Intelligent Pre-alarm System for Construction Cost Risk under Multi-Source Data Fusion

Judong Tao

Anhui Province Liangji Project Management Co., Ltd., Hefei, Anhui, 230000, China

Keywords: Construction project cost; Multi-source data fusion; Intelligent pre-alarm system; Risk prediction; Coping suggestions

Abstract: This article focuses on the intelligent pre-alarm system of construction project cost risk under multi-source data fusion. This study uses multi-source data fusion technology to integrate engineering drawings, market prices, construction records and other multi-source data, and builds a risk pre-alarm model with the help of intelligent pre-alarm related technologies, such as support vector machine algorithm. Through the application verification in a 50,000-square-meter comprehensive commercial building project, the results show that the prediction accuracy of the pre-alarm system for design change risk is 89.29%, the prediction accuracy of material price rise risk is 86.96%, and the prediction accuracy of construction schedule delay risk is 88.89%. The effective rate of risk response suggestions is 88% in the risk of design change, 85% in the risk of material price increase and 87.5% in the risk of construction schedule delay. The research shows that the system is excellent in risk prediction and response suggestions, and has high practical value, which provides a new and effective way for risk management of construction project cost.

1. Introduction

With the vigorous development of the construction industry, the scale and complexity of engineering projects have increased, and the risk of engineering cost has become more and more prominent, which not only affects the economic benefits of the project, but also relates to the promotion and quality of the project [1]. The traditional cost management method can't meet the demand of modern engineering for accurate risk pre-alarm and effective control, so building an efficient cost risk pre-alarm system has become the focus of the industry [2]. With the rapid development of information technology, multi-source data fusion technology has gradually emerged. Massive data has been accumulated in the field of construction engineering, covering engineering drawings, market price information, construction progress records and other aspects [3-4]. Through multi-source data fusion technology, these scattered data can be integrated and their potential value can be tapped, which can provide more comprehensive and accurate data support for the pre-alarm of project cost risk [5]. With the help of machine learning, data analysis and other means, intelligent pre-alarm technology can deeply analyze complex data, find potential risks in time, and realize intelligent pre-alarm of risks.

It is of great theoretical and practical significance to study the intelligent pre-alarm system of construction project cost risk under multi-source data fusion [6]. Theoretically, it enriches the theoretical system of project cost risk management and promotes the theoretical innovation and development in this field; In reality, it helps to improve the cost management level of construction enterprises, identify risks in advance, reduce cost overruns, delay in construction period and other issues, enhance the competitiveness of enterprises, and ensure the healthy and stable development of the industry [7].

Although multi-source data fusion and intelligent pre-alarm technology have been applied in other fields, the application in construction cost risk management is still in the exploratory stage [8]. The existing research has some shortcomings in the depth of data fusion and the accuracy of pre-alarm model. Therefore, it is urgent to study the intelligent pre-alarm system of construction project cost risk under multi-source data fusion. This article aims to build a scientific and effective

  DOI: 10.25236/icacel.2025.191

intelligent pre-alarm system through in-depth study of relevant theories and technologies, and provide new ideas and methods for the risk management of construction project cost.

2. Construction project cost risk under multi-source data fusion

2.1 Risk factor identification and risk index system

The construction cost runs through the whole life cycle of the project, and there are hidden risk factors in each stage. In the project planning stage, the rationality of the planning scheme has a significant impact on the cost. If the planning positioning is not accurate, it may lead to the adjustment of the project scale, and then increase the cost [9]. The design stage is equally critical, and insufficient design depth and frequent design changes are common risks. If the preliminary design fails to fully consider the construction conditions, there may be a lot of changes in the construction drawing design, resulting in waste of materials, delay in construction period and increased cost. The risks in the construction stage are more complicated. Improper selection of construction technology may affect the quality and progress of the project and increase the extra cost. For example, an immature waterproof technology is adopted in a building project, which leads to leakage in the later stage and has to be reworked. In addition, material price fluctuations, personnel changes and other factors will also have an impact on the cost. The price of building materials in the market fluctuates frequently due to the relationship between supply and demand and policy regulation. If the price dynamics are not timely grasped, there may be losses during procurement. In the completion stage, the settlement audit is not strict, which may lead to the inflated project cost. For example, the calculation error of engineering quantity and high quota will make the final settlement amount deviate from the actual cost.

Based on the above risk factors, it is very important to construct a scientific and reasonable risk index system. The system should cover the key indicators from pre-project planning to completion settlement, as shown in Table 1:

Table 1 Construction Project Cost Risk Indicator System

Stage	Risk Indicator Name	Indicator Description	Quantification Method
Planning Stage	Rationality of Planning Scheme	Evaluates alignment with market demand and scale rationality	Composite score (50% market alignment + 50% scale rationality), out of 100 points
Design Stage	Design Change Rate	Reflects design stability; change rate affects cost	(Number of design changes ÷ Total number of designs) × 100%
Construction Stage	Material Price Fluctuation	Measures price changes of key materials	(Current material price - Base price) ÷ Base price × 100%
Construction Stage	Construction Schedule Deviation	Reflects deviation between actual and planned progress	(Planned progress - Actual progress) ÷ Planned progress × 100%
Completion Stage	Settlement Audit Accuracy	Monitors accuracy of settlement	(Correctly audited amount ÷ Total declared amount) × 100%

2.2 Correlation between multi-source data and risk indicators

Multi-source data provides a strong support for the quantification of risk indicators. Engineering drawing data can be used to analyze the rationality of design and determine the potential risk of design change. Through the digital processing of drawings, relevant design parameters are extracted, and compared with similar projects, the design economy is evaluated. The market price data is directly related to the fluctuation index of material price. With the help of the price monitoring platform, the price information of all kinds of materials can be obtained in real time, and the price trend can be analyzed to provide a basis for purchasing decision. The construction record data can reflect the construction progress, quality and so on. By analyzing the data such as construction log and quality inspection report, the deviation index of construction progress can be accurately calculated. The fusion application of multi-source data makes the quantification of risk indicators more accurate and comprehensive, and lays a solid foundation for the pre-alarm of construction project cost risk.

3. Design of intelligent pre-alarm system for construction cost risk

The intelligent pre-alarm system of construction project cost risk adopts hierarchical architecture design to realize efficient function integration and data interaction. The intelligent pre-alarm model of construction project cost risk is shown in Figure 1:

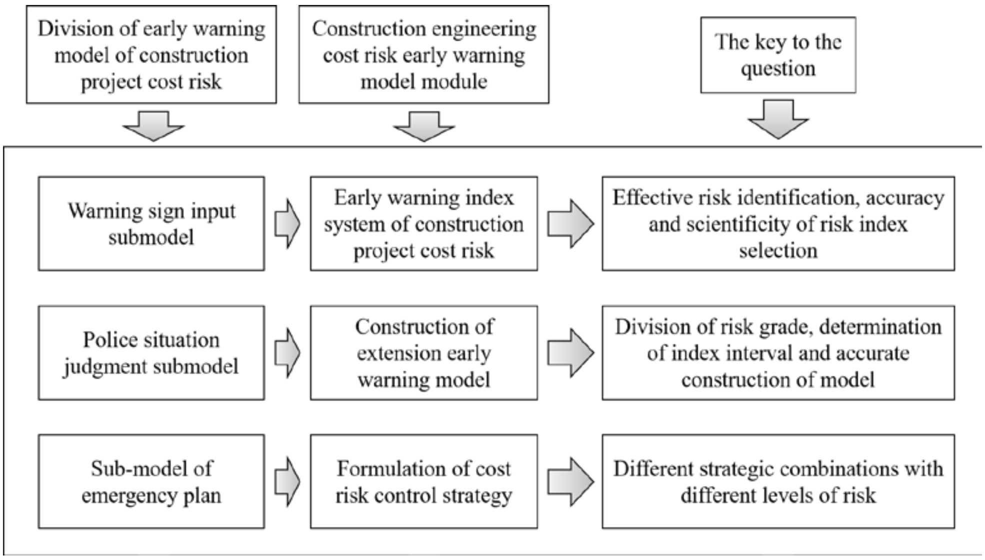

Figure 1 Intelligent Warning Model for Construction Cost Risk

It is divided into data layer, data processing layer, model layer and application layer from bottom to top. The data layer is responsible for collecting multi-source data, including engineering drawings, market price information and construction records. These data come from a wide range of sources and have various formats, which are the basis of system operation. The data processing layer cleans, transforms and integrates the collected data to meet the requirements of subsequent analysis. The model layer uses intelligent algorithm to build a risk pre-alarm model, and through the study and training of historical data, it mines the laws contained in the data. The application layer presents the prediction results of the model to users in an intuitive form, providing risk pre-alarm information and corresponding countermeasures.

3.1 Design of data processing module

Data acquisition: Multi-source data can be obtained in various ways. Collect market price data from related industry websites by using web crawler technology; Docking with the construction management system to obtain construction record data; Digital scanning equipment is used to convert engineering drawings into electronic data. The original data often has problems such as noise, missing values and abnormal values. For the missing values, the mean filling method or the missing value prediction algorithm based on machine learning is used to fill them. Assuming that there is a missing value for a feature X in the data set, and the average value of X is $\overline{X}$, the missing value can be filled as $\overline{X}$. For abnormal values, a reasonable threshold range can be set to identify and correct. In the material price data, if a material price exceeds the historical price range (standard deviation), it is judged as an abnormal value and needs further verification or correction. In addition, this article also converts data in different formats into formats suitable for analysis, such as extracting unstructured data from engineering drawings into structured data for subsequent processing.

3.2 Construction of risk pre-alarm model

In this article, support vector machine (SVM) algorithm is used to build a risk pre-alarm model. SVM can find the optimal classification hyperplane in high-dimensional space, and has good classification effect for small samples and nonlinear data. Its basic principle is to map the data in low-dimensional space to high-dimensional space through kernel function, so that a hyperplane can be found in high-dimensional space to separate different kinds of data. Let the training data set be:

$$L\{(x_i, y_i)\}_{i=1}^{n} \quad (1)$$

Where $x_i \in R^d$ is the input feature vector and $y_i \in \{-1,1\}$ is the category label. The goal of SVM is to find a hyperplane:

$$w^T x + b = 0 \quad (2)$$

Maximize the margin $\frac{2}{\|w\|}$, subject to:

$$y_i\left(w^T x_i + b\right) \geq 1, i = 1, \ldots, n \quad (3)$$

The model uses historical engineering cost data to train SVM model, and selects the optimal model parameters, such as penalty parameter C and kernel function parameter γ, by cross-validation. The grid search algorithm is used to traverse different parameter combinations, and the classification accuracy is used as the evaluation index to find the parameters that optimize the model performance. In the process of training, the parameters are constantly adjusted, so that the model can accurately identify different risk States.

4. System application and verification

In order to test the effectiveness and practicability of the intelligent pre-alarm system of construction project cost risk, a comprehensive commercial building project is selected as an application case. The project has a total construction area of 50,000 square meters, covering various functional areas such as commercial shops, dining areas and underground parking lots. The project duration is 24 months.

In the process of project implementation, the intelligent pre-alarm system is fully applied to cost risk management. The system collects multi-source data such as engineering drawing change information, market material price fluctuation data and construction progress records in real time, and analyzes and processes them through data processing module and risk pre-alarm model.

Table 2 Risk Prediction Accuracy of the Pre-alarm System

Risk Category	Actual Occurrences	Predicted by System	Accurate Predictions	Prediction Accuracy
Design Change Risk	30	28	25	89.29%
Material Price Rise Risk	25	23	20	86.96%
Construction Delay Risk	20	18	16	88.89%

As can be seen from Table 2, the design change risk actually occurred 30 times, and the pre-alarm system predicted 28 times. Among them, it was accurately predicted 25 times, and the prediction accuracy rate reached 89.29%. In terms of the risk of rising material prices, it actually happened 25 times, the pre-alarm system predicted 23 times and accurately predicted 20 times, with an accuracy rate of 86.96%. However, the risk of construction schedule delay actually occurred 20 times, and the pre-alarm system predicted 18 times and accurately predicted 16 times, with an accuracy rate of 88.89%. On the whole, the pre-alarm system has a high prediction accuracy for all kinds of risks and can effectively find potential risks in advance.

In this study, the effectiveness of the risk response suggestions given by the pre-alarm system is evaluated (see Table 3).

Table 3 Effectiveness of Risk Response Suggestions

Risk Category	Suggestions Adopted	Risk Impact Reduced	Effectiveness Rate
Design Change Risk	25	22	88%
Material Price Rise Risk	20	17	85%
Construction Delay Risk	16	14	87.5%

It can be seen from Table 3 that in the risk response of design changes, suggestions were adopted for 25 times, and the risk impact was successfully reduced for 22 times, with an effective rate of 88%. The suggestions for dealing with the risk of rising material prices were adopted for 20 times, and the risk impact was reduced for 17 times, with an effective rate of 85%. The suggestions for dealing with the risk of construction schedule delay were adopted 16 times, and the risk impact was reduced 14 times, with an effective rate of 87.5%. This shows that the risk response suggestions provided by the pre-alarm system are highly effective and can effectively help the project team to take reasonable measures to deal with risks.

5. Conclusions

In this article, the intelligent pre-alarm system of construction project cost risk under multi-source data fusion is studied and practiced, and a series of results have been obtained. In the aspect of system design, the hierarchical architecture is adopted, and the design from data layer to application layer ensures the effective processing of multi-source data and the realization of risk pre-alarm function. The risk pre-alarm model adopts support vector machine algorithm, which shows good performance after training and optimization.

Through the application verification of the actual commercial building project, the system performance is excellent. From the perspective of risk prediction accuracy, it has a high prediction accuracy for major risk categories such as design changes, rising material prices, and construction schedule delays, which can detect potential risks in time and strive for response time for the project team. The effectiveness of risk response suggestions is also satisfactory, which helps the project team to reduce the negative impact of risks on the project cost and effectively improves the cost management level.

However, there are still some limitations in this study. On the one hand, although the model performs well in case projects, different types of construction projects have different characteristics, and the system may need further adjustment and optimization when it is popularized and applied. On the other hand, data collection is limited by existing data sources and technical means, and with the emergence of more data types and acquisition methods in the future, it is expected to further improve the system performance.

References

[1] Wu, J. Research on the Evaluation Method of Environmental Pollution Prevention Engineering Cost in Construction[J]. Environmental Science and Management, 2020, 45(03), 190-194.

[2] Wang, L. M., Gao, Y., & Song, J. The Operational Logic and Implementation Path of

Comprehensive Budget Thinking in EPC Project Cost Management[J]. Construction Economy, 2021, 42(S1), 80-84.

[3] Ren, D. Y. Analysis of Influencing Factors and Diagnostic Strategies for Railway Tunnel Engineering Cost[J]. Microcomputer Applications, 2022, 38(07), 131-134.

[4] Lin, X. M., Xia, G. B., & Yu, X. H. Research on Performance Evaluation of University Infrastructure Project Cost Management[J]. Construction Economy, 2025, 46(3), 74-80.

[5] Shao, S., Zhao, X., Ao, H. N., et al. A Power Engineering Cost Prediction Model Based on Gradient Boosting Decision Tree Algorithm[J]. Journal of Shenyang University of Technology, 2025, 47(03), 302-308.

[6] Yang, J., & Wang, X. W. Application of BIM in Engineering Cost Management[J]. Industrial Construction, 2023, 53(S02), 783-784.

[7] Li, X. M. Material Price Risk Control in Construction Project Cost Management[J]. Materials Protection, 2020, 53(10), 175-176.

[8] Qian, Q. Y., Shen, Y. F., & Liu, Z. S. Risk Modeling and Evaluation of Whole-Process Cost in Power Transmission and Transformation Projects Based on Grey Theory[J]. Microcomputer Applications, 2023, 39(11), 111-113.

[9] Ma, X. Y. Risk Assessment of Foundation Pit Construction in Subway Stations Based on Multi-Level Correlation[J]. Highway, 2023, 68(12), 264-268.