Policy-Oriented Risk Assessment and Control Strategies for Engineering Costs: Insights from Gray System Modeling

YANGPING YAO, XING TANG

Abstract In order to ensure the economic benefits and quality standards of construction projects, engineering cost risk assessment and control is particularly important in engineering project management. This paper constructs the engineering cost risk assessment index system based on the identification process of engineering cost risk factors and the establishment process of assessment index system. Then use the entropy weight method to solve the risk assessment index weights, combined with the gray system theory to obtain the gray correlation degree of cost risk assessment, and modeling assessment of engineering cost risk index. Taking a construction project as an example, the cost risk assessment is used to propose the engineering cost risk control strategy. The impact of the design stage in the cost risk assessment is the largest (0.3273), the impact of the completion stage is the smallest (0.0581), and the gray correlation of the overall cost risk is between 0.223 and 0.236, which is at the level of low risk and general risk. After the implementation of cost risk assessment management, the return yield of the investor increased by 8.52 percentage points. By analyzing the importance of project cost risk assessment and discussing its theoretical basis and practical application, in order to provide theoretical support and practical guidance for improving the level of project cost risk control.

Keywords: • gray system • entropy weight method • gray correlation • engineering cost • risk assessment

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1 Introduction

In recent years, the rapid development of the national economy and the improvement of science and technology have promoted the vigorous development of the construction industry, and the number of construction projects in China has been increasing. Large capital investment, long construction period and susceptibility to external factors are important features of construction projects, which also determine the existence of a variety of risks in construction projects (Jung & Han, 2017; Ali, Zhu, & Hussain, 2018; Portugal-Pereira et al., 2018; Yuan, Xiang, Li, & Zhang, 2020). These risks are generally, but not limited to, from the changing external environment, huge investment management, strict contract conditions and complex technology and many other aspects (Gunduz & Maki, 2018; Aljohani, Ahiaga-Dagbui, & Moore, 2017). In the process of engineering construction, the cost risks faced by construction enterprises include objective risks, contract risks and other aspects, and different risk factors interact with each other, characterized by complexity (Islam, Nepal, Skitmore, & Attarzadeh, 2017; Wibawa, Santiana, Suasira, Sudiasa, & Sumardika, 2023; Ali Ghaffarianhoseini et al., 2017). The project cost risk also has the characteristics of instability, national policies, economic factors and other factors will lead to fluctuations in the cost of the project (Silvius, Kampinga, Paniagua, & Mooi, 2017; Marinina & Nevskaya, 2017). Various operational behaviors are not effectively regulated, which also has a certain impact on the project cost deviation (Zou, Kiviniemi, & Jones, 2017; Lo & Liou, 2018). In addition, variability, passivity, and the whole process are also notable features in the construction cost risk of construction enterprises.

Risks are symbiotic with engineering projects, but without effective prevention and management of risks, the smooth implementation of the project will be affected. Therefore, construction project risk management is an important link to ensure the smooth implementation of the project. Among them, risk evaluation is the core of risk management, scientific and effective assessment of the project risk level, can be targeted to prevent the adverse effects of risk (Alves, Gersonius, Kapelan, Vojinovic, & Sanchez, 2019; T. K. Wang, Zhang, Chong, & Wang, 2017; Liu, Yang, & Forrest, 2017).

Ou-Yang and Chen (2017) describe the positive impact of risk management measures on project performance in engineering procurement construction projects, and the use of Monte Carlo to simulate the design process of construction projects based on the project risk management workflow helps decision makers to assess risk management planning and avoid cost overruns. Afzal, Shao, Nazir, and Bhatti (2021) investigated artificial intelligence methods in construction risk management practices and proposed to apply a hybrid approach of fuzzy logic and extended Bayesian belief networks to cost-risk assessment to capture the high complexity and risk interdependencies of construction costs. Xia, X. Wang, Wang, Yang, and Liu (2017) design a Bayesian network-based risk assessment model from the perspective of project phases, which identifies multiple key risks during the project life cycle and develops easy-to-understand risk representations and risk propagation paths to provide decision makers with a realistic approach to risk assessment. Islam, Nepal, Skitmore, and Kabir (2019) combine the fuzzy group decision-making method and Bayesian confidence network to construct a fuzzy typical model (FCM), which is used as the basis for designing a knowledge-based expert risk assessment system that overcomes the limitations of project cost management decisions in terms of expert judgment, subjectivity, and uncertainty, and effectively prevents project cost overruns. Islam, Nepal, and Skitmore (2019) incorporate project phases into project cost overrun risk assessment and proposes an improved Fuzzy Group Decision Making Approach (FGDMA), which is able to understand the background of the project risk and its profile even in the face of different project scenarios and accurately identifies the key cost overrun risks therein, which contributes to the comprehensive assessment of project risks. Shehadeh, Alshboul, and Hamedat (2022) developed a utility function to model the behavior and risk impacts of both parties to a target cost contract for a construction project, and through simulation and analysis of project characteristics and construction cost variations, it identifies the optimal benefit-risk sharing ratio between the two parties to the transaction, which helps to produce a more reliable target cost contract. Afzal, Shao, Junaid, and Hanif (2020) show that risk analysis plays an important role in controlling cost overruns in complex construction projects with high uncertainty. Taking an urban transportation project as an example, designing a cost-risk strain architecture that identifies and evaluates the expected total construction cost as well as the additional risk cost is conducive to maintaining the stability of the project cost budget.

Engineering cost risk assessment and control is an important aspect of construction project management and one of the important means to ensure the quality and efficiency of engineering construction. Based on the identification process of project cost risk factors, the article constructs a project cost risk assessment index system from five stages: investment decision, design, bidding, construction and completion. Through entropy weighting method to solve the weight of indicators to analyze the importance of factors affecting engineering cost risk, and combined with grey system theory to assess the level of construction cost risk, but also verified the specific effect of engineering cost risk assessment on the optimization of engineering project cost management. Based on the results of engineering project cost risk assessment, new ideas are provided for optimizing the engineering cost risk control strategy.

2 Engineering cost risk assessment index system

In construction projects, controlling and managing construction costs is a key element in ensuring the smooth running and successful completion of the project. Project cost involves expenditures in many areas, and it is important and necessary to deeply analyze and evaluate the factors affecting project cost. With the rapid development of the construction industry and the intensification of competition, project cost control and management has become one of the key factors for the success of construction projects. Efficient construction cost management can help project teams reasonably allocate resources, reduce risks, optimize costs, and ensure on-time project delivery within a limited budget. In the field of construction engineering, the study of engineering cost risk assessment has attracted extensive attention.

2.1 Identification of construction cost risk factors

2.1.1 Engineering cost risk assessment

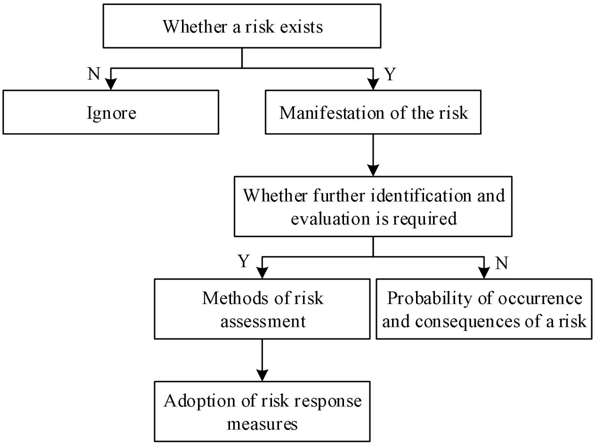
Assessment and prioritization of cost risks in engineering projects. Cost risks are assessed and prioritized after identifying them to determine the priority of response (B. Yu & Yu, 2023). There are three common engineering project cost risk assessment methods:

1) Risk impact assessment. The degree of impact of cost risk is assessed through quantitative or qualitative methods, such as comprehensive analysis of the likelihood of the occurrence of risk events, the degree of impact and the degree of urgency and other indicators.
2) Risk probability distribution analysis. Analyze the probability distribution of cost risk by collecting historical data and combining expert experience to predict the probability of occurrence of risk events and the degree of impact.
3) Risk sensitivity analysis. Analyze the key risk factors through changes and simulation to assess the sensitivity and degree of impact of risks on the project cost in order to determine the risk response strategies and measures.

2.1.2 Risk factor identification process

According to the construction mode of the construction project and the characteristics of the project cost management, the risk of the project since the inclusion of the construction plan in the pre-decision-making stage, to the program design stage, to the bidding and construction stage of the risk identification, the development of the construction project cost risk identification process as shown in Figure 1, in order to establish a complete risk assessment system for the cost of the project to lay the foundation (J. Wang, 2020).

Figure 1: Project cost risk identification process



According to the engineering cost risk identification flow chart, to identify the engineering cost risk factors, this paper mainly analyzes and researches through the following steps:

1) Investigate the relevant staff of construction project, etc., and through their experience, list the cost risk factors that may arise from the project in the pre-decision-making stage, design stage, budget stage, construction stage and completion stage, and summarize and classify the cost risk factors that may arise.
2) Invite experts related to the cost of construction projects to screen and list the cost risk factors that may arise in each stage of implementation listed in the first stage.
3) Organize the risks listed by the above experts, delete the unlikely and almost impossible risk factors, keep the very likely and possible cost risk factors, and integrate them with the risk factors proposed by the experts to get the first risk list.
4) And then the first risk list again to seek expert advice, deletion and addition, through repeated times for the integration and harmonization of views, until to ensure that the risk factors are unanimously recognized, the final list of risks as the cost risk of the research object.
5) Number the finalized risk factors.

2.2 Establishment of a system of risk assessment indicators

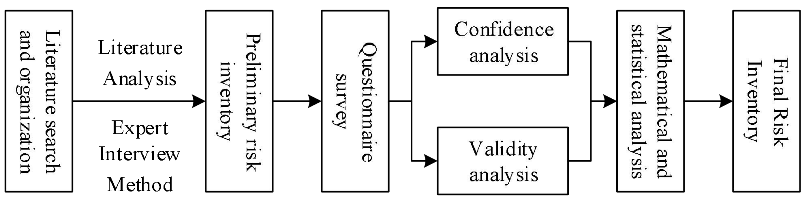
2.2.1 Process for establishing the indicator system

The establishment of engineering project cost risk evaluation index system is a key step in risk evaluation, to ensure the comprehensiveness, scientificity and effectiveness of the system, the following principles should be followed:

1) The principle of systematicity requires that from the overall system of the engineering project, the logical relationship between the indicators should be considered comprehensively, and strict screening should be carried out in order to comprehensively reflect the state of risk, while avoiding repetitive crossover between the indicators.
2) The principle of scientificity emphasizes that the indicator system must objectively and realistically reflect the substance of the project and be able to reflect the correlation between the indicators.
3) The principle of significance requires that the selected indicators should be able to effectively represent the status of the evaluation object, and the number should be reasonable to avoid too many indicators and data redundancy to ensure the reliability of the evaluation results.

The process of indicator system establishment is shown in Figure 2. Through the methods of literature analysis and expert interviews, we have sorted and analyzed the relevant literature, and used the literature frequency statistics method to screen out the risk factors, identify the unique risks in the cost of engineering projects, and initially establish the list of cost risk factors. In order to ensure the significance of the indicators, we used the questionnaire, and on the basis of the questionnaire reliability and validity analysis, we screened out the key risk factors through mathematical statistics, and formed the final list of risk factors.

Figure 2: Index system establishment process



2.2.2 System of risk assessment indicators

According to the principles of systematicity, comprehensiveness and prominence, combined with the process of establishing the cost risk assessment index system of engineering projects given in the previous section, the cost risk indicators of investment decision stage, design stage, bidding stage, construction stage and completion and acceptance stage of engineering projects are screened, and the evaluation index system is constructed as shown in Table 1 (Yang & Li, 2019). The system contains five dimensions, and under the jurisdiction of 22 secondary indicators.

Table 1: Cost risk assessment index system

Criterion layer	Index layer	Code
Investment decision stage (A)	Project size	A1
	Construction standard	A2
	Area selection of construction area	A3
	Investment estimation rationality	A4
	Feasibility of the financing scheme	A5
Design stage (B)	The design budget review	B1
	Budget review of construction drawings	B2
	Feasibility of the design	B3
	Design schedule	B4
	Quota design	B5
Bidding stage (C)	Bidding document integrity	C1
	Preparation and review of bidding and control prices	C2
	Contract type and pricing mode	C3
	The terms of the contract are reasonable	C4
Construction stage (D)	Construction schedule and schedule	D1
	Construction and technical measures	D2
	Machine price	D3
	Construction environment	D4
	Natural disasters, unirresistible factors	D5
Completion stage (E)	Completion settlement review	E1
	Final audit	E2
	Quality acceptance of work	E3

3 Engineering cost risk assessment model construction

With the development of social economy and the acceleration of urbanization, the scale of construction projects is expanding, the complexity continues to deepen, more and more fields and specialties are involved, and the difficulty of cost risk management increases. In construction projects, the cost of materials, labor, equipment and other resources continues to increase, putting forward higher requirements for project cost management. If effective control measures are not taken, cost deviation will seriously affect the feasibility and economy of the project. Cost risk assessment is an indispensable aspect of construction project management. Only by adopting scientific methods and effective measures can we maximize the quality and benefits of engineering construction and then achieve the goal of sustainable development.

3.1 Entropy weight method and gray system theory

3.1.1 Entropy weighting method for solving weights

The entropy weighting method is a widely used method for testing the magnitude of data dependence, which measures the strength of the interdependence among the variables of a multivariate by calculating the information entropy of the system's random variables, i.e., a measure that represents the dependence among random variables (Shi, Li, Han, & Yang, 2024). In essence, the entropy weighting method is a comprehensive consideration that regulates the weights of the system and can be used in decision analysis and evaluation of pros and cons. The entropy weighting method can be used to evaluate the correlation between multiple indicators in a system by collecting all the indicators together and calculating how much weight there is between each indicator.

According to the degree of change of the evaluation indicators, the entropy weight method is used to calculate the weight of the evaluation indicators, the specific steps are as follows: if for n sample, the evaluation is carried out by m evaluation indicators, and the corresponding value of each indicator is $Y=\left[Y_{ij}\right]_{n\times m}$, $Y_{ij}\geq 0\left(i=1,2,\cdots,n;j=1,2,\cdots,m\right)$. $Y_{ij}\geq 0$ is taken here to ensure that the value of the data is within the range of $\left[0,1\right]$ after normalization. In the calculation, the index scale type and dimension of engineering cost risk assessment are different, and the raw data need to be standardized.

The forward normalization formula is:

$$y_{ij}=\frac{y_{ij}-\min\left(y_{ij}\right)}{\max\left(y_{ij}\right)-\min\left(y_{ij}\right)} \tag{1}$$

The inverse normalization formula is:

$$y_{ij}=\frac{\max\left(y_{ij}\right)-y_{ij}}{\max\left(y_{ij}\right)-\min\left(y_{ij}\right)} \tag{2}$$

Since the entropy value ranges from $\left[0,1\right]$, the raw data must be normalized to satisfy the requirements to obtain the judgment matrix $P=\left(pij\right)_{m\times n}$, ($i=1,2,\cdots,m;j=1,2,\cdots,n;m$ denotes the number of indicators and n denotes the number of objects) with the following formula:

$$p_{ij}=\frac{y_{ij}}{\sum_{j=1}^{m}y_{ij}} \tag{3}$$

According to the entropy principle, the entropy value of indicator i is obtained H_i, the coefficient of variation D_i, and the entropy weight W_i^s. Then:

$$H_i = -k\sum_{j=1}^{n} p_{ij} \ln p_{ij} \tag{4}$$

$$D_i = 1 - H_i \tag{5}$$

$$W_i^s = \frac{D_i}{\sum_{i=1}^{m} D_i} \tag{6}$$

Where k is a constant, to make $H_i \in [0,1]$, generally take $k = \ln n^{-1}$.

3.1.2 Gray systems theory

Gray systems analysis is widely used as a common analysis method, and the basic principles of optimization and modeling and holistic are similar to those of traditional systems analysis methods. The basic purpose of system analysis, i.e., optimization, the means and ways of system optimization, i.e., modeling, and the basis and starting point of system analysis, i.e., holistic. The basic principles of gray system include the principle of difference information, the principle of non-uniqueness of solution, the principle of least information, the principle of cognitive basis, the principle of priority of new information, and the principle of indestructibility of grayness (Lin, Zeng, Dai, & Zhang, 2024).

A series of comprehensive analysis methods of gray system have been formed on the basis of the principles of gray system theory. It mainly includes gray correlation analysis, gray cluster analysis, gray decision-making and so on. Among them, the gray correlation analysis method is regarded as the most representative analysis method with the highest application frequency. Gray correlation analysis method is suitable for the system data is limited, the requirements of the law is not strict and the data gray scale is large. Gray correlation analysis method is based on the development trend and the degree of similarity or dissimilarity between the factors to measure the degree of correlation between the factors, the factors can be independent, but does not affect the results of gray correlation analysis. The closer the curves of the data series are, the greater the degree of correlation between the corresponding series, and the opposite is true, the smaller the degree of correlation. Using this method, we can distinguish the degree of influence of different factors on the system, and select the factors that promote the development of the system to be strengthened, and select the factors that hinder the development of the system to be suppressed.

3.2 Engineering cost risk assessment model

3.2.1 Gray correlation matrix and degree of correlation

Gray correlation analysis methods use linear interpolation to make the observed information into a small truncated polyline, and then use curve fitting to obtain a tight relationship between the comparison system and the reference system. Gray correlation is used as the most basic element to construct the judgment sequence correlation. The steps to implement the gray correlation analysis method are first to construct the correlation model, the reference and comparison sequences, then to calculate the correlation coefficient, and finally to rank the correlations.

Let X_i be a system factor, then X_i be the set of observations $x_i(k)$, $k=1,2,\cdots,n$ on k, i.e:

$$X_i(k)=\left(x_i(1),x_i(2),\cdots,x_i(n)\right) \tag{7}$$

When k represents the sequence of observation objects, discrete time, indicators, $X_i(k)=\left(x_i(1),x_i(2),\cdots,x_i(n)\right)$ represents the system behavior on k, will do gray correlation analysis processing of the factors with the change of k, resulting in the system gray correlation degree also changes.

Gray correlation analysis method is implemented in the steps of:

1) Determine the reference sequence, the comparison sequence, in which the comparison sequence as a collection of behavioral sequence features of the observation object, and the reference sequence as the system behavioral sequence features.
2) Eliminate the scale of the reference sequence and comparison sequence of the system.
3) Obtain the correlation between the reference sequence and the comparison sequence.

In this paper, we give the representative similarity correlation degree, Dunn's correlation degree, such that the expression of the reference series of the system is $X_0=\{x_0(j)\mid j=1,2,\cdots,m\}$, and assuming that the number of comparisons is $X_1,X_2,\cdots,X_n$, i.e., $X_i=\{x_i(j)\mid j=1,2,\cdots,m\}$, $i=1,2,\cdots,n$, the correlation coefficients ξ_{0i} between the reference sequence of the system and each of the comparisons are calculated as follows:

$$\xi_{0i}(j)=\frac{\Delta(\min)+\rho\Delta(\max)}{\Delta_{0i}(j)+\rho\Delta(\max)} \tag{8}$$

Where $\Delta_{0i}(j)=|x_0(j)-x_i(j)|$, ρ for the resolution factor, the value range of 0 ~ 1, so that $\rho=0.5$, ρ take the value of the smaller, the higher the discriminatory ability, usually ρ values with the specific circumstances. $\Delta(\max)=\max_i \max_j |x_0(j)-x_i(j)|$ is the maximum difference between two levels, $\Delta(\min)=\min_i \min_j |x_0(j)-x_i(j)|$ is the minimum difference between two levels.

4) Calculate the gray correlation.

From the above steps, it can be seen that $\xi_{0i}(f)$ is the degree of association of each comparison sequence with the reference sequence on different characteristic parameters or moments, so a large number of correlation coefficients will appear, which will result in the amount of information not being centralized, which is not conducive to the analysis of the system as a whole. In order to explore the overall system efficiently, it is necessary to aggregate all the correlation coefficients, i.e., to produce the gray correlation degree.

Let the correlation between the reference sequence and the comparison sequence be $\gamma\left(X_0,X_i\right)$, i.e., γ_{0i} . As the importance of each feature is different, it can lead to the uneven distribution of the weights of the feature indicators.

Let $a(j)$ is the weight of each feature indicator in the comparison series, indicating the relative importance of each indicator, the specific value of its allocation can be determined by the specific circumstances, and $\sum_{j=1}^{m} a(j)=1$, $a(j)\geq 0$, then the weighted gray correlation is:

$$\gamma_{0i}=\sum_{j=1}^{m}\xi_{0i}(j)a(j)i=1,2,\cdots,n \tag{9}$$

3.2.2 Cost risk modeling assessment

Assumptions x_1 and x_1' are expected and actual capital works costs, x_2 and x_2' are expected and actual auxiliary works costs, x_3 and x_3' are expected and actual site construction and compensation costs, x_4 and x_4' are expected and actual project management costs, x_5 and x_5' are expected and actual technical services costs, x_6 and x_6' are expected and actual commissioning costs, x_7 and x_7' are expected and actual production preparation costs, and x_8 and x_8' are expected, Actual other costs. From this, the formula for calculating the estimated cost of any project is:

$$Z_1\left(x_1,\cdots,x_8\right)=\sum_{i=1}^{8}x_i \tag{10}$$

The scale of each project, environment, geographic location, equipment types are different, if the historical cost data are compared directly, there is no comparability, so it is necessary to do standardization to obtain the project cost risk function for:

$$Z=\sum_{i=1}^{8}\left(\frac{x_i-x_i{}'}{x_i}\right) \tag{11}$$

Where $\frac{x_i-x_i{}'}{x_i}$ represents the balance rate of different costs. In the actual construction process, the factors have different impacts on the total cost, and their different impacts are reflected by assigning weights. Namely:

$$Z'=\sum_{i=1}^{8}\left[\varpi_i\left(\frac{x_i-x_i{}'}{x_i}\right)\right] \tag{12}$$

In the formula, ϖ_i represents the weight of each uncertainty factor. Combining the definition of risk and the actual situation of transmission and transformation project, the engineering cost risk degree function is established as:

$$R=\sum_{i=1}^{8}P_iZ_i \tag{13}$$

In the formula, P_i for the project cost i factors may appear the chance of over-budget, also belongs to the uncertainty factor. Based on the above analysis, it can be seen that the management cost, technical service cost, commissioning cost and production preparation cost in the project are static costs.

Assuming that the chance of the ontology cost balance rate exceeding the budget estimate P_1 satisfies the normal distribution with mean μ_{P_1} and variance δ_{P_1}, and the proportion exceeding the budget satisfies the normal distribution with mean $\mu_{\Delta_{x_1}}$ and variance $\delta_{\Delta_{x_1}}$, the variance of the cost risk function is expressed as follows:

$$D(R)=\sum_{i=1}^{8}\varpi_i^2\left[\left(\delta_{\rho_i}+\mu_{P_i}^2\right)\left(\delta_{\Delta_{x_i}}+\mu_{\Delta_{x_i}}^2\right)-\mu_{\rho_i}^2\mu_{\Delta_{x_i}}^2\right] \tag{14}$$

The chance of occurrence of all uncertainties and the amount of overestimation satisfy the independent normal distribution, so the risk of overestimation also conforms to the normal distribution, then R should satisfy the normal distribution, and its distribution function is expressed as:

$$F(R)=\frac{1}{\delta\sqrt{2\pi}}\int_{-\infty}^{R} e^{\frac{(t-\mu)^2}{2\delta^2}}dt \tag{15}$$

Based on data from previous engineering calculations, it is possible to calculate the ideal value and variance of the risk function.

4 Engineering cost risk assessment and control strategy

With the rapid development of the construction industry, the scale and complexity of construction projects are increasing, and project cost management is facing more and more challenges. As an important part of project management, project cost is directly related to the economic and social benefits of the project. However, in the process of project implementation, a variety of uncertainties may lead to cost deviation from the expected target, bringing great risks to the project. Therefore, it is particularly important to assess the risk of construction project cost and formulate corresponding coping strategies. This chapter is mainly based on the gray system model to quantitatively assess the construction project cost risk and provide support for proposing the project cost risk control strategy.

4.1 Weighting of construction cost risk indicators

4.1.1 Overview of construction works

During the construction of a building project, the relevant personnel should clarify the actual situation of the project construction, understand the natural conditions and geological and hydrological status around the construction site, and the site category, seismic protection level, seismic intensity are 3, B, 9 degrees, and the construction period is about 2 years. Influenced by multiple factors, the current construction cycle should be appropriately shortened, and the reduced construction period will lead to a number of cost risks, the relevant departments need to introduce the appropriate risk assessment model in due course, the use of the model's comprehensive analysis of the scientific control of the construction costs of the project.

When selecting the evaluation model, the technicians analyze the cost risk that may be formed within the construction project in accordance with the actual situation of the construction project, reasonably select the entropy weight method - gray correlation evaluation model, put the information data obtained into the evaluation model, and plan the evaluation model appropriately to effectively complete the transformation of the cost risk evaluation of the construction project, and effectively enhance the scientific application of the data index model. Evaluation of the scientific nature of the application. Before applying the entropy weight method-gray correlation evaluation model, technicians need to comprehensively investigate all kinds of risks in the cost of construction projects, and effectively enhance the control of the evaluation model according to the data information formed by the corresponding risks.

4.1.2 Analysis of evaluation indicator weights

Based on the collected information of construction project cost risk data, using the entropy weight method given in the previous section combined with the engineering project cost risk evaluation indexes, the weights of the engineering project cost risk evaluation indexes are calculated, and the weight distribution of the engineering project cost risk evaluation indexes is obtained as shown in Table 2.

From the weight distribution of the guideline layer indicators, the design stage has the greatest influence on the cost risk evaluation of engineering projects, accounting for 32.73%, followed by the investment decision-making stage, accounting for 26.32%, the third ranked is the bidding stage, with a weight share of 20.18%, and the fourth and the fifth are the construction stage and the completion stage, with a weight proportion of 14.96% and 5.81%, respectively. In the process of cost risk assessment of construction projects, the design stage, the investment decision stage and the bidding stage have a relatively large degree of influence on the cost risk assessment of construction projects. Combined with the whole life cycle of the construction project, the design and investment decision-making stages are the content of the work in the early stage of construction, and play a guiding role for the subsequent development of various tasks. For example, a large part of the engineering changes in the construction stage is from the design phase of the survey is not clear or the design and construction site is too different, which shows that the risk factors are mutually influential and correlation exists. Therefore, to strengthen the early design and investment decision-making stage of risk management, avoid or reduce the cost of subsequent work in advance of the cost risk, in order to effectively reduce the overall cost of the project risk.

Table 2: Cost risk evaluation index weight

Code	A (0.2632)	B (0.3273)	C (0.2018)	D (0.1496)	E (0.0581)	Composite weight
A1	0.0635	-	-	-	-	0.0167
A2	0.1028	-	-	-	-	0.0271
A3	0.1542	-	-	-	-	0.0406
A4	0.2186	-	-	-	-	0.0575
A5	0.4609	-	-	-	-	0.1213
B1	-	0.3524	-	-	-	0.1153
B2	-	0.1014	-	-	-	0.0332
B3	-	0.2573	-	-	-	0.0842

Code	A (0.2632)	B (0.3273)	C (0.2018)	D (0.1496)	E (0.0581)	Composite weight
B4	-	0.0526	-	-	-	0.0172
B5	-	0.2363	-	-	-	0.0773
C1	-	-	0.2827	-	-	0.0571
C2	-	-	0.3745	-	-	0.0756
C3	-	-	0.1246	-	-	0.0251
C4	-	-	0.2182	-	-	0.044
D1	-	-	-	0.2124	-	0.0318
D2	-	-	-	0.1875	-	0.0281
D3	-	-	-	0.2358	-	0.0353
D4	-	-	-	0.2066	-	0.0309
D5	-	-	-	0.1577	-	0.0236
E1	-	-	-	-	0.3428	0.0199
E2	-	-	-	-	0.3074	0.0179
E3	-	-	-	-	0.3498	0.0203

From a single risk factor:

1) The greatest impact in the investment decision-making stage is the financing program feasibility (A5) is low, and its combined weight is 0.1213. The financing program is related to the choice of investment program, will make the investment objectives can not be achieved, its feasibility should be to achieve the degree of the final program.
2) The design phase of the greatest impact is the design estimate review (B1) is not comprehensive and error, its comprehensive weight is 0.1153. As an important basis for follow-up work, will lead to construction and the original plan to produce differences, resulting in a number of design changes and secondary design, but also lead to the supplier's engineering claims, which in turn has a negative impact on the cost, can be seen for all types of risk is the result of the interactions. The result of this is that for all kinds of risks, it is the result of mutual interaction.
3) The bidding stage of the greatest impact is the bidding control price preparation and review (C2), its comprehensive weighting of 0.0756. Some of the bidding control price preparation and review of the improper, did not use the original list of unit prices, but re-grouping prices, which will have an impact on the cost.
4) The greatest influence in the construction stage is the price of manpower, machinery and materials (D3), with a combined weight of 0.0353. The construction project will be affected by the manpower, machinery and building materials, which will lead to the creation of the project cost risk.
5) The greatest influence in the completion stage is the acceptance of work quality (E3), with a combined weight of 0.0203, which is an important part of the completion of the construction project, and is also a concrete manifestation of the actual cost and investment results, which should be emphasized and control measures should be taken accordingly.

4.2 Validation of engineering cost risk assessment

4.2.1 Establishment of a risk assessment matrix

This paper divides the cost risk of a construction project into four levels, namely "low", "average", "large" and "major", and uses the principle of 1-10 points to score each evaluation index, the higher the score, the higher the corresponding risk. Based on the above principles, this paper invites the owner's representative, project manager, construction manager, tracking audit, supervision manager and other relevant experts involved in the project to form a group of experts to judge the risk level by means of a questionnaire survey. In this paper, a total of five experts were invited to score the cost risk of the construction project, and the results are shown in Table 3.

Table 3: Cost risk assessment matrix

Criterion layer	Code	Expert1	Expert2	Expert3	Expert4	Expert5
Investment decision stage (A)	A1	9	2	6	2	8
	A2	8	5	2	4	9
	A3	5	1	2	3	2
	A4	2	1	2	2	7
	A5	1	2	1	2	6
Design stage (B)	B1	5	3	1	1	5
	B2	2	5	2	5	4
	B3	3	2	3	2	2
	B4	2	4	2	3	2
	B5	1	2	1	1	3
Bidding stage (C)	C1	5	3	2	2	1
	C2	2	5	4	4	2
	C3	8	6	2	2	3
	C4	7	2	3	2	2
Construction stage (D)	D1	6	1	2	3	2
	D2	8	8	5	2	2
	D3	4	4	2	3	1
	D4	2	8	6	2	2
	D5	6	3	8	1	6
Completion stage (E)	E1	2	4	2	4	2
	E2	3	7	1	5	2
	E3	5	8	1	5	1

4.2.2 Gray correlation assessment results

Based on the construction cost risk assessment matrix, combined with the gray correlation matrix and correlation degree calculation method given in the previous section and the weights obtained by entropy weighting method, the weights are weighted with the risk assessment matrix in order to obtain the gray correlation degree, and then get the cost risk assessment results of the construction project as shown in Table 4. In the table, GCC and GC are gray correlation coefficient and gray correlation degree, respectively. On the basis of the risk level divided in the previous paper, this paper refers to the existing scholars about the use of normal distribution mathematical model to deal with the risk correlation approach, selects 1 times the standard deviation as the benchmark for the cost risk assessment of the construction project, selects 2 times the standard deviation as the benchmark for the cost risk of the construction project exceeds the anomalies, and classifies the risk criterion into four grades. That is, the risk correlation is between (0.231~0.238), the cost risk assessment level is low risk, between (0.225~0.231), the cost risk assessment level is general risk, between (0.196~0.225), the cost risk assessment level is greater risk, and lower than 0.196, the cost risk assessment level is significant risk.

As can be seen from the table, the gray correlation of the investment decision stage, design stage, bidding stage, construction stage, and completion stage of the cost risk assessment of this construction project is 0.235, 0.227, 0.223, 0.236, and 0.229 respectively, and its risk assessment level is between low risk and general risk. This indicates that the cost risk of the construction project is low, but there are some indicators that need to be emphasized. In addition, in the indicator layer of cost risk assessment, its gray correlation ranges from 0.225 to 0.237, which is also between low risk and general risk. This indicates that the construction project has set up a more reasonable financing program in the investment decision-making stage, and the overall construction scale and standards are in line with the investment budget. The feasibility of the design program is effectively evaluated in the design phase, and the construction drawing budget is examined more strictly. The bidding stage, construction stage and completion stage have made excellent cost evaluation, which provides reliable support for reducing the cost risk of construction projects and fully ensures the stable development of construction projects.

Table 4: Project cost risk assessment results

Criterion layer	**GCC**	**GC**	**Code**	**GCC**	**GC**
Investment decision stage (A)	0.958	0.235	A1	0.799	0.232
			A2	0.772	0.227
			A3	0.875	0.234
			A4	0.941	0.234
			A5	0.845	0.226
Design stage (B)	0.842	0.227	B1	0.816	0.228
			B2	0.908	0.233
			B3	0.775	0.236
			B4	0.841	0.235
			B5	0.915	0.231
Bidding stage (C)	0.637	0.223	C1	0.813	0.236
			C2	0.835	0.235
			C3	0.805	0.236
			C4	0.937	0.237
Construction stage (D)	0.845	0.236	D1	0.899	0.231
			D2	0.754	0.228
			D3	0.778	0.225

Criterion layer	GCC	GC	Code	GCC	GC
			D4	0.874	0.234
			D5	0.942	0.232
Completion stage (E)	0.769	0.229	E1	0.845	0.237
			E2	0.863	0.235
			E3	0.879	0.229

4.2.3 Effectiveness of project cost management

Based on the previous construction project cost risk assessment results, it can be seen that the current project still exists in the general risk situation, so for the optimization of the relevant stages of the general risk, in order to verify the specific effect of the project cost risk assessment index system for optimizing the project cost management. Combined with the cost risk modeling results given in the previous section to solve the comprehensive cost risk index, Table 5 and Table 6 are the cost risk of project investors before and after the management and the effect of project cost management before and after the comparison.

Before carrying out cost risk management, the static investment of the construction project totaled 105.3602 million yuan, with a return yield of 8.37%, and the investor's cost risk index reached 0.751, based on the risk level can be seen that the current cost risk level is high. Based on the optimization of the project cost risk assessment index designed in this paper, the cost risk of the investor of the construction project is effectively controlled, and its risk index is reduced from 0.751 to 0.095, with an overall decrease of 87.35%. In addition, after the implementation of the project cost risk assessment management strategy, the costs in the project have been effectively reduced, the overall static investment is 91.791 million yuan, and the return yield of the investor return from 8.37% to 16.89%. Therefore, through the above statistics and comparisons, it is proved that the project cost risk assessment model designed in this paper has a good effect on optimizing the project cost risk and reducing the construction project cost budget.

Table 5: The cost risk of the project investor before and after management

Index	Pre-management	Post-management
Engineering change	0.563	0.135
Market price fluctuation	0.745	0.084
Job distribution mismatch	0.368	0.113
Bidding cost is not accurate	0.429	0.052
Irresistible force	0.267	0.036
Integrated cost risk index	0.751	0.095

Table 6: The effect of cost management is compared (*10^4yuan)

Project	Pre-management		Post-management	
	Major engineer	Auxiliary engineer	Major engineer	Auxiliary engineer
Construction cost	2651.48	1035.04	2236.51	869.71
Equipment purchase cost	354.29	145.63	234.46	126.38
Installation cost	1246.62	1033.25	1215.38	1005.29
Preparatory cost	689.37	266.92	641.29	216.54
Relocation compensation	952.51	845.87	952.15	485.67
Land royalty	852.46	462.58	842.07	345.46
Return yield	8.37%		16.89%	

4.3 Engineering cost risk control strategy

4.3.1 Establishment of a sound risk assessment mechanism

Risk evaluation and control in the cost control of construction project engineering is the key to ensure the success of the project. The construction unit should establish a sound risk assessment mechanism, build a systematic risk identification and evaluation system based on actual needs, and adopt quantitative and qualitative means to comprehensively evaluate the risks in the cost management and control system of construction projects. Construction units can utilize the risk matrix method to identify high-risk factors such as material price changes, design changes, construction schedule delays, etc., and take effective measures according to the risk assessment results. At the same time, strengthening the training of talents is an important part of improving the project cost control ability. Specifically, the construction unit can provide systematic vocational training for the staff, including cost estimation, contract management, and project schedule control. The construction unit can build a resource sharing platform, and can also implement real-time monitoring and data analysis of the whole process of the project with the help of building information modeling, big data technology, etc., so as to realize the refined management of the project, guard against potential project investment risks, and improve the overall level of project cost management and control of construction projects.

For example, a certain construction unit has established a management structure based on the knowledge system in engineering management and centered on time, cost and quality according to its own actual situation, and organizes relevant business training on a regular and irregular basis in conjunction with the actuality of various aspects of the engineering project. Specifically, it includes knowledge in risk management, contract management and communication to ensure that every employee has a solid theoretical foundation and strong practical skills. During the construction phase, the project team utilized the earned value management model to track the progress of the project and changes in costs in real time, ensuring that the project was completed on schedule within a reasonable timeframe.

4.3.2 Enhanced internal control oversight implementation

Strengthening internal control and supervision in the cost risk assessment of engineering projects has a pivotal position, which is also to ensure that the cost risk assessment of engineering projects is standardized and effective core measures. The cost risk assessment process should develop a set of comprehensive and strict assessment procedures, operating procedures, and provide clear operating standards for cost risk assessment personnel. Starting from the development of the cost risk assessment program, the cost risk assessment objectives, scope, methodology and time schedule should be clearly defined to ensure that the cost risk assessment work is carried out in an orderly manner. During the implementation of the cost risk assessment, the cost risk assessment personnel should follow the operating procedures, conduct a meticulous review of the cost risk assessment objectives, and ensure the adequacy and appropriateness of the cost risk assessment evidence.

The cost risk assessment report is the final result of the assessment work, and the accuracy and objectivity of the report should be ensured to avoid subjective assumptions and misleading statements. On this basis, an effective cost risk assessment feedback mechanism should be established to respond to the comments and suggestions of the assessed units in a timely manner, and to enhance the interactivity and transparency of the cost risk assessment work. In addition, internal audit supervision should be strengthened, a strict supervision mechanism should be established, and a special supervision department or post should be set up to dynamically supervise and check the process of cost risk assessment, so as to ensure that the cost risk assessment personnel work strictly in accordance with the procedures and operating procedures. The supervision department should focus on the implementation of the cost risk assessment plan, the collection of evidence, the analysis process, the preparation of the report, the approval process and other key aspects to ensure the quality and efficiency of the cost risk assessment work. If necessary, a reporting and complaint mechanism should also be established to encourage internal staff and the public to report irregularities in the cost risk assessment work, so as to detect and correct problems in a timely manner, and to guarantee the impartiality and authority of the cost risk assessment work.

4.3.3 Enhanced communication and collaboration with the parties

Ensure smooth information flow and collaboration among all relevant parties, establish a sound communication and coordination mechanism for project cost risks, and ensure smooth information flow among the project team and between the project team and stakeholders. Hold regular cost risk management meetings to share cost risk information, discuss cost risk response strategies and track the progress of cost risk handling. Summarize and evaluate the cost risk management process of the project, analyze the success and failure of cost risk management, and feedback the lessons learned to the project team and stakeholders to provide reference for the cost risk management of the project.

Strengthen the project team members' understanding of and attention to cost risk, conduct cost risk education and training for the project team during the project start-up phase, make the team members clear about the concepts and types of project cost risks as well as the importance of cost risk management, and organize regular cost risk management training and learning to improve the team members' ability to identify, assess, and cope with cost risks. In the process of project implementation, regular cost risk identification and assessment activities are carried out to identify potential cost risk factors and assess their likelihood and degree of impact, and team members are encouraged to actively participate in cost risk identification and assessment activities to enhance the team's awareness of cost risk.

5 Conclusion

The article proposes an engineering cost risk assessment model based on gray system model, and verifies the application effectiveness of the model through examples. In the process of engineering cost risk assessment, the design stage has the greatest influence, and its weight value reaches 0.3273, and the influence of the completion stage is the smallest only 0.0581. When the engineering cost risk assessment model is used for the evaluation of cost risk, its gray correlation is between 0.223 and 0.236, and the level of the cost risk is between the low risk and the general risk. After using the evaluation system as the engineering cost management, the reported rate of return of the investor increased from 8.37% to 16.89%, and the overall cost cost was effectively controlled, which better enhanced the economic benefits of the construction project. Therefore, engineering cost risk control needs to establish a perfect risk assessment mechanism, strengthen the internal control and supervision mechanism, strengthen the communication and collaboration of all parties to the project, and reduce the engineering cost risk.

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