Dynamic Calculation and Analysis of the Fee Rate for Safe and Civilized Construction in Railway Transportation Engineering Based on PSO-SVM

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Abstract. To effectively address the issue of lagging utility of safety and civilized construction fee rate standards in current subway engineering projects, this paper proposes establishing a dynamic rate calculation model based on PSO-SVM to accurately determine the actual rates. Initially, the study conducts a factual statistical analysis of the calculation numerator. Subsequently, it constructs a PSO-SVM model to predict the settlement cost of unsettled projects and proportionally extracts the billing base as the denominator for rate calculation. Finally, based on the critic analysis method, the rates are calculated. The research findings demonstrate that this calculation method accurately and effectively calculates the safety and civilized construction fee rates for subway engineering projects. Relevant authorities can refer to the research results to adjust the rates and address the issue of lagging utility of rate standard guidelines.

Keywords: Railway Transportation Engineering; PSO-SVM; the Fee Rate for Safe and Civilized Construction

1 Introduction

The construction of subway engineering is an important approach to alleviate urban traffic congestion. With the rapid growth in the scale of subway construction projects, significant safety accidents have been increasing year by year, posing serious threats to public life and property safety[1]. The severe situation of subway engineering safety production urgently requires scientific management of safe and civilized construction costs to ensure safety production. According to China's engineering safety construction and engineering cost management system, the safety and civilized construction fee is a special expense to guarantee the safe construction of engineering projects, and it is non-competitive expenses that must strictly adhere to the engineering cost quota standards issued by the construction industry management department. Its amount is calculated by extracting the billing base from the completion settlement cost and multiplying it by

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the safety and civilized construction fee rate issued by the management department. The cycle from the commencement of a subway project to the final completion of the settlement record typically takes at least 2.5 to 3 years. During this period, national policies and the market economy environment may change, and the safety and civilized construction fee calculated based on the prescribed fee rate is affected by the timeliness of data, lagging behind current needs.[2][3]Therefore, dynamically and reasonably determining this fee rate standard is of significant importance.

Although scholars have qualitatively analyzed the calculation methods of safety and civilized construction fees in subway projects in different cities, the issue of dynamically calculating these fees has not been resolved. As a result, it is challenging to provide timely and scientifically guided instructions for safety and cost management in subway engineering projects. In light of this, the author conducts a refined analysis of the composition of safety and civilized construction fees. A cost collection form is established to accurately record safety and civilized construction fees, which serves as the numerator for the dynamic calculation of safety and civilized construction fees in subway projects. By constructing a Particle Swarm Optimization Least Squares Support Vector Machine (PSO-SVM) model and utilizing its settlement cost for unsettled projects, the billing base is extracted as the denominator. Consequently, the dynamic determination of fee rate standards is achieved, aiming to ensure safety and civilized construction in subway projects at reasonable cost standards.

2 Related Work

To achieve the accurate estimation of safety and civilization construction fees for subway projects, a research team with rich engineering experience and solid professional knowledge was established. Firstly, a comprehensive investigation was conducted on the charging system of safety and civilization construction fees for subway projects in this city, focusing on the actual situation of safety and civilization construction fees in 21 major central enterprises and local state-owned enterprises in City W's construction market.

The investigation included professional classification of subway projects, composition of costs, billing bases, and other aspects. Based on the comprehensive investigation, a cost and information collection form was established. The contents of the statistical form mainly included the safety and civilization construction fee collection information table, sample characteristic indicators, and basic information of sample sections. Meanwhile, to ensure the authenticity and validity of the collected data, the collected data were reviewed by a professional project management company, laying a solid foundation for subsequent calculation work.

After completing the data preparation, the research team conducted a study on the dynamic calculation method of safety and civilization construction fees through literature analysis, expert interviews, empirical research, and other methods. To calculate the settlement cost of unsettled projects, different machine learning algorithms were compared, and optimization algorithms were introduced. Ultimately, the PSO-SVM method with the highest calculation accuracy was determined for predictive analysis, and the safety and civilization construction fee's final rate was calculated based on the critic weighting method.

3 Sample Information Research and Cost Statistics

According to national regulatory documents, safety and civilized construction fees refer to expenses incurred in accordance with the current national construction safety, construction site environmental, and sanitation standards, as well as relevant regulations.[4] These expenses include the procurement, renewal, and installation of construction safety protection equipment and facilities, improvement of safety production conditions and working environments, as well as the construction, maintenance, dismantling, cleaning, or amortization expenses of temporary buildings, structures, and other temporary facilities necessary for project construction. The breakdown of these fees includes safety construction fees, civilized construction fees, environmental protection fees, temporary facility fees, and smart construction site fees.[5] Based on the aforementioned division of safety and civilized construction fees, it is necessary to specify the included sub-items for each type of fee, describe the work content and measurement units of each sub-item, and establish a cost information collection form to accurately record the expenses.

In addition, according to the research methodology, it is necessary to predict the billing base. This requires selecting the main characteristic indicators that affect the safety and civilized construction fees and project costs of subway engineering projects. These indicators are selected through literature analysis and research interviews. The characteristic indicators of civil engineering include construction information and geological information. Construction information comprises methods of foundation treatment, construction methods, building area, number of floors, burial depth, etc., while geological information includes rock grade, geological conditions, etc.

Lastly, to comprehensively calculate the total fee rate, it is necessary to collect basic information about the sample sections. The main collected information for the sample sections includes four categories: project name, project basic information, section cost statistics, and section safety and civilized construction fee statistics. Project basic information includes project type (such as underground station excavation method), safety and civilized goals (such as qualified construction sites, demonstration sites, etc.), location (within or outside the third ring road), project duration, and project status (unsettled or settled). Section cost statistics include contract amount, labor cost, machinery cost, and current completed project value. Safety and civilized construction fee statistics for the section include the total amount and current expenditure of safety and civilized construction fees.

Conducting research and cost statistics on sample information according to the above research steps can prepare data for subsequent fee rate calculations for subway engineering projects.

4 Predicting Settlement Costs Based on Pso-Svm

To calculate the settlement cost of unsettled projects, this study constructs a PSO-SVM prediction model for forecasting. PSO-SVM, as a hybrid method combining particle swarm optimization and support vector machine, exhibits significant advantages in addressing small sample prediction problems.[6] These advantages include optimizing generalization performance, adapting to high-dimensional data, overcoming data imbalance, flexibility, robustness, and simple parameter adjustment, all of which effectively enhance the model's prediction accuracy and generalization ability.[7] The research focuses on subway engineering, where the number of research samples is limited, and there exists a certain mapping relationship between the settlement cost of subway engineering and its engineering features. Leveraging model computations, inputting engineering feature indicators yields settlement cost results, and finally, the accuracy of the predictions is evaluated through parameters outputted by the model.

To construct the model, the study first needs to determine the model's input and output layers. Based on the data reported by the companies, an initial screening of input indicators is conducted. Common engineering features, such as the number of station floors, construction methods, and types of retaining structures and support methods, are identified. To improve the model's generalization ability and combine with model test results, indicators with these common features are removed. The resulting input indicators include building area, contract cost, unilateral cost, and burial depth, while the output indicator is the settlement cost. The accuracy of the prediction results can be represented by the RMSE (Root Mean Square Error), MAE (Mean Absolute Error), MAPE (Mean Absolute Percentage Error), and R2 (Coefficient of Determination). Among these, RMSE and MAE reflect the actual situation of prediction errors, while MAPE is a percentage value where smaller values indicate higher model accuracy. Additionally, R^2 results closer to 1 indicate higher model accuracy.

5 Empirical Analysis

This study conducts an empirical analysis of fee rate calculation for civil engineering sections of railway transportation projects in City W in recent years, covering both settled and unsettled projects. The numerator of the calculation is obtained through accurate statistics, while the denominator represents the calculation base. For unsettled costs, the denominator is calculated using the PSO-SVM model, and the billing base is extracted proportionally.[8] The prediction steps are outlined as follows:

Step 1: Collect and compile the training and testing datasets required for the model. Partial input indicators, as well as training and testing data for the model.

Step 2: Model Training and Prediction Model training and testing involve randomly selecting 80% of the samples for training and 20% for testing. Utilizing MATLAB, the model structure is trained and parameters are adjusted using input and output indicator data from the testing table until the model's target error meets the requirements. After statistical calculation, the prediction accuracy of the PSO-SVM prediction model is summarized as follows in the Table 1:

Table 1. Data accuracy of civil engineering-training set

RMSE	MAE	MAPE	R^2
2060.6281	1256.5537	0.04842	0.94913

Based on the analysis from the above table 1, the effectiveness of the established PSO-ELM prediction model is as follows: The model fitting effect is excellent, with a small root mean square error (RMSE), indicating minimal errors among individual predicted data points. The mean absolute percentage error (MAPE) is extremely small, indicating low overall dispersion of predicted data. The maximum error is at a minimal level, indicating the absence of extreme outliers. This suggests that each predicted data point demonstrates very good predictive performance.

The comparison of model predictions is depicted in the following Figure 1, indicating that the PSO-ELM prediction model exhibits excellent fitting performance and can meet the accuracy requirements for settlement cost prediction.[9]

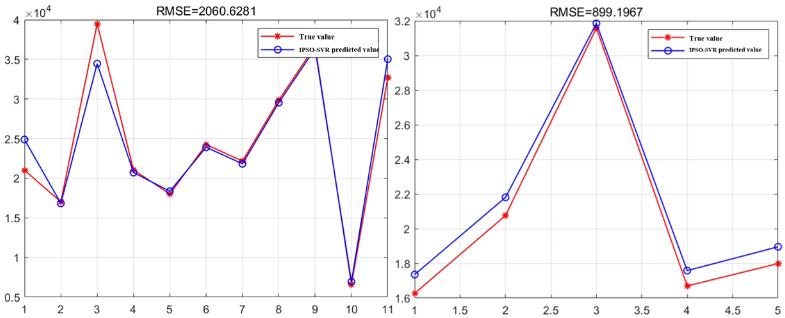

Fig. 1. Comparison of Training and Testing Set Prediction Results (Model output)

Step 3: Model Prediction Results The input of the prediction samples into the trained model yields the results as shown in Table 2:

Table 2. Prediction results of civil engineering samples (Author's own work)

Station name	Contract price	Calculate the estimated value	Floating percentage
Huashanhe Station	32339	29447	-8.94%
Huangpiguang-chang Station	21338	21273	-0.31%
Gujiashan Station	25873	26414	2.09%
Huashanxincheng Station	19376	20381	5.19%
Tangyunhai Station	43080	43154	0.17%
Machi Station	42483	42894	0.97%

From the above prediction results, it is evident that the predicted settlement costs, which are within approximately $\pm 10\%$ of the contract costs, demonstrate the feasibility of using this model for predicting engineering settlement costs.

Through the outlined steps, the prediction of settlement costs for unsettled projects has been accomplished, and the cost information for each section is now fully prepared, facilitating the calculation of safety and civilized construction fees for civil engineering projects. This study, based on the CRITIC analysis method, considers factors such as project scale, construction site, contract amount, and safety and civilized construction objectives.[10] The importance of each factor calculated through CRITIC analysis is presented in the Table 3.

Table 3. Weight calculation results of CRITIC (Model output)

item	Index variability	Index conflict	Amount of information	weight
X1：Contract price	10274.318	2.764	28397.995	35.00%
X2：Floor area	5846.911	2.823	16506.295	20.35%
X3：Safe and civilized goal	6709.817	3.176	21309.196	26.27%
X4：Construction address	5117.663	2.914	14912.995	18.38%

After removing samples with data anomalies and inadequate supporting materials, and considering the weights obtained for each indicator, along with the scores provided by experts for each indicator, a combined subjective and objective approach was used to assess the authenticity and validity of the reported data for the sample sections. The results of the fee rate calculation are presented in the Table 4. From the calculation results, it can be observed that the fee rate is 9.96%, with an actual increase of 7.26%, which falls within a reasonable range.

Table 4. Table of measurement results (Author's own work)

Civil engineering	Estimated rate	《2018 Quota》
rate	9.96%	9.29%
Rate fluctuation	-	7.26%

6 Conclusions

This study establishes a rate calculation model for safety and civilized construction fees in subway projects based on PSO-SVM, effectively achieving dynamic rate calculation. Initially, the study adopts a method of accurately recording and statistically analyzing the calculation numerator, followed by multiple rounds of data verification to ensure the authenticity and validity of the data reported. Subsequently, the PSO-SVM prediction model is employed to forecast rates for unsettled projects, effectively addressing the challenges of small sample sizes and limited data in regional subway projects.[11] The model's fitting performance is demonstrated through output charts, meeting the requirements of practical calculations with satisfactory prediction accuracy. Finally, utilizing the critic weighting analysis method, the study comprehensively considers the basic conditions such as construction address and project scale for each sample section, ultimately realizing the rate calculation for civil engineering in subway projects. The calculation results indicate a slight increase in actual rates compared to the standard rates, which aligns with the recent advancements in safety and civilized construction standards. Relevant authorities can refer to this research approach to periodically adjust safety and civilized construction fee rates dynamically[12]. Additionally, they can consider the research conclusions to adjust the current rates, addressing the issue of lagging utility in guiding fee rate standards.

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