefficient matrix

	Depreciation charge	Direct wage and additional	oilfield maintenance expenses	Underground operation fee	Fuel cost	Material cost
Depreciation charge	1.000	0.144	0.071	-0.047	0.623	0.061
Direct wage and additional cost	0.144	1.000	0.973	0.554	0.628	0.909
oilfield maintenance expenses	0.071	0.973	1.000	0.535	0.643	0.943
Underground operation fee	-0.047	0.554	0.535	1.000	0.197	0.437

Table 3: Interpretation of total variance

Component	Initial Eigenvalues		
	Total	%of Variance	Cumulative%
1	4.448	44.481	44.481
2	2.619	26.185	70.666
3	1.530	15.303	85.970
4	0.779	7.793	93.763
5	0.296	2.961	96.723

Table 4: Component matrix

	Component		
	1	2	3
Depreciation charge	0.144	-0.018	0.941
Direct wage and additional cost	0.980	0.176	-0.014
oilfield maintenance expenses	0.978	0.069	-0.042
Underground maintenance fee	0.535	0.271	-0.169

Table 4 is a component matrix. In the first principal component, the value of three indicators such as direct wage and additional cost, oilfield maintenance cost and material cost is greater than 0.9, indicating that the first principal component mainly explains the information of the three indicators. Similarly, the second main component mainly describes the information of 4 indicators such as overhaul fee, other exploitation fee, reserve use fee and power fee. The third principal component mainly explains the information of depreciation expense and fuel expense. The three principal components basically contain all the information of the population, which indicates that the principal component analysis method has higher accuracy.

Set the principal component vector is βi (i = 1, 2, 3), then the eigenvector is γi= βiλi (i =1, 2, 3).

Principal component Fi= γiZX (ZX is matrix obtained after X standardization, and since X sample has larger space, this study will not introduce the original data matrix of X and ZX but directly calculate the results).

So:

F1=0.068 217ZX1+0.464 656ZX2+0.463 65ZX3+0.253 626ZX4+0.323 54ZX5+0.442 879ZX6+0.167 027ZX7+0.245 346ZX8+ 0.300 692ZX9+ 0.144 354ZX10

F2=-0.010 97ZX1+0.108 571ZX2+0.042 579ZX3+0.167 476ZX4-0.029 19ZX5-0.049 41ZX6+0.510 759ZX7-0.463 02ZX8-0.433 26ZX9+0.540 167ZX10

F3=0.760 536ZX1- 0.011 14ZX2- 0.034 34ZX3-0.136 31ZX4+ 0.526 723ZX5-0.058 59ZX6-0.071 87ZX7-0.260 95ZX8- 0.130 9ZX9- 0.175 02ZX10

Combining the principal component

$$F = \frac{\lambda_1}{\lambda_1+\lambda_2+\lambda_3}F_1 + \frac{\lambda_2}{\lambda_1+\lambda_2+\lambda_3}F_2 + \frac{\lambda_3}{\lambda_1+\lambda_2+\lambda_3}F_3$$

The principal component synthesis model:

F = 0.167 304ZX1+ 0.271 5ZX2+ 0.246 748ZX3+0.157 985ZX4+ 0.252 244ZX5+ 0.203 663ZX6+0.229 226ZX7-0.060 56ZX8+0.000 275ZX9+0.208 096ZX10

4. Results and Discussion

Through principal component analysis of oil production cost in Sinopec Shengli Oilfield, the following conclusions can be drawn according to SPSS operation process:
(1) From principal component synthesis model

$$F = 0.167304ZX_1 + 0.2715ZX_2 + 0.246748ZX_3 + 0.157985ZX_4 + 0.203663ZX_6$$
$$+ 0.229226ZX_7 - 0.06056ZX_8 + 0.000275ZX_9 + 0.208096ZX_{10}$$

we can get that the coefficients of direct wage and additional cost (X2), oilfield maintenance cost (X3), fuel cost (X5), material cost (X6), overhaul cost (X7) and power cost (X10) are all greater than 0.2, indicating that these costs have great influence on oil production cost and should be controlled as main factors.
(2) According to Table 1 (Correlation Coefficient Matrix), it can be seen that the correlation coefficients of direct wage and additional cost, oilfield maintenance cost and material cost are all greater than 0.9, and the costs of these three items have stronger correlation. It’s necessary to clarify the special relationship and causality among the three factors in controlling oil production cost, which is conducive to more effectively control these three costs.
(3) From principal component synthesis model

$$F = 0.167304ZX_1 + 0.2715ZX_2 + 0.246748ZX_3 + 0.157985ZX_4 + 0.252244ZX_5 + 0.203663ZX_6$$
$$+ 0.229226ZX_7 - 0.06056ZX_8 + 0.000275ZX_9 + 0.208096X_{10}$$

the collected data ZX after standardization can give a specific score for the cost control of each well, and compare and evaluate it.

5. Conclusions

The risk assessment of cost control of chemical projects is carried out with principal component analysis. This study finds that it’s essential to carry out the cost control of chemical projects from the following aspects: first, to strictly control the material cost: on the one hand, to guarantee the correct output of the process, and on the other hand, to improve the efficiency of the process, eliminating non-value-added activities and minimizing auxiliary value-added activities as much as possible. Some process bottlenecks should be eliminated as much as possible to improve the efficiency of overall process activities. For the key points in the material flow, it’s crucial to carry out the scientific design and clear out the closed loop of the flow to form a template. Second, to control the power cost and fuel cost. In the chemical projects, the proportion of power cost and fuel cost is larger, and belongs to the direct production cost. Therefore, in the chemical projects, it is necessary to establish the man- hour wage standard and man- hour quota based on the labor quota, and fixed number and posts of employees, and specify the man- hour cost consumption quota. At the same time, it’s important to establish the appraisal method, make clear the responsibilities of the post and establish the responsibility system.

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